Chapter 3 Addressing Economic and Social Challenges

In order to achieve the goals set in the 5th Basic Plan: Sustainable Growth and Self-sustaining Regional Development, Ensure Safety and Security for Our Nation and its Citizens and a High-Quality, Prosperous Way of Life and Addressing Global Challenges and Contributing to Global Development we will work to solve challenges strategically by exploiting all scientific and technological innovations. Considering the reconstruction status from the Great East Japan Earthquake and other disasters, the national and local governments will work together on S&T innovations that will contribute to development of new technologies and new industries in the disaster-stricken areas.

Section 1 Sustainable Growth and Self-sustaining Regional Development

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

In the area of environment and energy, the "Progressive Environment Innovation Strategy (decided by the Meeting to Promote Comprehensive Innovation Strategy on January 21, 2020)" was formulated with the aim of establishing and socially implementing innovative technologies toward the GHG emission reduction goal set by the long-term strategy.

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.

Under the "Advanced Low Carbon Technology Research and Development Program (ALCA)" and MIRAI program: "Realization of a Low Carbon Society, a Global Issue" area, the Japan Science and Technology Agency (JST) is promoting R&D on technologies pertaining to innovative sunlight 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, and include development of silicon solar cells with conversion efficiency at 35% or higher.

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.

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

With an eye toward commercialization of floating offshore wind power generation systems that can adjust 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 an offshore substation in the waters off Fukushima, for verification of safety, reliability and economy of floating systems. Toward establishment of a low-cost floating offshore wind power generation system technology, the ministry has been conducting design validation and development of efficient maintenance technology based on the verified data of a low-cost floating offshore wind power generation system at a depth of 50m to 100m below the surface of the sea off the coast of Kitakyushu city.

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 FY2019 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.

Toward cost reduction of floating offshore wind power plants, since FY2018 the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has been studying design and safety evaluation methods, etc. aimed at simplification of the floating structure and installation methods while ensuring safety. Based on the study during FY 2018, MLIT amended the technical standards and safety guidelines to reflect design and safety evaluation methods for simplification of the floating structure in March 2020.

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

In order to solve problems of geothermal power generation, which include high risk and cost of resource exploration, operation efficiency and output stability at the power generation stage, MLIT has been developing technologies to improve exploration accuracy and drilling speed, streamline development and operation and stabilize output. The ministry is also conducting detailed prior examination of the next generation geothermal power generation (supercritical geothermal system) with high generating capacity, which is a highly anticipated development.

In order to ensure advancement and effective utilization of innovative techniques and promote necessary technology innovation toward prevention of global warming, the Ministry of the Environment (MOE) promoted not only use of renewable energy and rational use of energy but also development, demonstration and dissemination of technologies related to drastic reduction of energy consumption through use of new materials such as gallium nitride (GaN) and cellulose nanofiber (CNF), fuel cells, hydrogen energy, storage battery, CCUS[1], for example.

(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

1 Carbon dioxide Capture, Utilization and Storage

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 CO_2 (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) non-destructive assay of nuclear materials using the active neutron technique, and 2) nuclear forensics that identify the origin and history of illegal nuclear and other radioactive materials. Observations at Horonobe town and Mutsu city based on the noble gas joint measurement project with CTBTO[1] are contributing to strengthen detection capability for nuclear tests.

ii) Basic and fundamental R&D for nuclear science

In the Nuclear R&D, Infrastructure and human resource Working Group that was set up under the Nuclear Science and Technology Committee, the Subdivision on Research Planning and Evaluation in June 2019, the Council for Science and Technology comprehensively studied the following subjects: (1) development of new technologies that drastically improve safety, reliability and efficiency of use of nuclear energy, and (2) R&D and infrastructure/human resource development toward strengthening of human

1 Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization

resources, technologies and industrial infrastructure beyond the boundaries of industry, academia and government.

JAEA is conducting basic and fundamental research in such fields as nuclear engineering, reactor engineering, fuel and material engineering, nuclear chemistry, environment and radiation science, partitioning and transmutation, computational science and advanced nuclear science.

In addition, R&D on high-temperature gas-cooled reactors which have the possibility of a wide-range of industrial application including power generation and hydrogen production and inherent safety has been promoted in terms of the contribution to the enhancement of safety and to the diversification of nuclear use.

iii) Development of revolutionary nuclear technologies

Because nuclear energy is a practical option for carbon-free society, it is important to promote innovation of nuclear technologies that meets diverse demands of society in addition to safety improvement. Under the "program to support innovative nuclear technology development that responds to demand of society" In FY2019 METI started to support development of nuclear technologies with excellent safety, economy and mobility possessed by private companies and others.

iv) 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, based on the Global Nuclear-HRD Initiative (GN-HRD). In the Human Resource Development and Research Program for Decommissioning of Fukushima Daiichi Nuclear Power Station under the Center of World Intelligence Project for Nuclear S&T and Human Resource Development ("the World Intelligence Project"), MEXT in cooperation with the Collaborative Laboratories for Advanced Decommissioning Science (CLADS) by the Japan Atomic Energy Agency (JAEA) has been promoting human resource development based on the needs in the field of the decommissioning of Fukushima Daiichi Nuclear Power Station .

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.

v) 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 December 27, 2019). 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.

Based on the Acceleration Plan of Reactor Decommissioning R&D for the TEPCO Fukushima Daiichi Nuclear Power Station (published in June 2014), MEXT has been promoting basic/fundamental R&D and human resource development in order to consolidate knowledge in Japan and overseas for safe, steady decommissioning. Specifically, CLADS is conducting basic/fundamental research including handling of fuel debris, treatment and disposal of radioactive wastes and clarification of accident development scenarios at the International Collaborative Research Building (Tomioka town, Futaba-gun, Fukushima). Furthermore, the World Intelligence Project that has been implemented since FY2015 was changed from a commissioned project of MEXT to a subsidy project conducted by JAEA in FY2018. Through merging and linking excellent knowledge and experiences in various fields beyond the nuclear field around CLADS and across organizations of universities, research institutes and private companies, R&D and human resource development has been promoted in response to the medium- to long-term needs in actual decommissioning.

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

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.

vi) Nuclear fuel cycle technology

The Strategic Energy Plan (Cabinet Decision on July 2018) states "In order to resolve the issues related to reprocessing and disposal of spent fuels and mitigate the risks for and the burden on future generations, the government will make efforts towards a nuclear fuel cycle that contributes to the reduction of the volume and harmfulness of high-level radioactive waste and effective utilization of resources while adequately taking the past history into consideration and continuing to gain the understanding of relevant municipalities and the international community, and will promote reprocessing and plutonium use in LWRs[1]." Also "the government will promote R&D of fast reactors. through international cooperation with the United States and France."

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.

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

Based on the decommissioning plan (approved by the Nuclear Regulation Authority in March 2018) JAEA has been working on decommissioning. First, unloading of the fuel assemblies from the reactor core to the fuel pool will be completed by the end of 2022 giving the highest priority to safety. Transport of the fuel assemblies from ex-vessel storage tank to the fuel pool started in August 2018 and transport from the reactor core to ex-vessel storage tank started in September 2019. Future decommissioning of Monju will be safely, steadily and systematically carried out while listening to local voices.

vii) Technology development toward radioactive waste disposal

The government is advancing basic/fundamental research of nuclear transmutation and group separation technologies using accelerators, which can contribute to the significant reduction of volume and hazardousness of high-level radioactive wastes.

For disposal of low-level radioactive wastes from research facilities and medical institutions, JAEA has been advancing necessary initiatives according to the "Plan on implementation of burial disposal" (approved in November 2009; changes to the plan were approved in November 2019)" that was formulated by JAEA based on the "Basic policy for implementation of burial disposal" (decision by the Ministers of MEXT and METI in December 2008) presented by MEXT and METI.

viii) 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.

ix) 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.

x) 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 technical cooperation based on the Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology (RCA)" in the Asia-Pacific region, financial support to IAEA with contribution to the 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 Japan's excellent human resources and technologies. IAEA in cooperation with Japan designated an IAEA Response and Assistance Network Capacity Building Centre (IAEA-RANET-CBC) in Fukushima Prefecture in 2013 and implemented training for relevant people in Japan and abroad to strengthen their ability in preparation for and response to emergencies in August and November 2019. Its activities for international strengthening of nuclear security include an international symposium on transport security of nuclear materials held in cooperation with JAEA and the Integrated Support Center for Nuclear Nonproliferation and Nuclear Security (ISCN) in Tokyo in November 2019.

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[1]). 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).

xi) 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 (Act 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 15, 2019 the government reported the result of safeguard implementation activities in Japan during 2018 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,

1 OECD Nuclear Energy Agency

concluded that all the nuclear materials in Japan are used solely for peaceful purposes in 2018 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) the helical reactor (National Institute for Fusion Science (NIFS), the Large Helical Device (LHD)) and 3) the laser fusion reactor (Institute of Laser Engineering, Osaka University, GEKKO-XII Laser).

Based on international agreements, Japan has also been taking part in the ITER Project[2], which demonstrates the scientific and technological feasibility of fusion energy through the construction and operation of an experimental reactor. Japan, in partnership with EURATOM, 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.

METI has been developing a panel that integrates electric power production and supply, which is necessary for space photovoltaic power generation, while at the same time conducting technology development for its weight reduction and efficiency improvement of the power transmitting unit in order to contribute to efficiency improvement of wireless power transmission using microwaves.

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

<Reference>

Website on fusion energy study: Fusion Energy -Connect to the Future
https://www.mext.go.jp/a_menu/shinkou/fusion/

The way to fusion energy - ITER
https://www.youtube.com/watch?v=QEohCE1famE (Source: iter japan – QST)

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

2 International joint project to demonstrate scientific and technological feasibility of fusion energy through the construction and operation of an experimental fusion reactor based on a seven-party international agreement (Japan, EURATOM, the U.S.A., Russia, China, South Korea and India)

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

Construction of ITER (International Thermonuclear Experimental Reactor) in September 2019
(Cadarache in Saint-Paul-Lès-Durance, France)
Source: ITER Organization

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

METI is conducting the technological development and demonstration of batteries and fuel cells. Specifically, the ministry is promoting efforts for implementation of technological development for optimal control and management methods when introducing large batteries for power systems, which 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,[1] 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 120 hydrogen stations, mainly in four major cities, as of FY2019.

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.

Storage batteries are an area where Japan has an advantage as represented by the invention of the lithium ion battery, for which Mr. YOSHINO Akira received the Nobel Prize in chemistry in 2019, and is also positioned in the Progressive Environment Innovation Strategy (decided by the Meeting to Promote Comprehensive Innovation Strategy on January 21, 2020.) MEXT is strongly promoting R&D in this area. For example, the ministry is promoting R&D related to the next-generation storage battery with greatly higher performance compared with conventional ones in a technology area of special focus of the "Strategic Basic Research Programs - Advanced Low Carbon Technology Research and Development (ALCA)" of JST. The "JST MIRAI program – Large-scale project" is promoting R&D of a high-efficiency, low-cost, compact and long-life innovative hydrogen liquefaction technology that will contribute to expansion of hydrogen utilization including hydrogen power generation, storage of surplus power and transportation means.

1 Innovative storage battery with higher energy density compared to all-solid batteries and lithium ion batteries

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

The Cabinet Office through SIP has been working on the "Energy system of IoE society" since FY2018 toward realization of an IoE society where various energy sources are connected to a network enabling supply and demand management of energy. The project promotes R&D toward social implementation of the universal power module and wireless power transmission systems, which will enable optimum control of diverse input power sources including renewable energy.

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.

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.

Under the "JST MIRAI program – Large-scale project" JST started R&D on an innovative thermoelectric conversion technology that enables use of heat sources in the environment (e.g. waste heat, body heat) as independent source for sensors in FY2019.

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 reducing NOx from engines and improving their efficiency, and technologies for electrification of aircraft propulsion, while taking into account the potential R&D trends for next-generation airplanes and beyond. While developing, maintaining and improving large-scale experimental facilities (e.g. jet engines for technology demonstration and wind tunnels), JAXA will create and transfer innovative aeronautic technologies to the industry at an appropriate time and readiness revel.

The New Energy and Industrial Technology Development Organization (NEDO) has been implementing 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 (revised in July 2019), 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 that use the next-generation semiconductors including gallium nitride (GaN) which will enable significant reduction of power consumption by 2030, MEXT under "R&D on next-generation semiconductors contributing to realization of an energy-saving society" has been

promoting R&D on the next-generation semiconductors integrally from materials processing to device and system applications, also using theories and simulations. The results include the world's first success in developing technology to use P-type GaN only for a specific part of GaN substrate, which is necessary for realization of semiconductor devices.

Under the "Strategic Basic Research Programs – Advanced Low Carbon Technology Research and Development Program (ALCA)"and JST MIRAI program: "Realization of a Low Carbon Society, a Global Issue" area, JST is promoting R&D on innovative materials development/application and chemical processes. In FY2019 JST succeeded in establishing a new environment-friendly and energy-saving synthesis process for a bioplastic material (furan dicarboxylic acid) by simplifying the complex multistep process.

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; technology to replace the batch method of functional chemicals with the flow method; technology for accurate and speedy evaluation of performance and characteristics of lithium-ion cell materials, and; an integrated manufacturing process and component production of highly functional lignocellulose nanofiber[1].

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

Column 2-1 Next-generation semiconductor GaN will bring about an environmentally-friendly future society

Mr. AKASAKI Isamu, Mr. AMANO Hiroshi and Mr. NAKAMURA Shuji were selected to receive the 2014 Nobel prize for physics for their invention of blue light emitting diode (LED.) Based on the invention, long-life and low power consumption blue LED was developed. White light can be expressed by a combination of blue LED with green LED and red LED that had been already developed, or by using blue LED and yellow-color fluophor. The innovation led to energy saving in various fields including lighting equipment and the backlight used for liquid crystal panel of smartphones

Gallium nitride (GaN) used for the semiconductors of the blue LED has potential for further energy saving in all equipment, which can contribute to drastic reduction of GHG emissions not only in Japan but around the world. Power electronics equipment that controls electric power (e.g. conversion from alternating current to direct current) is built into almost all electronic equipment. Use of GaN can greatly reduce their power loss and make equipment smaller and lighter. This is why it is expected to realize energy saving of various kinds of equipment handling electric power and dream-like technologies such as flying cars. The technology can be also applied to optical devices including lasers with higher brightness and smaller spread of light compared with LED, and communication equipment that enables higher-speed and larger-volume communication compared with communication using conventional semiconductors.

For use in such equipment, however, it is necessary to stably obtain GaN crystals of higher quality compared with GaN crystals used for blue LED. In 2019 the Ministry of the Environment succeeded in the development and demonstration of an electric car with a motor controller using GaN, but further R&D is necessary for the spread of power electronics equipment using GaN. To this purpose, the ministry is promoting basic research of technology to produce GaN crystals with few defects and technologies necessary for production of high-performance semiconductor devices. In addition, the Consortium for GaN Research and Applications and other organizations are promoting activities to further accelerate GaN R&D in industry-academia cooperation. Through these all-Japan efforts a society where the next-generation semiconductor GaN is used in diverse places is approaching.

Wafer of GaN crystal with few defects (circular thin plate made of crystals of semiconductor material

Provided by Nagoya University

Outline figure of electric car using GaN (upper left) and a real machine exhibited at Tokyo Motor Show 2019 (lower right

Provided by the Ministry of the Environment

(2) Ensuring stable resources and cyclical use

A. R&D of seabed resource exploration/production

Based on the result of SIP 1st period "Next-Generation Technology for Ocean Resources Exploration," the Cabinet Office launched the SIP 2nd period "Innovative Technology for Ocean Resources Exploration" in FY2018. The program aims to establish, demonstrate and socially implement: in stages and ahead of other countries, innovative technology for Ocean Resources Exploration for rare earth mud and other mineral resources on the deep-sea floor from 2,000m to 6,000m below sea level, which accounts for two thirds of Japan's exclusive economic zone.

Since FY2018 MLIT has been supporting technology development for integrated control equipment of an electric system for the Floating Production Storage and Offloading System (FPSO) and autonomous underwater vehicles (AUVs) for submarine pipeline maintenance, and promoting advance into the ocean development market by the maritime industry.

In order to contribute to the promotion of industrial use of the ocean by Japan, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) is promoting understanding of biological and physical cycles in the ocean and the origin of useful resources and providing obtained scientific knowledge, data, technologies and samples to the related industries.

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 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. 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 Strategic Urban Mining Technology and System" among the program to increase the sophistication of the resource circulation system, the ministry is working on the development of technologies for automatic sorting of waste products and components and high-efficiency refining.

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

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.

Under the Strategic Basic Research Programs – Advanced Low Carbon Technology Research and Development Program (ALCA) and JST MIRAI program: "Realization of a Low Carbon Society, a Global Issue" area, JST is promoting R&D on innovative biotechnology to produce chemicals from biomass, which can replace petroleum products. In FY2019 JST succeeded in improving productivity of muconic acid, a material of nylon, by changing microorganism used for production and using different types of sugar for proliferation of the microorganism and production of the target material.

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 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.

Furthermore, in order to promote "smart agriculture" using robotics, AI, IoT, drones and other leading-edge technologies, in FY2019 MAFF launched research on advanced production management using ICT, an automated driving system of farm machines using satellite positioning information and image data, and robots for levee weeding and harvesting, for example, and started technology demonstration of the economic effect of their introduction to the production field. In addition, 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 promotion of ICT utilization in agriculture in cooperation with other ministries and agencies. Furthermore, in cooperation with relevant ministries, private companies, universities, national research and development agencies and other partners, MAFF constructed the Agriculture Data Coordination Platform and started its 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.

Column 2-2

Maximizing productivity through real-time measurement of photosynthesis

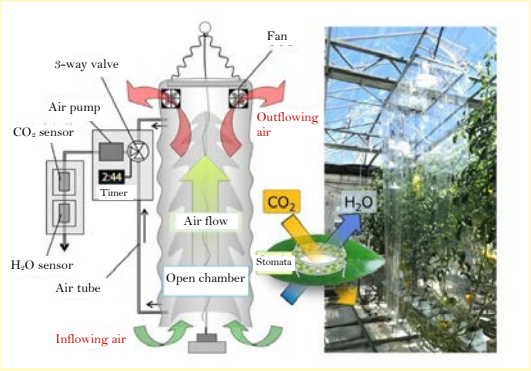
A sunlight-type plant farm is a facility to produce crops efficiently and in a large-scale by maximizing solar energy. Various factors including temperature, humidity and CO_2 concentration are controlled by computer, but the largest purpose of the environmental control by day is "maximization of photosynthesis" of the cultivated crops. However, it was difficult to grasp the state of photosynthesis of crops in real-time in the field of agricultural production.

Newly developed "real-time photosynthesis measurement system" enables measurement of photosynthesis of the whole body of individual plants in production field. Plants under cultivation are covered with a transparent film for which the bottom part is open ("chamber") and air in the chamber is continuously discharged using fans installed at the top of the chamber. As a result, outside air flows into the chamber through the open part at the bottom of the chamber. At this timing, the difference in CO_2 concentration between the air that flows in and the air that flows out is used to calculate the speed of photosynthesis of the plants in the chamber.

The system is already in the market through a university venture and other players and used as a photosynthesis monitoring tool in the field of smart agriculture.

This invention attracts attention as a system to optimize the cultivation environment (e.g. temperature, humidity and CO_2 concentration), which used to be adjusted based on the experience and intuition of farmers, based on the figures of direct measurement of the photosynthesis of the plant.

The system has been developed under the "Project to Create Future Agriculture Using AI" commissioned by MAFF. The project is promoting activities to optimize environmental control based on photosynthesis information and also optimize labor management by accurately predicting growth and yield.



Conceptual diagram (left) and photograph (right) of the real-time photosynthesis measurement system
Provided by Toyohashi University of Technology and Ehime University

■Table 2-3-1/Major projects for stable supply of energy, resources and food (FY2019)

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
		Project to develop and demonstrate smart agricultural technologies
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.
		Project to support innovative nuclear technology development that responds to the demands of society
	METI	Commission for R&D toward efficiency improvement of wireless power transmission for space photovoltaic power generation
	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, earth thermal, etc. (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
		Development of evaluation techniques for energy-saving electronic device materials
		Technology development for construction of a bio fuel production system
		Technology development to expand introduction of geothermal power generation, ground surface heat system, etc. (NEDO subsidy)
		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, also based on the new Healthcare Policy (Cabinet Decision on March 27, 2020) that entered the second period in FY2020 and the Plan for Promotion of Medical Research and Development (decided by the Headquarters for Healthcare Policy on March 27, 2020.)

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 (BINDS) to allow industries and universities to share information by developing technological bases, for example, a world-class level radiation facility, cryo-electron microscopy, a compound library facility and protein production and bioinformatics technology facility and genome/epigenome analysis. In response to COVID-19 the ministry is working to contribute to early practical application of treatment, remedy, vaccine, etc. by the whole society including pharmaceutical and other private companies beyond academia, through research support including compound library and in silico simulation, by taking advantage of BINDS's knowledge and knowhow pertaining to support for practical application.

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 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 research on technology development for drug discovery, including drug target/biomarker search in industry-academia-government collaboration and research on drug design.

Through AMED, METI has been implementing: "technology development for innovative middle-molecule drug discovery" to develop fundamental middle-molecule drug discovery technology that can dramatically expand drug targets, and the "project for utilizing glycans in the development of innovative drug discovery technologies" that aims to expand drug targets and reduce side effects by using as drug target glycoprotein that is specifically exhibited in cancer cells and other diseased cells. Furthermore, since FY2019 the ministry has been implementing "development of technology for marker search for stratified patients" to search for bio markers that can identify patients for which specific drugs or treatment are effective.

(B) Innovations in biomedical structural and synthesis technology

Through AMED, MEXT has been conducting the Science and Technology Platform Program for Advanced 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 FY2019 the program supported 31 medical equipment development projects. In the "project to develop technologies of advanced medical equipment, systems, etc." METI adopted and supported 6 tasks in FY 2019 for development of advanced medical equipment and systems in the 5 priority areas[1] selected

1 (1) Further acceleration and simplification of inspection/diagnosis, (2) integration of diagnosis and treatment to maximize outcome, (3) prevention, (4) complementation of physical functions deteriorated due to aging and improvement of QOL, and (5) advancement of diagnosis and treatment through digitalization and use of data

based on the competitive potential of Japanese medical equipment, need for public support, medical value and other criteria. For development of advanced medical equipment and systems, eight tasks were adopted and implemented for development of technological applications that connects fundamental technologies or basic elemental technologies to non-clinical applications in the coordination area for raising the level of the competitiveness of the Japanese medical equipment industry. In addition, four development guidelines to promote practical use of medical equipment were published in FY2019.

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. Creation of innovative pharmaceuticals, etc. using centers to create innovative medical technologies

Center to create innovative medical technologies is the collective term for "translational research centers" that have been developed by MEXT since FY2007 and "core clinical research hospitals" that are approved by MHLW based on the Medical Care Act (Act No. 205 of 1948).

MEXT, in cooperation with MHLW and through the Japan Agency for Medical Research and Development (AMED), has been working on creation of innovative pharmaceuticals and medical devices, regenerative medicine products and other products by using the centers to create innovative medical technologies. At the centers, since FY2017 AMED has been implementing the Strategic Translational Research Promotion Program that aims to strengthen ability to nurture seeds in and outside of the centers, and establish them as permanent centers. Thus AMED has been supporting development of innovative medical technologies originating in academia.

In order to promote high-quality clinical research necessary for development of innovative Japanese pharmaceuticals and medical devices, since 2015 MHLW has been approving hospitals that play a central role in international-standard clinical research and doctor-centered clinical trials as the core clinical research 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 using the hospitals 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 development of medicine safety evaluation method using human iPS cells and research on screening to identify candidate compounds for drugs. The ministry

is also seeking to establish the foundation of safe and effective regenerative medicine by promoting research into tumorigenicity and other areas that are hurdles for the early clinical application of regenerative medicine that uses human cells, such as iPS cells.

Through AMED, METI is implementing the Project Focused on Developing Fundamental Technology, Aiming at Industrialization in the Field of Regenerative Medicine and Gene Therapy. In this project the ministry is developing evaluation methods for safety, efficacy, etc. of each regenerative medicine product and supporting development of product development systems in collaboration with contract research organizations (CRO) for example. In addition, the ministry is developing applied technologies to evaluate the safety, etc. of medical drugs using cells of various organs in application of regenerative medicine technology.

For gene therapy, METI developed technology to culture and produce high-quality and highly-safe vectors for therapy and is developing internationally competitive mass production technology.

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 dies from cancer (about 370,000 persons/year as of FY2018). 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. Also, a treatment facility is under construction in Yamagata Prefecture. 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 International Brain Science Research Promotion Program (Brain/MINDS Beyond) 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-

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.

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 Framework for Acceleration of Dementia Measures compiled in 2019 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 Research and Development Project for Dementia.

METI through AMED is implementing the Project to Develop Infrastructure for Demonstration of Public-Private Innovations of Dementia Measures. The aim is to establish reliable assessment methods and indices for both medical and non-medical personnel by promoting suppression, early detection, etc. of cognitive decline and developing verification infrastructure to examine new products/services for reliable use by companies, medical staff, local governments, nursing staff and non-medical personnel.

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.

I. Response to COVID-19

COVID-19 that was reported in China in December 2019 developed into the declaration of pandemic by the World Health Organization (WHO) on March 11, 2020 and has exerted enormous influence in Japan and abroad.

In response, MEXT is strengthening infrastructure for research of infectious degasses and accelerating research to address COVID-19. Specifically, by subsidy through AMED, Grant-in-Aid for Scientific Research (Special Fellowship Program) and other programs the ministry is promoting development of fundamental technologies related to medication, vaccine and rapid diagnosis

As regards development of medication, for example, the Institute of Medical Science, The University

of Tokyo, supported by the Japan Initiative for Global Research Network on Infectious Diseases mentioned above, discovered that Nafamostat (trade name: Fusan) that is used for treatment of pancreatitis may inhibit infection of COVID-19. In addition, Favipiravir (trade name: AVIGAN) that is influenza medicine, ciclesonide (trade name; Alvesco) that is bronchial asthma medicine, Remdesivir (trade name: Veklury) that has been developed to treat Ebola hemorrhagic fever and other drugs are expected to be effective and their clinical study has started. Remdesivir was approved as a special case on May 7 based on the result of multinational clinical studies led by doctors.

For rapid diagnosis, as a result of R&D using infectious disease research centers in Asia supported by the Grant-in-Aid for Scientific Research (Special Fellowship Program), Nagasaki University jointly with Canon Medical Systems Corporation established a rapid diagnosis technology using the fluorogenic LAMP method. Furthermore, as part of Research Complex Program, Kanagawa Prefecture and RIKEN jointly established a rapid diagnosis technology using the SmartAmp method in Kawasaki Tonomachi Center. Both methods have been evaluated by MHLW and the National Institute of Infectious Diseases (NIID), made available in administrative inspection and are covered by insurance. In order to ensure smooth development of such medicines, vaccines and rapid diagnosis methods, the government is working to strengthen infrastructure of overseas infectious disease research centers and enhancement of drug discovery research bases for academia and companies through the Basis for Supporting Innovative Drug Discovery and Life Science Research (BINDS)

When a gene recombination experiment related to COVID-19 requires confirmation by the minister based on the Act on the Conservation and Sustainable Use of Biological Diversity through Regulations on the Use of Living Modified Organisms (Act No.97 of 2003, so-called Cartagena Act,) necessary examinations are carried out while ensuring rapidity and safety in view of its importance.

Trial use of the super computer "Fugaku" that has been developed by RIKEN toward full-scale operation from 2021 was partially pushed forward to search for drug candidates, while an extraordinary public call for research was made to address COVID-19 by using computation resources of super computers held by universities, etc. Large-scale radiation facility Spring-8, Japan Proton Accelerator Research Complex (J-PARC) and other major facilities will accept application for use and requests for analysis related to drug discovery research. These cutting-edge research facilities are used for early production of results for COVID-19 countermeasures.

Furthermore, MEXT is promoting response to COVID-19 from various aspects, which include an information portal site that gathers necessary points of infectious disease research and research results related to MEXT for researchers.

Under a R&D program established in FY2020, JST aims to contribute to implementation of R&D results in the policy making and public relations process of public health administration. The program covers tasks to advance methods to present scientific evidence for social decision making in emergencies, which include risk assessment based on evidence and harmonization of interests for fair risk distribution through analysis of reactions by citizens and consumers to various social phenomena caused by COVID-19 by utilizing knowledge of social sciences and humanities including behavioral economics, social psychology, legal studies and ethics. JST also publicly solicited multinational joint research pertaining to prevention of the spread of COVID-19 by Japanese and foreign researchers in nonmedical fields including infection modeling and is providing emergency support.

For the period from 2014 to 2017, as part of "Science of Science Policy" in the Science, Technology and Innovation Policy, JST promoted policy studies with a view to social implementation, by conducting research on social implementation of mathematical models of infection, for example, while developing a system for social implementation of the results.

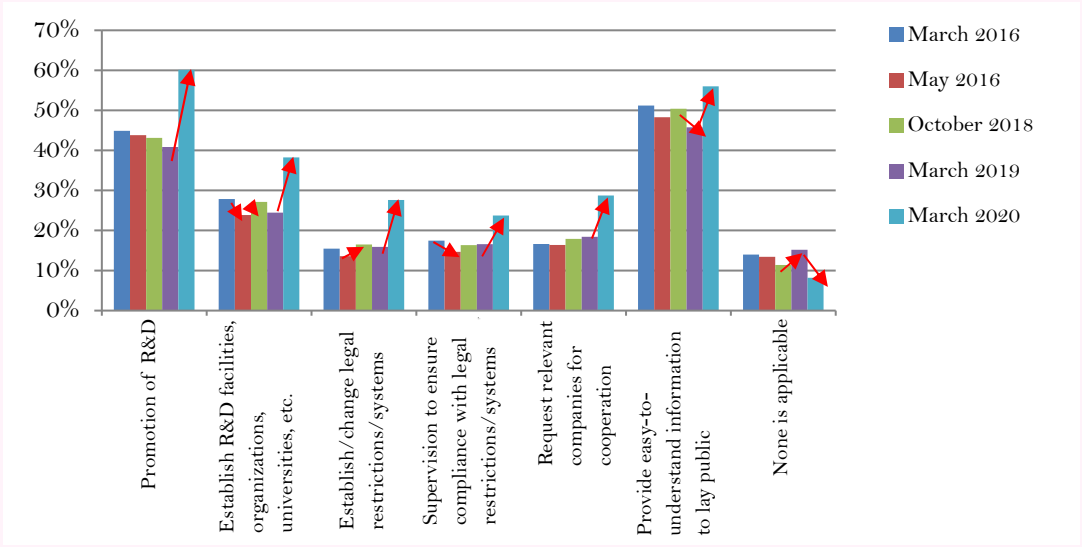
METI implemented demonstrations related to the performance and operability of GeneSoc, equipment that can rapidly detect COVID-19 virus using a real-time PCR method (jointly developed by the National Institute of Advanced Industrial Science and Technology (AIST) and KYORIN Pharmaceutical Co., Ltd.) In response to rising expectation for simple, swift and distributed virus inspection, and system development to prevent spread of infection and therapeutic apparatus for severe patients, for example, the ministry will support R&D on devices to detect COVID-19 virus and diagnostic agents as well as development and demonstration of equipment/systems meeting needs in the practice.

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 participated in establishing the Coalition for Epidemic Preparedness Innovations (CEPI) and has been contributing to CEPI since 2017. Since January 2020 CEPI has been signing partnerships with foreign research institutes, universities and private companies with the aim of promoting development of vaccine for COVID-19 and speedy clinical trial of candidate vaccines. As of March 31, 2020, CEPI has signed partnerships with eight vaccine development projects.

According to the survey of public attitude to science and technology conducted by the National Institute of Science and Technology Policy (NISTEP) in March 2020, public attention is increasing regarding measures related to science and technology that the government should take for prediction and countermeasures of infections including COVID-19 (Figure 2-3-2.)

■Figure 2-3-2/Percentage of answers and changes in the percentage concerning the measures the government should take for prediction and countermeasures of COVID-19 and other infectious diseases



Material created by NISTEP, MEXT

J. 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.

K. 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 promote networking using ICT in medical, nursing and health fields toward establishment and advancement of data distribution infrastructure, for solution of technical problem, MIC built a telemedicine model and a diagnostic aid model using receipt data and implemented a survey project contributing to rulemaking for a system (Personal Health Record) where life-long medical and other data of individual persons are managed in chronological order and used for multiple purposes at the person's judgment. Through AMED, the ministry implemented research toward development of a measure planning model for health guidance using AI, further improvement of an 8K endoscope system that MIC has developed, research toward realization of remote operation aid in application of the system and research for construction of an AI diagnosis aid system using high definition data.

Through AMED, METI implemented "Promotion of behavior modification taking advantage of health/medical information." This program constructed evidence for prevention/improvement of lifestyle

and other diseases by promoting behavior modification of patients of mild lifestyle diseases including diabetes through intervention based on daily health information obtained from the patients' wearable terminals, etc. The ministry also implements the "IoT behavior modification project" for other diseases. Its aim is to promote development of methods to appropriately use health data for examination by doctors by obtaining, analyzing and examining the effectiveness of everyday health data that are gathered using IoT devices and mobile applications, while at the same time creating business models that will promote efficient social implementation of the methods.

Column 2-3 Infectious Disease Study using Overseas Research Centers

Various new and re-emerging infectious diseases prevail in the world, especially in tropical areas. Due to hot and humid environments and delay in infrastructure development, old infectious diseases including dengue, malaria and tuberculosis are still rampant there. In addition, expansion of human settlement accompanying population increase and economic development has increased chances to come close to wildlife habitats, which has increased the risk of new infectious disease of animal origin. In the increasingly globalized modern society, new epidemics can spread across borders. This situation requires efforts to control infectious diseases in international cooperation.

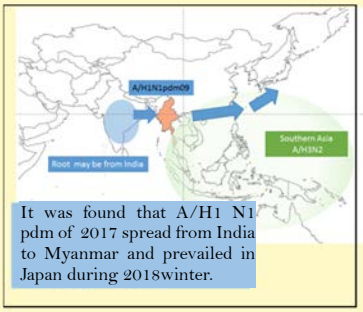
To address infectious diseases flourishing in many places, under the Japan Initiative for Global Research Network on Infectious Diseases launched by MEXT, nine universities[1] have conducted epidemiological studies in their infectious diseases research centers abroad. Epidemiological surveys in epidemic areas produced results contributing to elucidation of the factors related to epidemics, which include distribution, migration and variations of pathogens. For example, through gene analysis of influenza viruses, a research center in Myanmar found that the strain of influenza virus that caused outbreak in the country in 2017 is similar to the strain that prevailed in India in the same year and the same as the strain that prevailed in Japan a half year later. Information of global virus migration helps prediction of future epidemic strains and enables vaccine production ahead of epidemics. Centers in the Philippines and Thailand revealed the presence of asymptomatic carriers[2] of Norovirus. It is expected that elucidation of the influence of such carriers on the epidemic will help prevention of infection from spreading. Regarding gene analysis of samples necessary for development of test kits to judge infection and therapeutic drugs, etc., the universities are promoting the development of diagnostic techniques in view of social implementation and basic research including target search that is the starting point of drug discovery through speedy analysis of specimens, etc. obtained locally in their infectious disease research centers abroad.

To address COVID-19 that started in China in December 2019, using the Grant-in-Aid for Scientific Research (Special Fellowship Program) and taking advantage of infectious disease research centers in Asia, basic research has been implemented toward prevention, diagnosis and treatment development. The activities include collection and analysis of information related to COVID-19 and specimens, epidemiological survey on epidemic conditions and host animals, and establishment of rapid diagnosis techniques. (For the government's R&D related to COVID-19 countermeasures, see "Study on New and Re-emerging Infectious Diseases" in Part II, Chapter 3.)

Reference: the Japan Initiative for Global Research Network on Infectious Diseases
https://www.amed.go.jp/program/list/01/06/001.html

Operation using virus in a safety cabinet
Provided by AMED

Example of overseas research center (Research Institute for Tropical Medicine: RITM)
Provided by AMED



Identification of virus migration at the Myanmar center
Provided by AMED

1 Hokkaido University (Zambia center,) Tohoku University (Philippines center,) University of Tokyo (China center,) Tokyo Medical and Dental University (Ghana center,) Niigata University (Myanmar center,) Osaka University (Thai center,) Kobe University (Indonesia center,) Okayama University (India center,) Nagasaki University (Vietnam center)

2 People who are infected by virus but have not developed symptoms. They might spread infection without awareness

(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 "research on wide-area linkage of city functions in local cities in order to promote inter-zone linkage" and other research.

B. Research on transportation systems

The Integrated Innovation Strategy 2019 determined the direction to promote automated driving as a project of the SIP Second Period that is R&D program with increased focus on social implementation of results. In the SIP Automated Driving (expansion of system and services), MIC expanded practical application of automated driving of owner cars from expressways to general roads, while promoting R&D in four areas: (1) development and verification (demonstration experiment) of automated driving systems, (2) development of fundamental technologies for practical application of automated driving, (3) fostering of social acceptance of automated driving, and (4) strengthening of international cooperation, with the aim of practical application of logistics and mobile services using automated driving technology.

As an effort toward an automated driving society, MIC is studying technical requirements including frequency sharing that are necessary for introduction of V2X communication. In order to enable observation of surrounding traffic conditions toward realization of safe and secure automated driving, the ministry is conducting R&D on technologies to collect dynamic information from various information sources, integrate the information as real-time traffic conditions and distribute necessary information to automated driving vehicles.

As advancement of signaling information technology toward practical application of automated driving, the National Police Agency is implementing R&D on signaling information provision using road side infrastructure, cloud, etc.

In addition to research for solution of new traffic problems including automated driving and elucidation of accident causes, the National Research Institute of Police Science conducts research on traffic characteristics on high-standard expressways, and psychological characteristics of aged drivers, for example.

MLIT has been promoting technology development that helps further improvement of railway traffic safety, including development of a system to select priorities of track work by photographing the conditions along railway lines which can be an obstacle to safe travel of the trains (e.g. slant of trees, electrification poles and other structures) with a camera mounted at the head part of the train and analyzing the images.

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

In the field of electronic navigation, the Institute has been conducting R&D including "advancement of air traffic management through trajectory-based operation," "advancement of airport operation," "optimization of air traffic by utilization of onboard information" and "information sharing among parties concerned and advancement of aircraft flight." The aim of the R&D is to contribute to expansion of air 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 and other Welfare Equipment to support development of robotic devices that contribute to the independence of elderly people by private businesses.

Toward construction of a universal society where everyone including the elderly and people with disabilities can engage in activities freely without stress, MLIT Supported development of indoor digital maps and positioning environments by private sector entities at Shibuya Station and implemented demonstration experiments of indoor-outdoor seamless navigation service using commercial applications.

With the aim of establishing methods for visualization of barrier-free effect of houses/architecture, the National Institute for Land and Infrastructure Management (NILIM) is conducting research to grasp the ease of activities in a living environment (ease of living, ease of movement and ease of assistance) quantitatively using a barrier-free environment assessment program with indices of the physical activity level of residents (including the physically unimpaired, the elderly, wheelchair users and caregivers), which will improve health maintenance management of the residents in accordance with their life stage.

Column 2-4

Toward Aircraft Development in Cyberspace

Everyday numerous passenger jets are flying around the world to support the movement of people, but the aircraft industry is in oligopoly by a few foreign companies. What is expected to change the situation is the first Japanese domestic airplane in 60 years after YS-11: Mitsubishi Space jet that is now at the height of development. For Japan's aircraft industry, which has less experience in airframe development compared with competitors in Europe and the United States to survive fierce international competition, it is important to reduce development time so that it can offer aircraft meeting the market needs ahead of the world.

In this context, hopes are placed on aircraft development in cyberspace, the key part of which is numerical simulation of physical phenomena in computers. This is a technology to predict airflow around aircraft and performance of the airframe based on calculations using a super computer. It has the potential of replacing not only the wind-tunnel test that has been used for aircraft development since the era of Wright Brothers but also flight test using real airplanes. It is also expected to contribute to further pursuit for safety design, which includes simulation of various weather conditions and flight conditions that are dangerous for real airplanes. This technology is a specialty of Japan. As a result of efforts for many years, Japan Aerospace Exploration Agency (JAXA) has one of the world's fastest calculation programs that can complete simulation of air flow around an aircraft, which required a whole day 10 years ago, in just two minutes. Abundant use of these technologies from the design stage improves the completion of airplanes at an early stage and reduces reworking during flight tests, which will dramatically accelerate aircraft development.

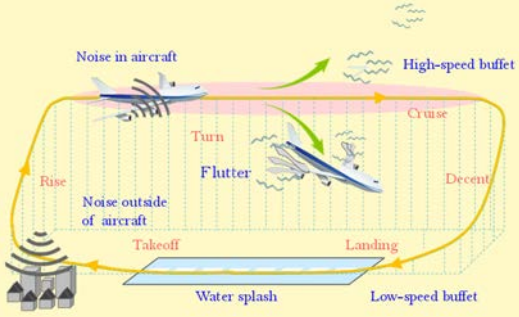


Figure 1 Non-steady phenomena targeted by ISSAC
Source: JAXA

Currently, however, their application is limited to simulations of conditions with almost steady aircraft speed and altitude (e.g. cruise condition). Aircraft development must consider various flight conditions including dangerous situations such as an oscillating airframe (see Figure 1.). Many of the phenomena are unsteady where flow state changes with time in a complex way. Since simulation of these phenomena takes considerable time even with the current technologies, it has not been practical for some aircraft design phases yet. In order to cancel this bottleneck of aircraft development, JAXA has been promoting the Integrated Simulation System of Aerospace vehiCles," the abbreviation of which is ISSAC after the famous Isaac Newton.

Calculation of unsteady phenomena produces an enormous amount of data. It is not easy to manually find out phenomena that are key to aircraft design among the data. For this purpose, ISSAC uses data mining technology that extracts the essential parts (characteristic structures) of the phenomena hidden in data. Extracted characteristic structures help not only understanding of the phenomena but also creating simplified models. Figure 2 is an example of an analysis result. From the calculation result of complicated buffet (flow oscillation) phenomena (upper part of Figure 2.) the analysis succeeded in detecting an essential characteristic structure called "buffet cell" (bottom part of Figure 2.). The data mining technique is classified as machine learning as with AI. For the future JAXA plans to actively introduce deep learning technology and develop advanced technology that model and reproduce phenomena in a simplified manner. This technology is expected to dramatically reduce calculation time and bring the further contribution of numerical simulation technology to the development of Japan's aircraft industry.

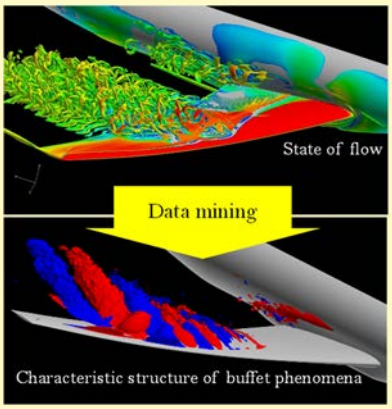


Figure 2 Extraction of characteristics through data mining
Source: JAXA

(3) Extending service life for efficient and effective infrastructure

Under PRISM (Public/Private R&D Investment Strategic Expansion Program) "innovative construction and infrastructure maintenance and innovative disaster prevention/mitigation technologies" the Cabinet Office promotes "change through innovation" by allocating additional budget to and accelerating promotion of i-Construction and other measures of relevant ministries and agencies. In order to realize steady and efficient infrastructure maintenance while accelerating open innovation brought about by effective use of data, the ministry in cooperation with MLIT will promote construction of an infrastructure data platform that coordinates data of the national and local governments and the private sector.

MLIT and METI have promoted the development and introduction of robots to maintain social infrastructure and implement anti-disaster measures more effectively and efficiently.

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. Taking COVID-19 countermeasures as turning point, the ministry will accelerate expansion of use of BIM/CIM[1] in public works to enable digital processing of a series of processes from design/construction to maintenance as well as stock utilization, while at the same time promoting digitalization of advanced skills. The aim is a drastic improvement of productivity and shift to noncontact/remote operations through digital transformation (DX) in the infrastructure and physical distribution fields.

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: more efficient maintenance of sewerage facilities and utilization of existing buildings, 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

1 Building Information Modeling/Construction Information Modeling
By introducing 3D model in the stage of survey and design the method facilitates information sharing across the project through linkage and development of the 3D models in each stage of subsequent construction, maintenance and renewal to ensure efficiency improvement and upgrading of a series of construction production and management systems.

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 2-3-3/Major policies for the realization of sustainable society in response to super aging and population decline (FY2019)

Ministry/ Agency	Implemented by	Project
MEXT	AMED	Grants for promoting the development of medical and health care research
METI	AMED	Project to Promote the Development and Standardization of Robotic Devices for Nursing Care and other Welfare Equipment
		Promotion of behavior modification taking advantage of health/medical information
		Technology Development of Advanced Medical Devices and Systems
		Medical-engineering collaboration business promotion project
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 response to the pandemic of COVID-19, the ministry will support return of production of products, components, materials, etc. that are now highly dependent on specific countries to Japan and conduct technology development that will contribute to resilience of the supply chain; the development will include replacement or reduction of use of components/materials that heavily rely on a single country and speedy and flexible recombination of the supply chain through data coordination, for example.

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/design, shipbuilding and operation by utilizing information

communication technologies including IoT and big data. According to the roadmap developed in June 2018 for practical application of automated navigation vessels, the ministry 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

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. To address these issues the "Safety and Security" section of the Integrated Innovation Strategy 2019 states that "we need to broadly utilize our advanced scientific technologies for prevention and mitigation of disasters, prolongation of service life of infrastructure and dealing with terror activity and crime as well as threats in various fields including cyberspace, space and oceans. In this context we will ensure the safety and security of our country and citizens through executing social implementation by uniting our various advanced scientific technologies in collaboration among the relevant ministries, industry, academia and government while responding to the outflow of science and technology information." Toward further strengthening of the efforts, the Meeting to Promote Comprehensive Innovation Strategy compiled the "Direction of Science, Technology and Innovation toward Realization of Safety and Security" in January 2020.

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 method for advance estimation of sediment disaster caused by a large-scale earthquake; and "the creation of disaster-resistant towns," including development of techniques for renovation of equipment, etc. to ensure the health and safety of evacuees in shelter.

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.

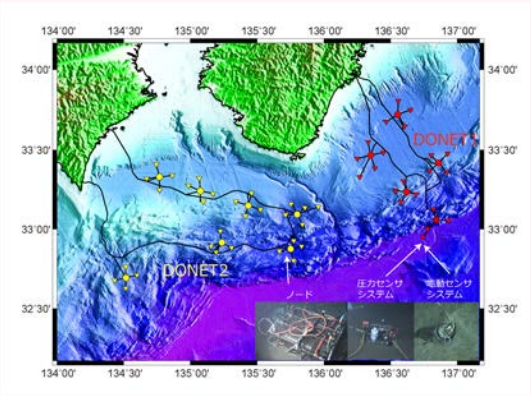
Towards early recovery and reconstruction after a major earthquake, MPAT is conducting research on forecasting earthquake- and tsunami-related deformation and performance degradation for structures in coastal areas and the areas behind them, and on improved safety and reliability for facilities in coastal 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 2-3-4/Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET)



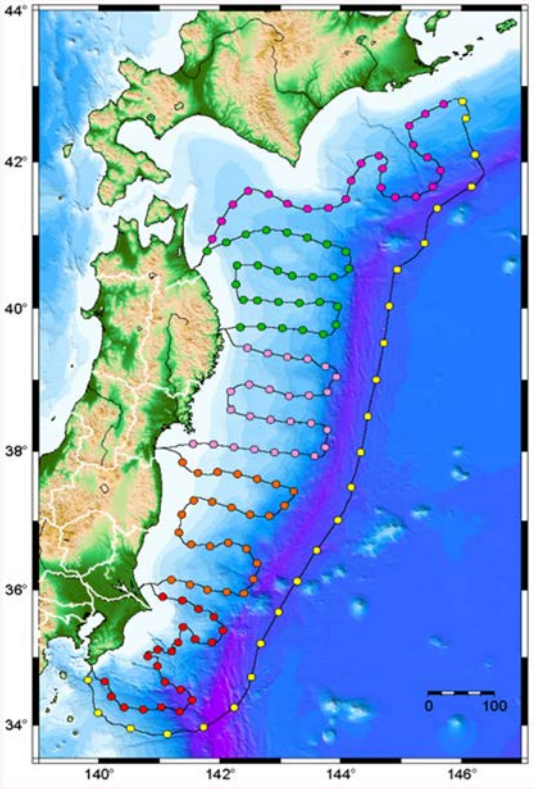
Source: MEXT

Considering that the long-term evaluations of the probability and magnitude 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 2016 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 conducting evaluation of tsunamis caused by various earthquakes.

MEXT 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. In the Integrated Research Project on Seismic and Tsunami Hazards Around the Sea of Japan, controlled-source structure survey 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 2-3-5). 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 2-3-6).

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

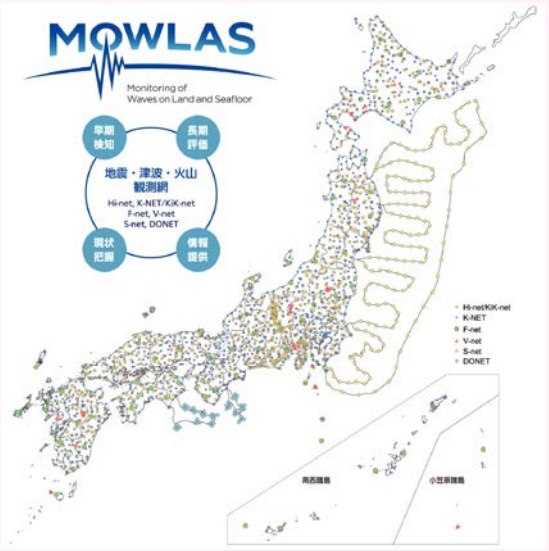


Source: MEXT

In the field of volcanology, the Integrated Program for Next Generation Volcano Research and Human Resource Development was launched in FY2016 in response to the eruption of Mt. Ontakesan in 2014. The program promoted integrated research of "observation, prediction and measures" in coordination and jointly with other fields in order to contribute to reduction of volcano disasters in addition to existing observation research. The project also fostered volcano researchers who have comprehensive knowledge and advanced technique.

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 2-3-6).

■Figure 2-3-6/Monitoring of Waves on Land and Seafloor (MOWLAS)



Source: MEXT

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, flood damage and sediment disaster and installed them in model areas. It also implemented 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

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

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 six land fault zones (Yokote-bonchi-toen, Itoigawa-Shizuoka Tectonic Line, Nosaka/Shufukuji, Kikukawa, Nishiyama and Unzen fault group [Hokubu]) and one coastal zone fault zone (Unzen fault group [Nantobu]). AIST added information of the flooded area on the coast of Fukushima Prefecture to the database on tsunami deposits. 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 accuracy of the observation equipment, AIST developed methods to downsize and reduce the cost of strain meters and methods to use existing unused wells. A prototype observation well was installed. Concerning the volcanoes where eruption activities were observed (Asamayama, Sakurajima and Aso (Nakadake), 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.

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in cooperation with universities and other relevant organizations is implementing survey and observation related to seafloor earthquakes and volcanoes by using research vessels and various types of observation equipment in the expected Nankai trough source region, and the oceans surrounding Japan and the West Pacific Ocean. By advancing methods to analyze data from these observations, JAMSTEC predicts transition of seismic and volcanic activities through large-scale and high precision numerical simulation.

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, 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 announcing the observation results from time to time.

1 Global Navigation Satellite System
2 There were 1,300 electronic reference stations across the country as of the end of March 2020.
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.

(3) Improvement of response capabilities

In the First Period of the SIP Program "Enhancement of Societal Resiliency against Natural Disasters (FY2014-2018)" the Cabinet Office developed the "Shared Information Platform for Disaster Management (SIP4D)" that is a technology to gather disaster information on digital maps and enable information sharing among relevant organizations. At the time of the heavy rain disaster centered in Saga Prefecture in late August 2019, the 2019 Boso Peninsula typhoon and the 2019 East Japan Typhoon, the Information Support Team (ISUT: a trial initiative of the disaster prevention department of the Cabinet Office) provided disaster response support by using SIP4D to integrate disaster-related data of relevant ministries and agencies. In the second period of 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 prevention weather information through Michibiki 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 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. At the time of the earthquake off the coast of Yamagata Prefecture in June 2019, the heavy rain disaster centered in Saga Prefecture in late August 2019, the 2019 Boso Peninsula typhoon and the 2019 East Japan Typhoon, NIED integrally summarized information collected in SIP4D and information collected in the disaster area and provided the results together with past information related to the disasters and their analysis results to the disaster response organizations through NIED-CRS (crisis response site).

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, MOD 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 FY2018, deployed the system at the Fire-defense Headquarters and studied optimization of its functions toward development of specification of a production model. In

addition, the NRIFD conducted R&D of the following technologies: (1) high-accuracy prediction of earthquake damage to oil tank (identification of characteristics of short-period ground motion that is likely to cause damage to the oil tank body, influence of long-period ground motion on individual tanks due to differences in underground structure, etc.); (2) Powerful foam extinguishing technology tailored to the scale of fire, oil type, etc. of oil tank; (3) More suitable assessment of fire risk of highly reactive chemical substances (e.g. water reactive substance, substance prone to ignition caused by heat accumulation) stored or handled in petrochemical complexes) and safety management while firefighting. In addition, NRIFD started R&D related to quantitative diagnosis standards, etc. on the soundness of steel plate with internal coating.

Furthermore, the NRIFD conducted 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 Trough earthquake or earthquake that hits the Tokyo area directly, the NRIFD conducted 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 conducted 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 due to a disaster, etc., and a wireless relay technology that uses aerial drones as virtual communication towers to swiftly ensure communication with isolated areas. Together with the municipality, NICT is conducting field demonstration experiments of these technologies.

NILIM is conducting the following activities: (1) development of technologies for the proposal of flood fighting menus for effective risk reduction based on the topography and river course characteristics, efficiency improvement of flood fighting activities and streamlining of activities, (2) research on collapse recognition and real-time flood prediction for responsive information communication to help evacuation and flood fighting; (3) development of technology for diagnosis of the possibility of evacuation and passing of emergency vehicles in the event of earthquake fire, and; (4) development of rapid testing of the soundness of key buildings (e.g. government offices) of local governments damaged by an earthquake. 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.

1 Unmanned Aerial Vehicle
2 Polarimetric and Inferometric Airborne Synthetic Aperture Radar

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

In response to the global outbreak of COVID-19, METI will advance introduction of EdTech to schools and development of online contents that promote home schooling. The ministry will also enhance support for non-face-to-face/remote business activities. The support includes promotion of use of cross-border e-commerce, construction of digital business talk platforms and promotion of smart security.

(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

1 Advanced Land Observing Satellite-2

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 Act Partially Amending the Act on Compensation for Nuclear Damage (Act No.90 of 2018) was enacted in December 2018 to take necessary measures for treatment that is appropriate to be implemented generally. The act established (1) a system to oblige nuclear operators to create and publish a policy for ensuring prompt and appropriate compensation for damage (compensation implementation policy) in the event of nuclear damage; (2) a system where the government lends a nuclear operator the funds necessary for provisional payment when the nuclear operator intends to make such payment to the person who suffered nuclear damage, and (3) special provisions, etc. concerning interruption of prescription when the Dispute Reconciliation Committee for Nuclear Damage Compensation discontinued mediation of settlement. The act was fully enforced on January 1, 2020.

■Table 2-3-7/Major projects for recovery and reconstruction from the earthquake disaster (FY2019)

Ministry/ Agency	Implemented by	Project
Reconstruction Agency	MAFF	Scheme to Revitalize Agriculture and Fisheries in the Disaster Area by Deploying Highly Advanced Technology (Reconstruction Special Account)
MEXT	MEXT	Dispute Reconciliation Committee for Nuclear Damage Compensation, etc. (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 preventing/reducing contamination 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 2-3-8).

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

Implementation of radiation monitoring

As of April 2019

Monitoring Coordination Meeting, Japan (Set up on July 4, 2011)

In order to provide easy-to-understand information integrally with implementation of "detailed monitoring" for public health, safety and security, coordinate the radiation monitoring conducted by relevant ministries and agencies, local governments and business operators with the aim of sure and planned implementation of radiation monitoring.

Comprehensive Monitoring Plan was decided on August 2, 2011 (final revision on February 1, 2019)

Chair: Minister of the Environment; Vice-chair: Parliamentary Vice-Minister of the Environment;
Secretary General: Director-General for Radiation Protection Strategy and Security, Secretary-General's Secretariat of the Nuclear Regulation Authority and Director-General, Environmental Management Bureau, Ministry of the Environment

Members: Director General for Nuclear Disaster Prevention of the Cabinet Office, Assistant to Secretary General of the Support Team for Residents Affected by Nuclear Incidents under the Nuclear Emergency Response Headquarters of Cabinet Office, Director General of the Security Bureau, National Police Agency; Director General of the Elementary and Secondary Education Bureau, MEXT; Councillor (Crisis Management), Minister's Secretariat, MHLW; Director-General, Council's Secretariat of the Agriculture, Forestry and Fisheries Research Council, MAFF; Deputy Director-General, Fisheries Agency; Deputy Vice-Minister for Security and Transport Safety Policy, MLIT; Deputy Director-General, Japan Meteorological Agency; Vice Commandant, Japan Coast Guard; Administrative Vice Chief of Staff, Joint Staff, MOD; relevant local governments, relevant nuclear operators and other parties found necessary by the chair

Major monitoring targets in the Comprehensive Monitoring Plan (modified on February 1, 2019)

***Monitoring system of ministries according to the Comprehensive Monitoring Plan**

Monitoring of the environment in general throughout Fukushima Prefecture (Nuclear Regulation Authority, Nuclear Emergency Response Headquarters, Fukushima Prefecture, nuclear operators and others)
- Release of measurement results of the portable monitoring posts, etc. installed in Fukushima and neighboring prefectures via the Internet
- Continuous measurement of air dose rate, airborne dust etc. around the NPP
- Check of distribution of air dose rate and deposition situations of various radioactive substances on the ground
- Periodical aerial monitoring within 80km of the NPP
- Detailed monitoring of the evacuation order areas

Monitoring of water environment (MOE, Fukushima prefecture)
- Concentration measurement of radioactive substances and measurement of the air dose rate in water, sediment and environment samples from rivers, lakes, marches, water sources, ground waters and coastline areas in Fukushima prefecture and neighboring prefectures

Monitoring in marine areas ((Nuclear Regulation Authority, MLIT, MAFF, Japan Coast Guard, MOE, Fukushima Prefecture, TEPCO and others)
- Measurement of radioactivity concentration of sea water, seafloor beds and marine life were monitored in (1) neighborhood sea area surrounding Fukushima Daiichi NPS, TEPC, (2) coastal sea area, (3) offshore area, (4) open ocean, and (5) Tokyo Bay.

Monitoring of the environment in general throughout Japan (Nuclear Regulation Authority, local governments and others)
- Internet publication of measurement results of air dose rate at monitoring posts in each prefecture
- Monthly concentration measurement of radioactive substances for precipitation composition (dust in rain or the air), once a year for clean water (at the faucet) to the same accuracy of analysis as the level research before the accident
- Aerial monitoring in the area of a relatively-high level of deposition amount of radioactive substances in the prefectures adjacent to Fukushima Prefecture

Monitoring of schools and nursery centers (Nuclear Regulation Authority MEXT, and Fukushima Prefecture and others)
- Internet publication of measurement results of air dose rate at schools, etc. in Fukushima Prefecture
- Concentration measurement of radioactive substances in water in outdoor pools
- Check of radioactive substances concentration in school lunches

Monitoring of seaports, airports, parks, sewage etc. (MLIT. Fukushima Prefecture, local governments and others)
- Concentration measurement of radioactive substances in sewage sludge
- Measurement of air dose rate at seaports, airports, urban parks, etc.

Monitoring of wild fauna and flora, wastes and removed soil (MOE, Fukushima prefecture, local governments, business operators and others)
- Collection and analysis of wild fauna and flora to contribute to understanding of radiation effect on natural ecosystems
- Concentration measurement of radioactive substances in final effluent from waste disposal and treatment facilities and measurement of the air dose rate at site boundary pursuant to the Act on Special Measures in relation to Measures for Environmental Pollution by Radioactive Materials

Monitoring of farm soil, forests and pastures (MAFF. Forestry Agency, local governments)
- Understanding of alteration in concentration of radioactive substances and clarification of the transfer characteristics in Fukushima Prefecture and others.
- Concentration measurement of radioactive substances in forest soil, branches, leaves, bark, forests wood and others in test areas in Fukushima Prefecture
- Concentration measurement of radioactive substances in pasture by prefectures
- Concentration measurement of radioactive substances in reservoirs in Fukushima Prefecture.

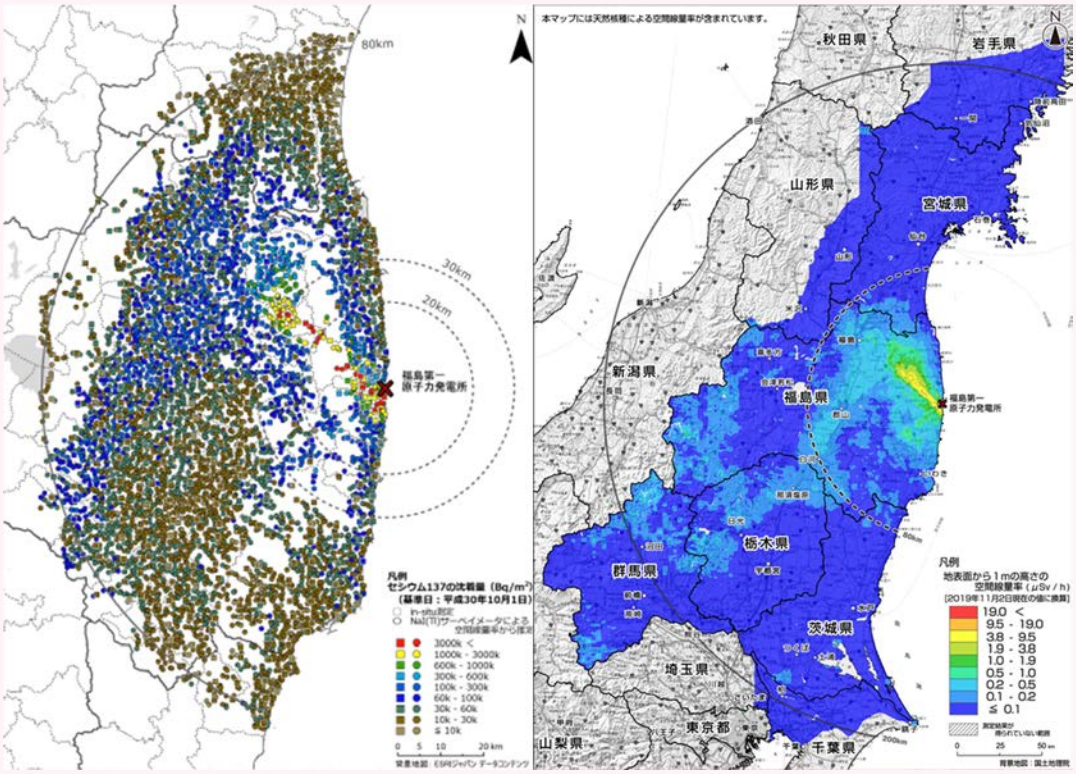
Monitoring of tap water MHLW, Nuclear Emergency Response Headquarters, local governments and others)
- Concentration measurement of radioactive substances in pure water from purification plants or raw water from intake sources by prefectures and in tap water by water sources in Fukushima Prefecture

Monitoring of foods (MHLW, Nuclear Emergency Response Headquarters, MAFF, Fisheries Agency, Fukushima Prefecture, relevant local governments and others)
- Concentration measurement of radioactive substances in foods
- Measurement of actual exposure dose due to ingestion of contaminated foods

*** The results of each monitoring as shown above are collectively published via the portal site set up on the Nuclear Regulation Authority website.**

Source: Secretariat of the Nuclear Regulation Authority

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



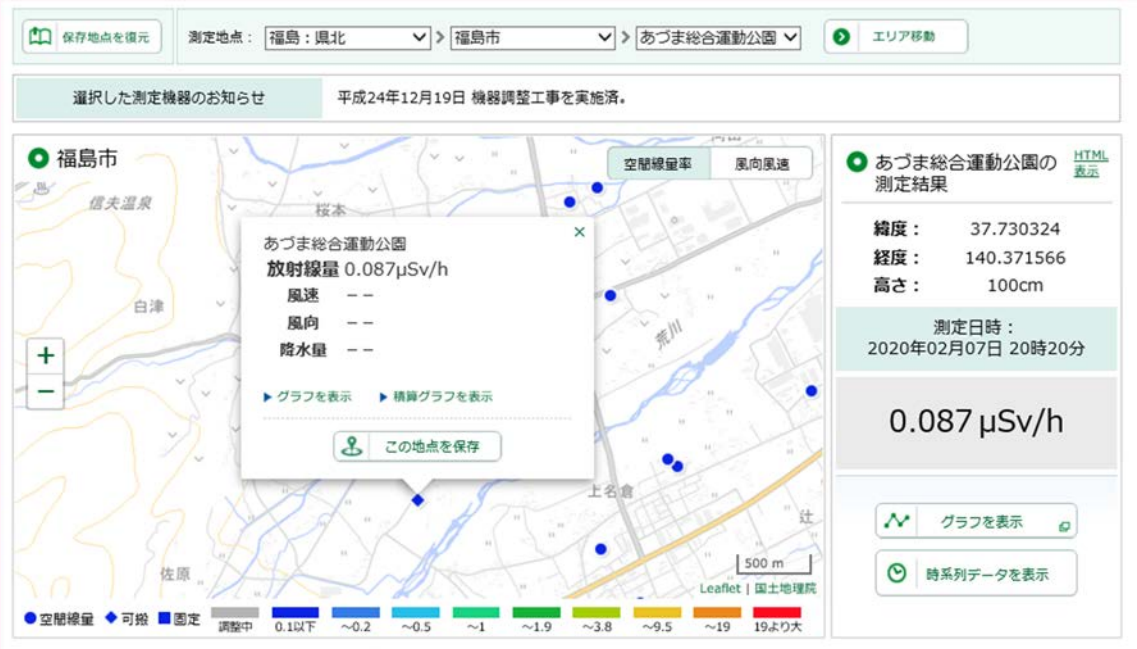
* Cesium 137 soil concentration map (as of October 1, 2018: 90 months after the accident) (left)
* Spatial dose rate map of Fukushima and neighboring prefectures (as of November 2, 2019: 103 months after the accident) (right)
Source: Secretariat of the Nuclear Regulation Authority

In FY2019, 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 2-3-9). The ministry also published the results of travel surveys conducted in cooperation with local governments. In addition, the ministry conducted aerial monitoring within and beyond an 80-km circumference from the TEPCO Fukushima Daiichi Nuclear Power Station and announced the air dose rates of the area (Figure 2-3-9). 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 2-3-10).

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

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



* The system has been managed by the Nuclear Regulation Authority (NRA) since April 2013.
Monitoring information of environmental radioactivity level, Nuclear Regulation Authority: https://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.

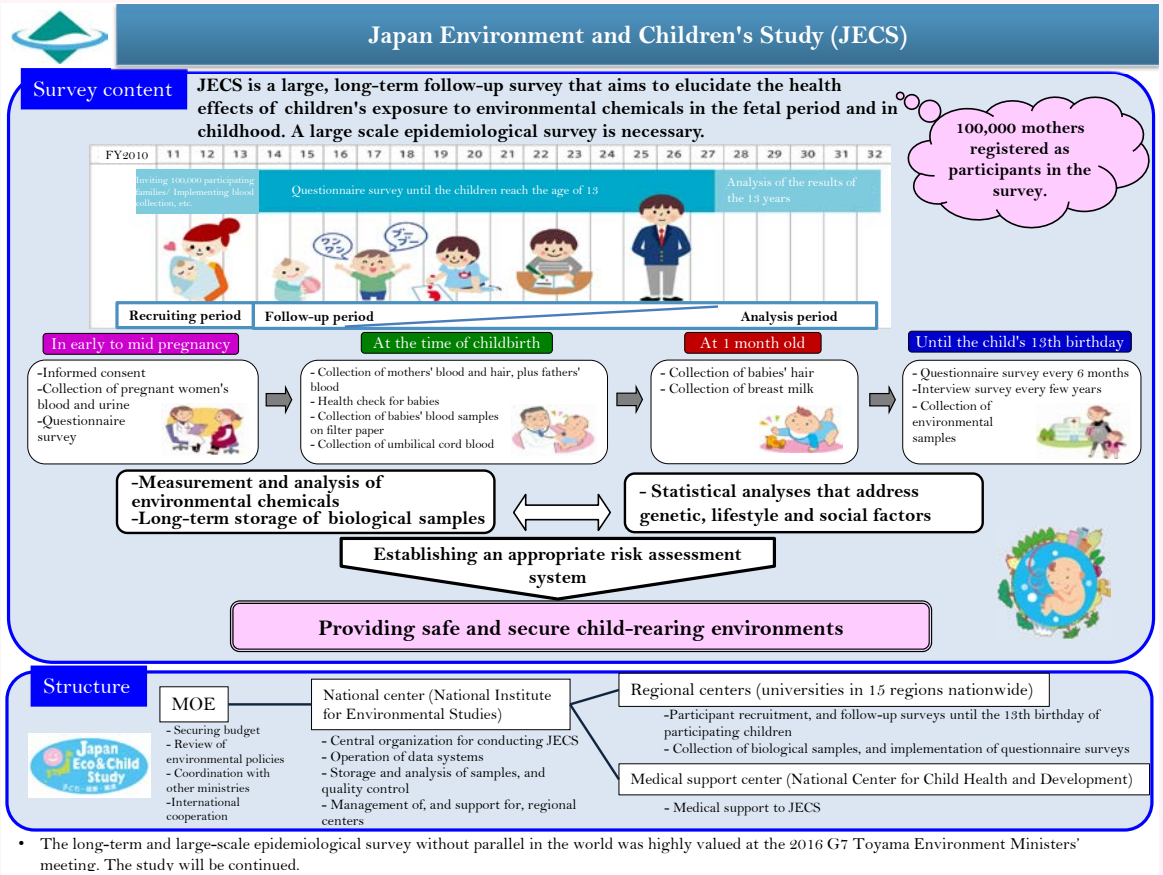
JAEA moved into the research building of the Fukushima Environment Creation Center. In coordination and cooperation with Fukushima Prefecture, the National Institute for Environmental Studies (NIES) and others, JAEA is conducting R&D into technology for measuring radiation doses, research on the behavior 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 2-3-11).

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 FY2019, "Dialogue with Families with Small Children in the Community" was implemented in order to communicate results of the study to the public in an easy-to-understand manner and to expand opportunities to think about the risk of chemical substances.

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



Source: MOE

■Table 2-3-12/Major policies to ensure food safety, living environment, occupational health, etc. (FY2019)

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

Source: MOE

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. Based on the strategy and with the aim of materializing initiatives for practical research and technology development "Policies for Cybersecurity Research and Technology Development" was formulated on May 17, 2019 and the initiatives have been promoted according to the policies.

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 Tokyo 2020 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 Tokyo 2020 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 formulated the Cyber Physical Security Framework (CPSF) that is compiling an overview of the measures required from industry in April 2019 and is developing guidelines for each industry field based on CPSF. In November 2018, AIST established the Cyber Physical Security Research Center to promote R&D to address increasingly sophisticated and complex threats with the integration of cyber

[1] Cyber Defense Exercise with Recurrence

space and physical space. The Industrial Cyber Security Center of Excellence established at the Information-technology Promotion Agency in April 2017 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.

■Table 2-3-13/Major policies for cyber security (FY2019)

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

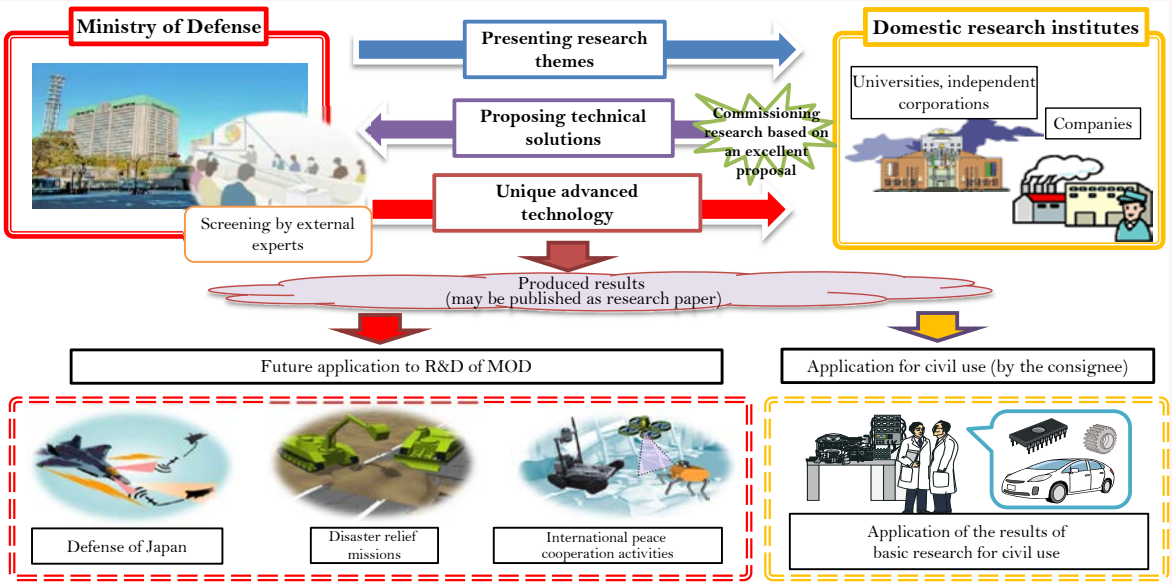
4 Addressing national security issues

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 2-3-14) in FY2015.

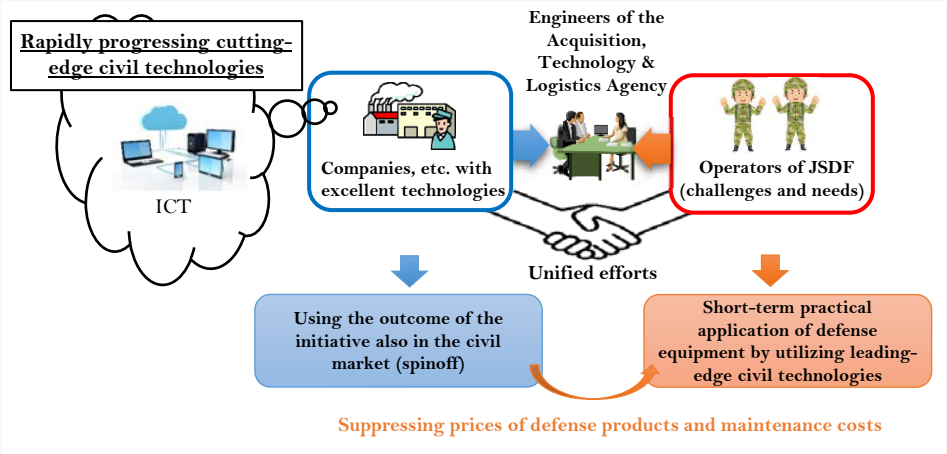
■Figure 2-3-14/Outline of the initiative for early practical use of rapidly progressing cutting-edge civil technologies



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 (Figure2-3-15).

■Figure 2-3-15/Outline of the initiative for early practical use of rapidly progressing cutting-edge civil technologies



Source: ATLA

The National Research Institute of Police Science has been developing a damage prediction simulator anticipating radiation attack in urban area. In FY2019 the institute improved its virtual radiation measurement system that uses simulated radiation sources and smartphones. The improved system is used for initial response drill simulating nuclear security cases, radiation education in the medical field and other purposes.

The institute also conducted demonstration tests of homemade bombs used for international terrorist attacks and their usage, evaluated their power and sensitivity, and implemented research on homemade bombs that are made using commercially available materials. The research will contribute to measures taken by managers of raw materials of explosives.

MOD has been conducting research for response to severe disasters such as a CBRN[1] contaminated environment. Examples are: research to facilitate unmanned vehicle operation by swiftly creating 3D area maps by integrating information obtained from multiple unmanned vehicles, and research on a threat determination system to estimate source areas based on dispersion prediction considering detailed topography including buildings in midtown and information from multiple sensors.

■Table 2-3-16/Major policies to address national security issues (FY2019)

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

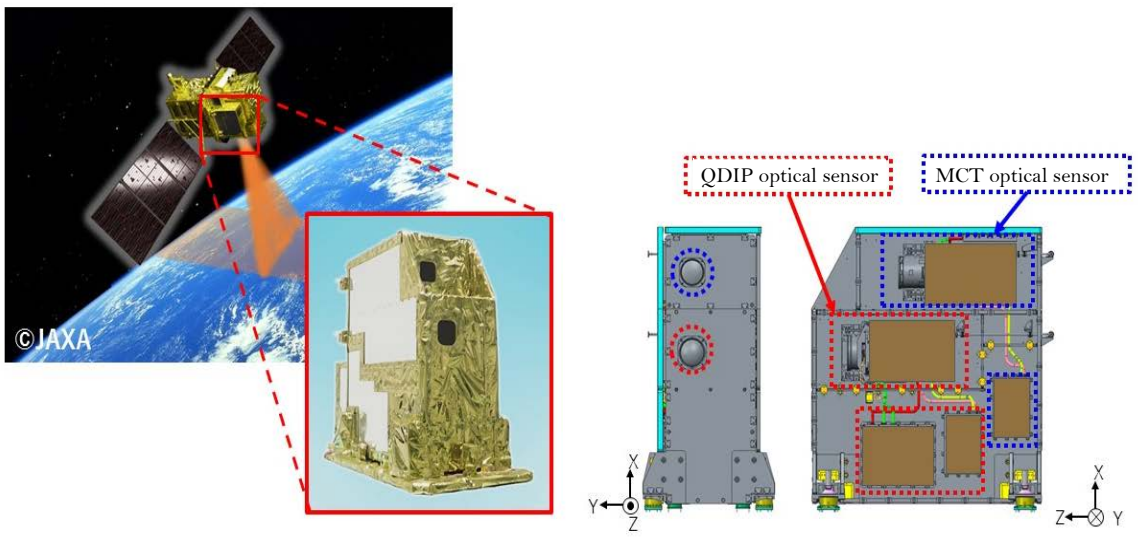
1 Chemical, Biological, Radiological, Nuclear

Column 2-5

Research on Satellite-mounted Dual-band Infrared Sensor

The Acquisition, Technology & Logistics Agency (ATLA) started research on the satellite-mounted dual-band infrared sensor in FY2015. ATLA plans to mount the sensor on the Advanced Land Observing Satellite (ALOS-3) that has been developed by JAXA and MEXT. After the launch of ALOS-3 using the H3 rocket in FY2020, empirical research will be conducted in space. With its ability to detect infrared rays emitted or reflected by objects whose temperature is above absolute zero, infrared sensor can collect image data in space through radiation and mostly sunlight reflection from clouds and various objects on the earth's surface.

Satellite-mounted dual-band infrared sensor is based on the Quantum Dot Infrared Photodetector (QDIP) that is a cooled quantum dot type infrared detecting element developed by ALTA and intended for mounting on a satellite. The sensor uses middle-infrared and far-infrared in multiple pixels. Use of the difference in emissivity and reflectance between the two infrared wavelength bands is expected to improve identification ability. Each pixel has a structure where sensing layers of different wavelength are laid vertically to the light receiving surface so that one detecting element can receive infrared rays of two wavelength bands. In addition to the dual band QDIP optical sensor, the satellite-mounted dual-band infrared sensor will also mount the Mercury Cadmium Telluride (MCT) optical sensor that is proven in space for comparison. This way ALTA will confirm performance characteristics of the dual band QDIP optical sensor as its first demonstration in space and accumulate technical knowledge on collection of infrared data from space. In the area of image processing, it is expected to enable extraction of characteristic targets from many heat sources through merging processing of middle and far-infrared images, for example, even when the target is difficult to detect and identify in the image at a glance



Satellite-mounted dual-band infrared sensor
Provided by MOD and JAXA

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 245 countries and institutions as members as of February 2020. 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" (ALOS-2) and so on, and has been conducting R&D for the Advanced Land Observing 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 CO_2 and methane observation technologies using the Greenhouse Gases Observing Satellite "IBUKI" (GOSAT) 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, GOSAT has been used for clarification of the global concentration distributions of CO_2 and methane, as well as estimation of absorptions and emissions by month and region. The project revealed a trend of rising concentration of CO_2 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. "GOSAT-2" improved the accuracy of observation of CO_2 and methane that have been observed by GOSAT and added CO to its observation 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 CO_2 emissions of "human origin" through observation and analysis of CO_2 emissions in combination with carbon monoxide emissions. The successor GOSAT-2 was launched in October 2018. In addition to succeeding the mission of GOSAT, 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 of emissions of human origin and improve accuracy of emissions estimation. Furthermore, the ministry started development of the Global Observing Satellite for Greenhouse Gasses and Water Cycle (GOSAT-GW) that mounts successor sensors of GCOM-W and GOSAT-2 respectively. The aim of the next greenhouse gas observation sensors to be mounted is to continue the mission of GOSAT and GOSAT-2 and further enhance their emission source monitoring ability.

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).

The Arctic is known as the place where warming is most rapidly progressing due to various mechanisms. On the other hand, melting of ice in summer presents the possibility of various uses for Japan and other countries. Both for response to global climate change and contribution to sustainable use of the Arctic, it is essential to enhance scientific knowledge that is their basis.

To this purpose, under the Arctic Challenge for Sustainability Project (ArCS), climate change in the 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.

In FY2019, in order to clarify changes in the marine environment and ecosystem in the Arctic Ocean and its surrounding seas, the ministry conducted observation using the oceanographic research vessel Mirai in conjunction with the Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC) in October because of the delayed formation of sea ice.

For Arctic research vessels that are observation and research platforms capable of observing the sea ice

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.

areas that have not been observed, MEXT developed constituent technologies including an autonomous underwater vehicle (AUV) capable of autonomous cruising and observation under sea ice, while building a frozen sea navigation aide system.

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.

In the Integrated Research Program for Advancing Climate Models (TOUGOU), 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, supercomputers including the Earth Simulator are used to advance climate change projection/prediction technologies through development of climate models, etc. The Ministry has made international contributions through the climate models that were developed in its projects: they are the most frequently used climate models in the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) that compiles scientific knowledge on climate change.

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 platform integrating observation and projection/prediction data

Under the Program to Promote Development of Global Environmental Data Platform, MEXT has developed the Data Integration and Analysis System (DIAS). DIAS is an information platform that accumulates, integrates and analyzes big data of the global environment (observation information, projection/prediction information, etc.) to contribute to solution of climate change and other global issues. DIAS has supported R&D in Japan and abroad and produced results including a system that predicts the inundation state of roads, blocks, etc. in real time. The ministry is working to establish a management structure to ensure its long-term stable use by a large number of users including researchers and 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 Science Council (ISC[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.

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

METI thinks that CO_2 is a resource. Therefore, in order to reuse CO_2 as fuel and material while at the same time promoting technology development of carbon recycling that suppresses CO_2 emissions to the atmosphere, the ministry formulated the Carbon Recycle Technology Roadmap in June 2019 and is advancing technology development in accordance with the roadmap.

Aiming at the practical use of CO_2 Capture and Storage (CCS), METI is advancing R&D for the demonstration of an integrated system designed to separate and capture CO_2 from large CO_2 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 CO_2 emissions reduction technologies, including a technology to partially substitute hydrogen for coke as a reductant in steel manufacturing and separate and capture CO_2 from blast furnace gas toward further decarbonization.

MOE has been compiling (1) costs of separating and recovering most of the CO_2 from exhaust gas from coal fired power plants, (2) design and construction of Japan's first full-scale CO_2 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.

1 This global academic organization aims to strengthen international activities in the applied science and other science fields for the benefit of society. ISC was established by integration of the International Council for Science (ICSU) established in 1931 and the International Social Science Council (ISSC) in 2018 and covers all scientific fields.

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.

Since FY2018 the ministries have been implementing demonstration of CO_2 Capture and Utilization (CCU), artificial photosynthesis and methanation[1] initiative as well as examination and evaluation of the CO_2 reduction effects over their lifecycle.

Toward achieving the medium- to long-term goal set by the International Maritime Organization (IMO) to halve GHG emissions from international shipping by 2050 and eventually eliminate them by the end of this century, in an industry-government-academia collaboration, MLIT formulated a roadmap compiling the direction and problems for development and dissemination of innovative energy-saving and decarbonization technologies. Japan proposed a new international framework to promote replacement of old ships to IMO and is promoting activities toward early agreement. Since FY2018 the ministry in cooperation with MOE has been conducting a model demonstration of a LNG fuel ship to maximize reduction of CO_2 emissions in actual operation.

With the aim of greatly reducing CO_2 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 Integrated Innovation Strategy 2019 (Cabinet Decision on June 21, 2019) took up environmental energy as one of the key areas where efforts should be strengthened. Toward achieving the **2**°C goal of the Paris Agreement, contribution to the 1.5°C goal and implementation of a carbon-free society as early as possible in the latter half of this century, relevant ministries/agencies, industry and academia shall cooperate to materialize relevant initiatives from R&D to social implementation.

In order to support planning and promotion of adaptation measures by local governments and other partners based on actual needs including disaster prevention, agriculture and heat countermeasures, MEXT in the "Social Implementation Program on Climate Change Adaptation Technology" has been developing ultra-high resolution climate change projection information for the near future, which 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 FY2019 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

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

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 control pests and invasive alien species, 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 has been implementing the "Comprehensive Strategic Research on the Mitigation of and Adaptation to Climate Change (S-14)" as one of the studies using the Environment Research and Technology Development Fund to develop quantitative basic data for effective and efficient ways to take mitigation/adaptation measures and contribute to appropriate planning of climate change countermeasures. 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 (FY2019)

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

Column 2-6 Approval of Japan's first GSSP and Name of a Geological Age "Chibanian"

On January 17, 2020, the International Union of Geological Science (IUGS) approved the application to register the "Chiba Section" that is a section of stratum exposed on the bank of the Yoro River in Ichihara City, Chiba, as a Global Boundary Stratotype Section and Point (GSSP). By this, a geological age of the Middle Pleistocene, that is a geological time period ranging between about 774,000 and 129,000 years ago, was newly named "Chibanian" and the name of a place in Japan is written in the history of the earth for the first time.

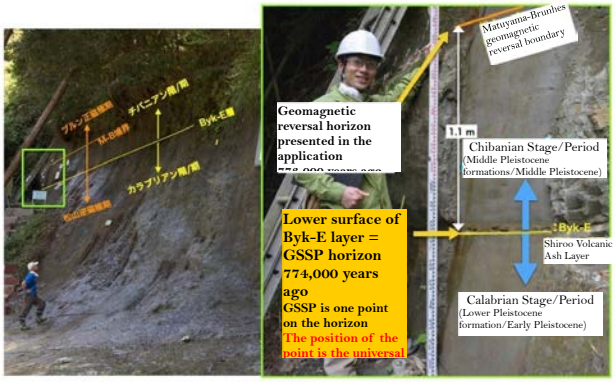
Currently the history of the earth is divided by 116 stratigraphic boundaries and each boundary is defined by the stratum that shows the boundary most clearly in the world. The section of the stratum is called GSSP and 73 GSSPs have been decided up to now.

The examination process of the Early -Middle Pleistocene GSSP started at the first stage working group in June 2017. In addition to Chiba Section two sites in southern Italy were also candidates. Because Chiba Section showed field reversal most clearly, the section was selected with more than 70% of the member votes in November of the same year. It was supported also by subsequent examinations and finally approved at this IUGS.

Most of GSSPs are in Europe, the United States and China. Because all GSSPs of the Cenozoic era from 66 million years ago to date are in the shores around the Mediterranean Sea, places in Italy and other Mediterranean countries were believed to be strong candidates also for GSSP of the Pleistocene. In this context, registration of Chiba Section as GSSP has a great academic significance. This is also a big opportunity for Japan to develop its presence in the geological field in the future.

Location of Chiba Section
Source: National Institute of Polar Research

GSSP horizon at Chiba Section and field reversal



GSSP horizon at Chiba Section and field reversal boundary
Source: Ibaraki University

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. On February 2019, another technical support organization for evaluation regarding invasive alien species was set up under IGES. At the 7th meeting of the IPBES Plenary held from late April to early May with support by the new organization, a report assessing global biodiversity and ecosystem service was accepted and a summary for decision-makers was approved and published. In order to ensure effective reflection of Japan's knowledge in the briefing session of the meeting and the assessment reports in the process of creation, the country held the domestic liaison conference in May gathering experts involved in IPBES in Japan from relevant ministries and agencies. Furthermore, in order to discuss the next global diversity targets based on the IPBES Global Assessment Report, a symposium, "Transformative Change Toward Society in Harmony with Nature", was held in December. 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.

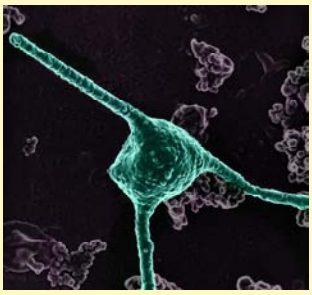
The National Institute of Technology and Evaluation (NITE) has been collecting, preserving and distributing biological genetic resources and has also been organizing information on these resources in terms of their genes and genetic lineages so as to make the information accessible to researchers and 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. Research has been conducted for restoration of the marine ecosystem off the Pacific coast of Tohoku region damaged by tsunami.

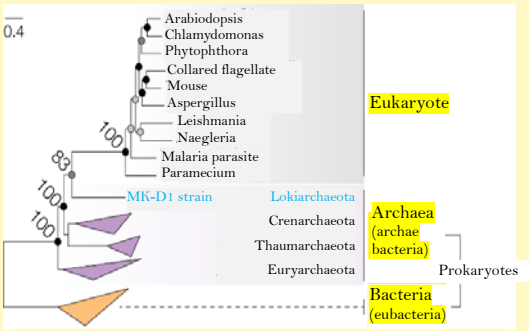
Column 2-7 Success of Cultivation of Archaea", a Microorganism Holding the Key to the Birth of Eukaryotes from Deep-sea Sediments

A wide variety of microorganisms are living in deep-sea sediment. Many of them are unknown microorganisms that have not been cultivated. Because understanding of these unknown microorganisms is expected to promote understanding of material cycle on the earth and the obtainment of useful biological resources, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has been studying subseafloor microorganisms for many years. One of the results is the world's first cultivation of archaea that are believed to hold a key to the birth of eukaryotes, taken from sea sediment retrieved by deep submergence research vehicle "Shinkai 6500."



Cultivated MK-D1 strain
Source: JAMSTEC

Life on earth is broadly divided into Archaea (archae bacteria), bacteria (eubacteria) and eukaryotes that have a complicated cell structure with nuclei. Plants and animals including we humans are eukaryotes. It is believed that the ancestor of eukaryotes emerged when an archaeon engulfed a bacterium that is the ancestor of mitochondria and started to live together. Recent research deduced that a group of archaea known as Asgard is closest to the ancestor of eukaryotes, but its presence has been confirmed only through environmental genome information and the form, size and way of life of archaea was completely wrapped in mystery. Therefore, cultivation of archaea was greatly awaited worldwide.



Systematic position of MK-D1 strain based on genome information
Source: AIST

To this purpose, a research team from JAMSTEC, the National Institute of Advanced Industrial Science and Technology (AIST) and other entities thought of an idea to use as incubator a reactor apparatus for sewer treatment using microorganisms. By simulating the environmental condition of deep sea methane-seep sites, the team succeeded in cultivating archaea belonging to Asgard from deep-sea sediment. Studying detailed characteristics of the archaea named MK-D1, the team found that its cell has a spherical form with diameter of 550nm (approximately one 2,000th of 1mm) and a structure not observed in other archaea – branching long and narrow tentacle-like protrusions. It was also found to be able to proliferate only in symbiosis with other microorganisms and proliferate extremely slowly: one 1,000th the speed of coli bacterium. Detailed DNA analysis revealed that it has many genes: including actin and ubiquitin, which were believed to be only in eukaryote. The team also proposed a new evolution story of emergence of eukaryotes, the "E^3" model, based on the characteristics of MK-D1 strain and past research results related to the origin of eukaryotes.

Bottom sampling by Shinkai 6500 in a methane-seep site
Source: JAMSTEC

The achievement appeared in an English science journal "Nature" in January 2020 and a photo of its interesting cell form was on the cover. The research was also chosen as one of the "Breakthroughs of the Year."

For the future, it is expected that further investigation of the MK-D1 strain, and cultivation of other archaea and primitive one-cell eucaryotes and elucidation of their characteristics will shed more light on the course of evolution from archaea to eucaryotes.

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.

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

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.

In order to contribute to the promotion of industrial use of the ocean by Japan, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) is promoting understanding of biological and physical cycle in the ocean and origin of useful resources and providing obtained scientific knowledge, technologies and samples to the related industries (See Chapter 3 Section 1, 1(2)).

(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 (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.

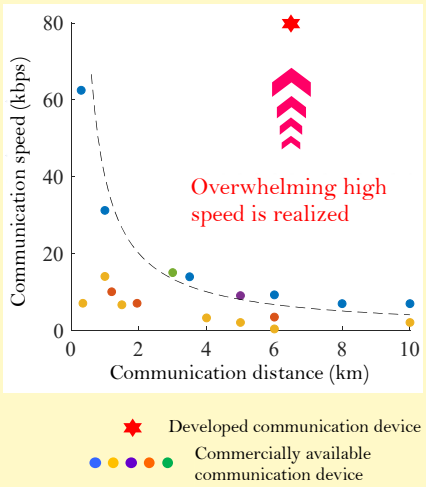
Column 2-8 Development of High-speed Underwater Acoustic Communication Device – Speed of 79kbps at the distance of 6,500m

Most terrestrial communications are conducted using electromagnetic waves, but underwater communication is generally conducted using sonic waves because electromagnetic waves easily attenuate under the sea. JAMSTEC is promoting basic research on horizontal Multi-Input and Multi-Output (MIMO) communication and development of multi-user communication devices to control multiple unmanned exploration vessels simultaneously.

Based on the results of this basic research and development, JAMSTEC uniquely developed a vertical high-speed underwater acoustic communication device in 2017. In acoustic communication under the sea, because waves of high-frequency area are absorbed, distance and communication speed are almost inversely related and the performance of conventional devices is around 40kbps·km However, the communication device developed by JAMSTEC accomplished more than 6.5km x 79.1kbps = 512kbps·km. This is the world's fastest speed that leaves existing communication devices in the dust. The device is mounted on manned submersible research vehicle "Shinkai 6500" and has already been used to transfer still images shot by camera to the mother ship. This enabled researchers on the mother ship and the operators to grasp the object observed by the vehicle and its operating conditions in real-time. Submersible "Alvin" of Woods Hole Oceanographic Institution of the United States also succeeded in an experiment of similar image transmission and the future global development is expected. These successes of high-speed communication suggest the possibility of underwater Wi-Fi and IoT that connect exploration vehicles to the Internet in the future. What is expected is not only contribution to R&D in the field of oceanology but also broad application to aquatic activities in general including ocean floor resource development, port construction works, diving and other leisure activities.

Picture received from Shinkai 6500
Source: JAMSTEC

Acoustic communication from Shinkai 6500
Source: JAMSTEC



Comparison with existing communication devices
Source: JAMSTEC

2 Promotion of R&D in space science

Space technologies including weather, communication, positioning and broadcasting satellites are closely related to the everyday lives of people in various fields including weather forecasting, car navigation system and financial trading. 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/Outlines of the Implementation Plan of the Basic Plan on Space Policy (Revised in FY2019)

Outline of the Implementation Plan of the Basic Plan on Space Policy (revised FY2019)

As of December 13, 2019
National Space Policy Secretariat

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

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

Satellite positioning

- Quasi-Zenith Satellite System development, improvement and operation
  - Establish a seven-satellite system, improve its function and performance, and develop and maintain ground equipment around FY2023.
- Promote utilization of the Quasi-Zenith Satellite System
  - Implement demonstration projects in more fields including agriculture, forestry and fisheries, drone logistics and automatic navigating ships, and create advanced application models
  - Enhance functions of the satellite safety confirmation system

Satellite remote sensing

- Information Gathering Satellites (optical / radar)
  - Launch the 1st data relay satellite in FY2020
  - Steadily implement development toward establishment of 10-satellite system
- Advanced optical/radar satellites (ALOS-3 and 4)
  - Promote development toward the launch in FY2020 (optical) and FY2021 (radar)
- Geostationary Meteorological Satellites
  - Carry out survey on methods for production, launch ad operation of the successor model in FY2020.
- Greenhouse Gas Observing satellites (GOSAT)
  - Steadily promote development of the 3rd satellite toward its launch in FY2025, while promoting international standardization under Japan's leadership and use of satellite data in climate change countermeasures by other countries
- Other remote sensing satellites
  - Start detail design of high-performance microwave radiometer3 in FY2020 toward mounting on the GHG and water cycle observation satellite
  - Study the vision of GHG observation missions in the future

Satellite communications and satellite broadcasting

- Engineering Test Satellite
  - Advance detailed design of the Engineering Test Satellite (9th satellite) with an eye toward its launch in FY2022
  - Work toward early establishment of satellite quantum cryptography
- Optical Data Relay Test Satellite
  - Launch the satellite and start its operation in FY2020
- 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, solid rocket booster and the system as well as fabrication of a real model
- Epsilon Launch Vehicle upgrades
  - Based on the synergy effect-oriented development plan with the H3 rocket, conduct overall basic design, continue detail design, and implement system development in FY2020.
  - Study concrete measures within FY2020 to strengthen competitiveness concerning the synergy effect-oriented Epsilon rocket with a view to transfer to the private sector

Space Situational Awareness (SSA)

- In FY2020 establish a space domain mission unit and promote various initiatives toward actual operation of the SSA system, while promoting activities pertaining to introduction of the SSA satellite and SSA laser ranging apparatus
- Implement feasibility study toward formation of an SSA platform available for private businesses
- Promote collaboration for sharing and utilization of space weather information

Maritime Domain Awareness (MDA)

- Strengthen MDA capability through survey and research of the latest technologies related to the automatic identification system (AIS) and other technologies to use the satellite for ship identification.

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

- Space science and exploration
  - Promote programming and implement front loading of technology
  - Operate Hayabusa 2 aimed at return to the earth at the end of 2020 and prepare for initial analysis of its samples.
  - Conduct study aimed at materialization of competitive small-scale plan4, and steadily develop Deep Space Exploration Technology Demonstrator (DESTINY+)
- Manned space activities including international space station plan
  - In order to ensure independent continuation of private-led space activities on low earth orbit after the termination of ISS operation, promote transfer of application/operation technologies to the private sector and efforts to facilitate unmanned operation/automation, while driving demand.
- International space exploration
  - Concerning participation in the international space exploration including the circumlunar manned space station (Gateway) proposed by the United States, materialize initiatives in the four fields which are subject to immediate cooperation.

Measures to strengthen the space industry, science and technology base and infrastructure

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

- Strengthen collaboration with community-led initiatives independently implemented by 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
- Further enhance available data of the data platform toward open and free use of the government's satellite data (Tellus). Complete the development by FY2020 toward privatization in FY2021 and beyond.
- Strengthen the linkage function between the G-spatial Information Center as hub and collection systems of various types of geospatial information including Tellus, agriculture, disaster prevention and infrastructure information
- Under the leadership of the public-private sector conference, accelerate study of environmental improvement for suborbital flight to contribute to future business development, considering activities of private businesses at home and abroad as well as international trends toward commercialization in the first half of 2020.

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

- Under the innovative satellite technology demonstration program, launch the No.2 satellite in FY2021, the No.3 in FY2022 and the No.4 in FY2024 taking advantage of the experience and achievements of No.1 and conduct demonstration experiment in orbit.
- Work on development and evaluation of low-price and high performance satellite components, while supporting demonstration of small satellites incorporating them in orbit.
- While studying an internationally competitive future transport system, specifically reflect the demonstration results of guidance control, propellant management and other technologies through flight test of small prototypes of the reusable space transportation system in the plan of flight test reusing the first-stage engine in international cooperation toward implementation in FY2022
- 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. Start expansion of opportunities to learn skills to use satellite data and operation of a platform for talents specialized in space business (S-Expert) in FY2019.
- While advancing efforts toward introduction and deepening of firm contracts, accumulate and sort out learned lessons, etc. regarding study of systems including service procurement.

Other initiatives to maintain and strengthen space industry and science technology

Space debris countermeasures

- Steadily promote concrete efforts by the relevant organizations to address the issue of space debris based on the agreed direction of the immediate activities and considering the study that includes a time axis.
- Steadily promote necessary technology development with cooperation of private businesses toward demonstration of related technologies in FY2022.

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 through space technologies toward achievement of SDGs

Source: Cabinet Office

(1) Space transportation systems

Space transportation systems that have a role to launch satellites are a key pillar for the development and utilization of space. 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 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 the Epsilon rocket with the H3 rocket has been implemented since FY2017 to reduce costs.

Launch of H-IIB F8
Source: JAXA

Using H-IIA, H-IIB and Epsilon, our key rockets, Japan successfully launched the Innovative Satellite Technology Demonstoration-1 in January 2019, Cargo Transfer Vehicle "KOUNOTORI-8" in September 2019 and Information Gathering

Satellite Optical-7 in February 2020.

(2) Global positioning satellite systems

The Cabinet Office started a high-precision positioning service based on a 4-satellite constellation of Quasi-Zenith Satellites MICHIBIKI on November 2018. Toward the 7-satellite constellation to be established in FY2023 and its function and performance improvement, the office is promoting the development of MICHIBIKI-5, 6 and 7. 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.

Quasi-Zenith Satellites MICHIBIKI (QZS-3)
Provided by the National Space Policy Secretariat, Cabinet Office

(3) Satellite communication and broadcasting systems

In order to realize internationally competitive next generation geostationary communication satellites, MIC and MEXT have been jointly 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 toward launch in FY2022.

(4) Earth observing system

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

With the aim of elucidating the mechanism of global water cycle and climate change, JAXA has been operating SHIZUKU (GCOM-W) launched in May 2012 and SHIKISAI launched in December 2017. Data from SHIZUKU together with the data from the Global Precipitation Measurement (GPM) core satellite launched in February 2014 under the international cooperation project with NASA[1] are used by JMA to improve the accuracy of precipitation estimates and for various other purposes, including weather forecasting and fishing ground detection. SHIKISAI is used also to grasp the situation of overseas large-scale forest fires.

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

In addition, DAICHI-2 (ALOS-2) launched in May 2014 is contributing to disaster prevention and management, and solutions to global issues such as global

1 National Aeronautics and Space Administration

warming through monitoring of various disasters, grasping of damage situations and the observation of forests and ice of Polar Regions, etc. Currently JAXA is also conducting research on advanced land observing satellite-3 (ALOS-3) capable of wide-area and high-resolution imaging, advanced land observing satellite-4 (ALOS-4), and the development of optical data relay satellites that can achieve optical communication between these satellites.

Technologies whose use for earth observation from satellite will contribute to disaster management/mitigation include sensing systems using the terahertz band that can sense water vapor and its oxygen concentration more accurately. MIC is working on R&D on fundamental technology toward its realization.

Toward stable operation of Japan's satellites, MEXT and JAXA have established and have been operating the SSA[1] system since FY2002 to observe space debris, etc. from the ground. The whole government including the Ministry of Defense is constructing a new SSA system toward FY2023.

(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. Venus Prove AKATSUKI put into Venus orbit in December 2015 produced results leading to the elucidation of the Venus atmosphere mechanism, while Geospace probe ARASE launched in December 2016 has contributed to deepening of the understanding of the interaction between the earth and solar activities through identification of the physical process of aurora generation, for example.

Asteroid prove HAYABUSA2
Provided by Mr. IKESHITA Akihiro

HAYABUSA2, an asteroid explorer launched in December 2014, arrived at the Ryugu asteroid in June 2018 and achieved several of the world's first brilliant feats including exploration by rover, formation of an artificial crater on the surface of the asteroid and twice-repeated touch downs to the same asteroid. It is believed that the explorer also succeeded in scientifically valuable sampling inside the asteroid. It is scheduled to return to Earth around the end of 2020.

In addition, the Mercury Magnetospheric Orbiter MIO of the BepiColombo international collaborative mission to Mercury (launched in October 2018) in cooperation with the European Space Agency (ESA) is in operation. JAXA is also developing the small moon landing demonstrator (SLIM[2]) in an attempt to conduct Japan's first lunar landing and the satellite XRISM[3] (both are scheduled for launch in FY2021). In this way JAXA has been active in establishing a leading position in the world as well as in promoting R&D

1 Space Situational Awareness
2 Smart Lander for Investigating Moon
3 X-Ray Imaging and Spectroscopy Mission

on space science that helps broaden the frontiers of space for humankind.

(6) Human space activities

The International Space Station (ISS) Program[1] is an international project collaboratively implemented by fifteen countries: Japan, the U.S.A., Europe, Canada and Russia. In this project, Japan assumes the role of developing and operating the Japanese Experiment Module "KIBO" and the uncrewed cargo transfer spacecraft "KOUNOTORI" (HTV[2]). KOUNOTORI has been used to resupply KIBO and the ISS. Japanese astronauts have carried out longstay missions aboard the ISS. The Japanese team has various achievements, such as establishing crewed and uncrewed space technologies, establishing an international presence for Japan, promoting 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 deploying small satellites), and educating young people. KOUNOTORI-8 was launched in September 2019 and resupplied such as with water, food, batteries and a small-sized satellite optical communication system. The batteries consist of new lithium-ion battery cells manufactured by a Japanese company and play an important role in continuous ISS operations.

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 unmanned cargo transfer spacecraft "HTV-X" with future space exploration in mind.

(7) International space exploration

Many countries have been increasing interest in space and planning Lunar surface and Mars exploration. In March 2019 the U.S. government announced a plan to return American astronauts to the moon by 2024. The plan is named the "Artemis Program" that includes development of the Lunar Orbital Platform-Gateway with the aim of acquiring necessary technologies through continuous activities on the moon toward human landing on Mars in the 2030s. In October 2019, the Strategic Headquarters for National Space Policy decided "Policy of Japan on the Participation in International Space Exploration under the Proposal of the United States." The Japanese government is coordinating with the agencies participating in this program so that Japan can contribute strategically in the fields in which it has advantages. Japan also plans to launch the Smart Lander for Investigating Moon "SLIM" in FY2021 and has been considering a joint lunar pole exploration mission by JAXA and ISRO[3].

(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

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

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 is developing the Hyperspectral Imager Suite (HISUI) that enables enhancement of remote detection capacity for oil resources. HISUI was launched in December 2019 and mounted in Japanese experiment module "Kibou" of the International Space Station. The ministry also supports development of low-price and high-performance space parts/components using civilian technologies, provides opportunities for their demonstration on orbit and is developing autonomous flight safety system toward drastic cost reduction of rockets for small satellite. 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 (Tellus).

■Table 2-3-19/Major policies to open up frontiers important for national strategies (FY2019)

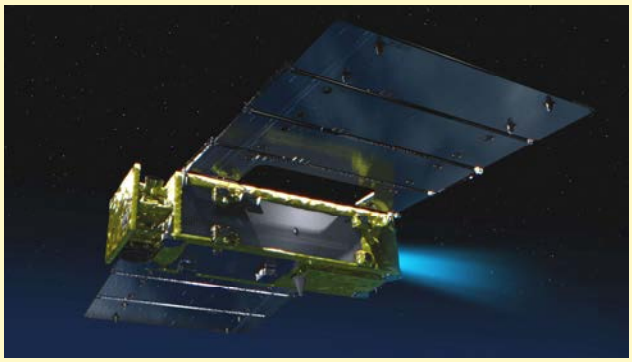
Ministry	Implemented by	Project
Cabinet secretariat	Cabinet Intelligence and Research Office	R&D of information-gathering satellites
CAO	CAO	Promotion of practical Quasi-Zenith Satellite System project
MEXT	MEXT	Japanese Antarctic Research Program
		The Arctic Challenge for Sustainability Project
	JAXA	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
		R&D of the Hyperspectral Imager Suite (HISUI) for remote detection of oil resources
		R&D for space industry technology and information infrastructure development (SERVIS project)
MLIT	JCG	Promotion of marine research in the EEZ of Japan

Column 2-9 TSUBAME – Japan's Super Low Altitude Satellite Technology Leading the World

On September 30, 2019, Super Low Altitude Test Satellite TSUBAME (SLATS) developed by JAXA completed orbit maintaining a 167.4km altitude that was listed in the Guinness World Records ® as the world's lowest altitude of an earth observation satellite and reentered the atmosphere on October 1, completing its innovative technology demonstration.

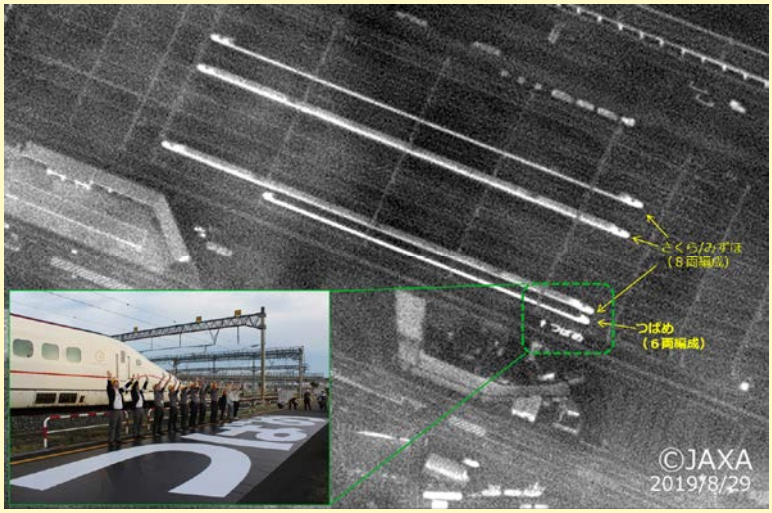
Far lower altitude of satellite orbit has the advantage that high resolution satellite images are possible using smaller sensors. However, below the 300km altitude that is called "super low altitude," atmospheric drag and concentration of atomic oxygen that deteriorates satellite materials are more than 1,000 times higher compared with altitudes of 600km to 800km where ordinary earth observation satellites orbit. For this reason, super low altitude was considered not adequate for earth observation satellites that require long-term operation and precise attitude and orbit control. TSUBAME was developed to obtain technologies that enable long-term earth observation at a super low altitude and launched on December 23, 2017.

Its name TSUBAME (means swallow in Japanese) was chosen based on the overwhelming majority of submissions from the public. The satellite's spreading solar paddle, flight in various attitudes and propulsion from its ion engine calls up an image of the bird spreading its wings and swiftly flying low. The satellite took a picture of a cheering salute to the Yakult Swallows, its namesake professional baseball team, and it was held up in the right stand of Jingu Stadium in April 2019. In August, the satellite took a picture of Kyushu Shinkansen "Tsubame." These public relation activities familiar also to children contributed to enhancement of the public understanding of the latest space development.



Imaginary drawing of TSUBAME jetting from its ion engine
Source: JAXA

The achievements of TSUBAME are expected to contribute to the development of the earth's upper atmosphere science and further bring about downsizing and cost reduction of future earth observation satellites as well as unprecedented earth observation missions.



Kyushu Shinkansen "Tsubame" shot by TSUBAME
Source: JAXA