Chapter 2 Acting to Create New Value for the Development of Future Industry and Social Transformation

In revolutionary times when economic and social systems and industrial structure rapidly change and it is difficult to see into the future, it is essential to create new knowledge and ideas that can change the game influencing the competitiveness of organizations and countries. This is why the government strengthens its efforts to actively create discontinuous innovations through bold attempts.

It will also strengthen undertakings to realize Society 5.0 ahead of the rest of the world. Society 5.0 is a future society where new values and services are created one after another through undertakings focused on active utilization of cyberspace, which will bring about prosperity to people who create society.

Section 1 Fostering R&D and Human Resources that Boldly Challenge the Future

The process of setting the bar high, and boldly attempting to consistently create unrivaled innovation without fear of failure, is important. It is required to encourage R&D with focus on the novelty of the idea and economic and social impact, and expand opportunities for people with more creative ideas and abilities to implement them in order to try these ideas in R&D projects under the jurisdiction of relevant ministries and agencies.

To this end, Ministry of Education, Culture, Sports, Science and Technology (MEXT) will promote R&D toward the stage where it is possible to determine the feasibility of practical applications, by setting technologically challenging goals based on social and industrial needs and clearly identifying targets with economic and social impact, inducing private investment and using diverse research results created by the Strategic Basic Research Programs, Grants-in-Aid for Scientific Research and other programs.

Column 2-1 Efforts to create innovation promoted by international competitions

In recent years efforts to create innovations have been promoted through international competitions aiming to solve problems confronting the world. Multiple parties including private companies, universities and research institutes are working together taking advantage of their respective strengths. For example, XPRIZE Foundation, a non-profit organization of the United States, is using a unique method where contestants compete for the prize set for a task chosen based on the needs of private companies, etc. Last year, the foundation started "Ocean Discovery XPRIZE" (major sponsor is Royal Dutch Shell) for high-speed mapping of a vast sea area using only unmanned search robots to create bathymetric charts. This competition gives an extremely difficult task of surveying a vast area equivalent to 10,000 Tokyo Domes more than 2,000 meter below sea level by using only search robots within a limited time and creating detailed bathymetric charts. To take up the challenge young researchers from Japanese private companies, universities and research institutes formed "Team KUROSHIO" and are advancing R&D to win the competition. Through such undertakings, we aim to demonstrate Japan's ocean survey technologies, create a new ocean community in Japan and thereby contribute to creation of new markets and revitalization of the existing markets.

<Mission of "Ocean Discovery XPRIZE">

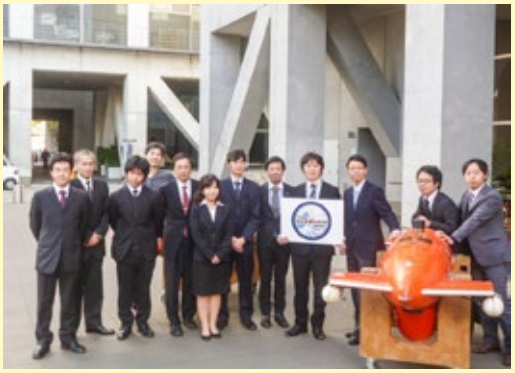
[Aim]
Sea bottom mapping of a vast area (500km²)
(Resolution: at least 5m horizontally and 50cm vertically)

[Key rules]
－Operation without mother ship (including deployment and collection)
－Bring in only one 40feet container
－Create a bathymetric chart within 48 hours
Total amount of prizes:$7 million

[ROUND 1] October to November 2017
Create a bathymetric chart 2,000m below the sea level for an area over 100km² and five photographs of sea bottom targets within 16 hours.

[ROUND 2] September 2018
Create a bathymetric chart 4,000m below the sea level for an area over 250km² and 10 photographs of sea bottom targets within 16 hours.

Image of submarine prospecting using unmanned search robots



Team KUROSHIO members
Japan Agency for Marine-Earth Science and Technology (JAMSTEC), the University of Tokyo, Kyushu Institute of Technology, National Institute of Maritime, Port and Aviation Technology. Mitsui Engineering & Shipbuilding, Nippon Marine Enterprises, Ltd, KDDI Research, Inc. and Yamaha Motor Co., Ltd.

Source: Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

*XPRIZE is
A global competition run by XPRIZE Foundation that is an American non-profit organization established in 1995. Its aim is to solve major problems of the world in five Prize Groups: Learning; Exploration; Energy & Environment; Global Development; and Life Science. Recently, Google Lunar XPRIZE to compete for the first unmanned lunar surface probe by the private sector has become a popular topic of conversation.

Section 2 Realizing "Society 5.0"

Society 5.0 advocated in the 5th Basic Plan aims to create a human-centered society that achieves both economic development and solution of social problems through sophisticated fusion of cyberspace and physical space. Toward Society 5.0 the government will focus on fundamental technologies including IoT[1], big data and artificial intelligence (AI) and initiatives necessary for building platforms utilizing these technologies.

1 Vision of Society 5.0

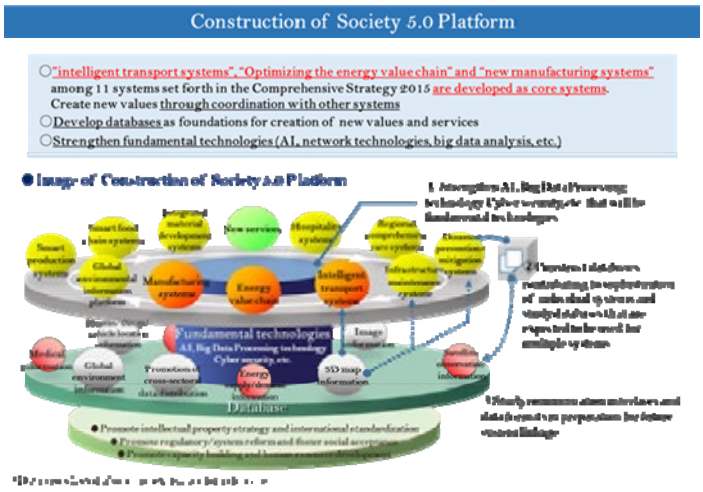
Society 5.0 is the new society following the hunter–gatherer society, agricultural society, industrial

1 Internet of Things

society, and information society. For example, Society 5.0 enables "people and life system in communities for Healthy Nation Japan" by securing of transportation means with automatic traveling vehicles, local production and local consumption of energy using distributed energy, and construction of ICT infrastructure for next-generation medical care, etc. not only in urban areas but also in rural areas. Rural areas will break free from their geographical, economic and social limitations. Society 5.0 includes social reforms that are solution of economic and social problems in addition to industrial reforms including strengthening of industrial competitiveness as seen in Industry 4.0 in Germany.

2 Undertakings necessary for the realization

Toward realization of Society 5.0, the 5th Basic Plan intends to develop 11 systems[1] identified based on the economic and social issues ahead of other systems, steadily work toward their coordination and collaboration and construct a common framework for various services including new services that are not assumed now. To show examples of the 11 systems, MEXT developed Data Integration & Analysis System (DIAS) as a global environment information platform ahead of the rest of the world. Since fiscal 2016, the ministry has been promoting development of an operation system and common fundamental technologies for its long-term and stable use by a large number of users including private enterprises in Japan and abroad under the "program to promote construction of a global environment information platform."



Outline of service platform
Source: Cabinet Office

In order to create an environment for safe and secure distribution and use of diverse and a large quantity of data including personal information across companies and industries, The National Strategy office of Information and Communications Technology, Cabinet Secretariat, has studied systems for smooth distribution and utilization of data with participation of individuals (PDS[2], Information bank[3], data market place[4]) and published an interim report at the committee on development of data distribution environment (March 2017).

1 Optimizing the energy value chain, building a global environment information platform, maintenance and upgrade of an efficient and effective infrastructure, attaining a resilient society against natural disasters, Intelligent Transport Systems, new manufacturing systems, integrated material development systems, and promoting integrated community care systems, hospitality systems, smart food chain systems, and smart production systems.

2 PDS (Personal Data Store)is a system for individuals to accumulate and manage their data including aggregation of data held by others, which has a control function pertaining to provision (including transfer of control) to a third party. There are distributed PDS where individual users accumulate and manage data using their own terminals, etc.(business operators can use the data with consent of the person,) and concentrated PDS where data is accumulated and managed with servers, etc. provided by a business operator (individuals commission accumulation/management of the data to the business operator)

3 Information bank is a business that manages personal data using PDS or other systems based on an agreement for data utilization with individual persons. It provides the data to third parties (other business operators) according to the users' instruction by determining the adequacy on their behalf based on the conditions specified beforehand. (Benefits regarding the provision/utilization of data are returned directly or indirectly to the persons by the business operators receiving the data)

4 Data Marketplace refers to a system that enables transactions by mediating between data holders and parties who want to use the data (market)(Its assumed functions include price formation/presentation, matching supply and demand, refinement of trade terms, standardization of trade objects and credit guarantee for transactions)

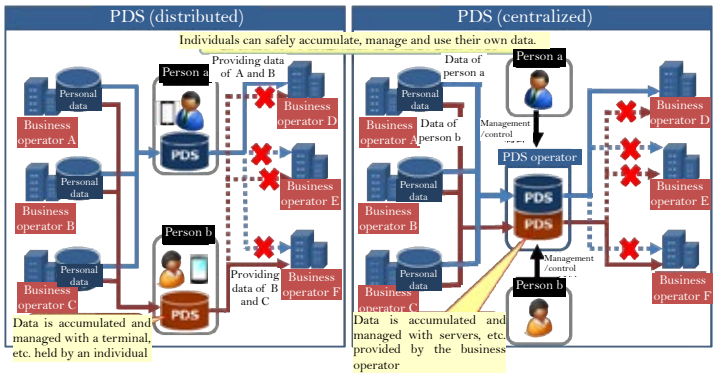


Image of PDS

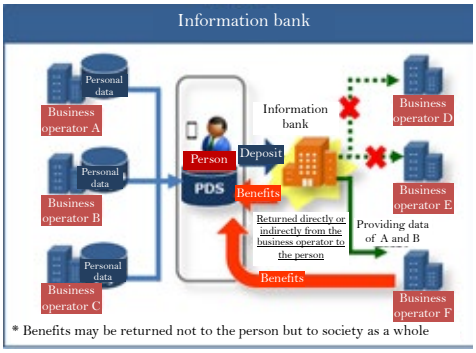


Image of Information Bank

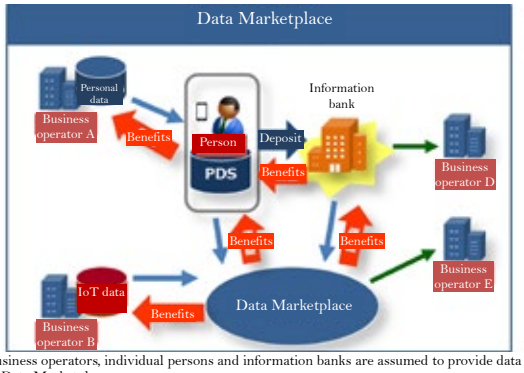


Image of Data Market Place
Created by the Cabinet Secretariat

The Ministry of Internal Affairs and Communications (MIC) is promoting R&D of multi-view image/3D image technologies conducted by private businesses as Hospitality Systems in preparation for Tokyo Olympic/Paralympic Games in 2020. MIC has been working to further improve the accuracy of the technologies through development of noise suppression technology essential for use of multi-lingual voice translation systems and assessing performance in actual scenes of use including commercial facilities, railways and taxies. In fiscal 2016 their use was demonstrated in six tourist destinations, etc. across Japan. R&D of other systems is also conducted in cooperation with the government departments.

Section 3 Enhancing Competitiveness and Consolidating Fundamental Technologies in Society 5.0

The 5th Basic Plan advocates Society 5.0 to achieve sustained improvement in the economic strength of the country. This requires construction of a platform for the high degree of merging between cyberspace and the real world in various fields and also consolidation of fundamental technologies necessary for the construction.

1 Efforts necessary for enhancement of competitiveness

With rapid progress of innovations and bewildering evolution of technologies in recent years, there is an increased need for development of human resources who can promote structural reform of industries through commercialization of technological innovations including AI, big data and IoT toward realization

of the fourth industrial revolution and Society 5.0.

To this end, in order to develop a broad range of human resources with basic education in mathematics and data science, who are necessary for revitalization of industrial activities in Japan in the future, the plan intends to strengthen mathematics and data science education regardless of whether the fields are humanities or sciences. The aim is to develop human resources who have mathematical thinking and data analysis/utilization abilities and can solve various problems of society, discover new tasks and create values from data. In order to enhance universities' functions to develop human resources for information technology, the plan will enhance practical education including project-based learning by forming a network for practical education in industry-academia collaboration, while at the same time promoting development of systematic education programs for adults who want to continue learning. Furthermore, in light of the increased expectation for engineering education to play the central role in human resource development toward realization of the 4th industrial revolution and Society 5.0, MEXT has been holding the "Committee on Approaches to Engineering Education in Universities" since January 2017. The committee has been studying appropriate education systems/curricula of under-graduate and graduate schools for future engineering education. This study is necessary for its reform to a system that can flexibly respond to changes in industrial/academic structure.

MIC launched the *Innou-vation* program. (*Innou* is Japanese for "unusual talent.") The program, which is under the Strategic Information and Communications R&D Promotion Program (SCOPE), supports R&D on ambitious technological themes by researchers with unusual talents. These efforts have great potential to generate global values that may have destructive effects on globally unpredictable areas of ICT, where new technologies and ideas emerge daily.

The Cabinet Office set up the "Committee on New Information Properties" under the Intellectual Property Strategy Headquarters to study approaches to protection and utilization of valuable data and artificial intelligence using machine learning, especially deep learning, that are not subject to copyright under the current intellectual property system. The committee will discuss specifics of support for contracts on data utilization and securing of fair competition order, development of an environment for facilitation of data preparation for AI learning, appropriate protection of learnt models and other matters. It will continue study of rights with limitation for the purpose of data utilization and approaches to protection of AI programs and products under the intellectual property systems.

2 Strategic strengthening of infrastructure technology

(1) Fundamental technologies necessary to build the Society 5.0 service platform

The fundamental technologies necessary to build the Society 5.0 service platform, in other words, the technologies concerned with distribution, processing, and accumulation of information in cyberspace, are the essential technologies in forming Society 5.0 and creating added value from big data. Therefore the government will especially strengthen the following fundamental technologies.

①Cyber security technology (Refer to Chapter 3, Section 2, 3)

In the Strategic Innovation Promotion Program (SIP) the Cabinet Office set up "Cyber-Security for Critical Infrastructure" to protect important infrastructures supporting the basis of people's lives against cyber attacks and has been promoting R&D activities for this purpose.

MIC has been implementing initiatives to respond to damages caused by malware infection of users and practical cyber defense exercises for public offices, operators of important infrastructure, local governments and others

②IoT system building technology

In order to create diverse IoT services, MIC has made efforts to establish a shared base of technology to quickly and efficiently interconnect vast numbers of IoT devices, and to connect or integrate IoT devices of different standards and multiple services with networks collectively, efficiently and safely. Also, MIC has strengthened efforts to make the technology an international standard.

National Institute of Information and Communications Technology (NICT) has created an environment (the IoT Test bed) that allows various businesses to develop and test optimal IoT systems and it has promoted the development and demonstration of advanced IoT services.

In order to promote smooth use of diverse geospatial information by enabling unified retrieval, browsing and acquisition, the Geospatial Information Authority of Japan (GSI) conducted a case study pertaining to "compilation of standard specifications and development of interfaces for connecting diverse information to absolute datum reference."

③Artificial intelligence technologies

In light of promoting toward R&D and commercialization of artificial intelligence technologies that are fundamental to realizing Society 5.0, MIC, MEXT, Ministry of Economy, Trade and Industry (METI) and other relevant ministries are making coordinated efforts where the Artificial Intelligence Technology Strategy Council plays the role of the control tower. In May 2017, the council developed "Goals of artificial intelligence R&D and a roadmap for the commercialization" in order for Japan to lead the world and accelerate a range of relevant actions from R&D to commercialization by gathering knowledge of industry, academia and the government. The ministries and agencies will strengthen their collaboration and promote R&D and commercialization of artificial intelligence technologies in the priority fields identified by the roadmap; productivity; health and medical/nursing care, and; spatial movement.

MIC at NICT has developed a system for objective assessment of human emotions using brain activity analysis technology. Using this system, the ministry developed an efficient information processing process according to unconscious value judgments appearing in brain activities, etc. MIC also has implemented R&D and demonstration of natural language processing, data mining, construction of dictionary/knowledge bases, etc. as artificial intelligence with the approach of understanding/creating intelligence based on social big data.

At the Center for Advanced Intelligence Project which MEXT established at RIKEN (Institute of Physical and Chemical Research), MEXT, other relevant ministries, universities, research institutes and others have been collaboratively studying and developing fundamental technologies of innovative artificial intelligence looking 10 years out, and conducting applied research for solutions to social challenges including health care, disaster prevention and infrastructure with the objective of further developing Japan's strength in iPS cells, manufacturing and other areas. At the same time, MEXT has been implementing research of ethical, legal and social problems arising from the spread of artificial technologies. In addition, the Japan Science and Technology Agency (JST) has been providing integrated

support for creative young researchers in the field of artificial intelligence, etc. and for challenging research tasks to open the way for new innovations.

METI established the Artificial Intelligence Research Center (AIRC) at the National Institute of Advanced Industrial Science and Technology (AIST) in May 2015. As a hub for research by academia and industry, the center has brought together excellent researchers and technologies, and has worked to form an environment that produces an efficient cycle for commercializing the results of goal-oriented basic research. Specifically, the center has worked on advanced research on brain-like artificial intelligence and artificial intelligence integrating data with knowledge, the development of tools for artificial intelligence frameworks and advanced core modules that enable the early bridging of research results and the development of a standard technique for quantitatively evaluating the effectiveness and reliability of artificial intelligence technologies. The New Energy and Industrial Technology Development Organization (NEDO) has been implementing the Development of Core Technology for Next-Generation AI and Robots Project since fiscal 2015 to merge artificial intelligence technologies and robot component technologies. Specifically, NEDO is working on R&D of artificial intelligence technologies at the AIRC, while at the same time working on R&D of innovative sensing technologies including odor sensors using olfactory receptors of living organisms and innovative actuator technologies enabling omnidirectional driving.

④Device technology

MEXT has been working on "the R&D Project for ICT Key Technology to Realize Future Society," Specifically, the ministry is implementing "Research and Development of Spintronics Material and Device Science and Technology for a Disaster-Resistant Safe and Secure Society" and "Research and Development on Highly-functional and Highly-available Information Storage Technology."

In the latter project, MEXT has, for example, promoted technologies for disaster-resistant storage systems to conserve stored information during major disasters and ensure sustainable services. A test was successfully conducted to demonstrate speedy pharmaceutical activity in the affected area, proving its effectiveness.

Toward advancement and energy saving of servers, personal computers, and next-generation automobiles, etc., METI has conducted R&D of optical electronics technologies combining integration technology of next-generation semi-conductor devices, optical circuits and electronic circuits and also improved their bases including standardization and communalization for diverse use of innovative devices and policy to guarantee reliability and safety. In addition, the ministry developed cross-sectional technologies supporting the next-generation IoT society, which include data collection systems, high-speed /large-capacity data storage systems, fundamental technologies for artificial intelligence/computer and advanced security.

⑤Network technology

In order to respond to the rapid increase of network traffic expected in Society 5.0, MIC has been conducting R&D aimed at practical use of an optical transmission system of over 1 Tbps per wavelength. Furthermore, aiming at application of a fundamental radio communication technology that enables super-high speed transmission at dozens of Gbps using terahertz waves from 275 to 370GHz that are

outside of the current frequency distribution worldwide, the ministry has been conducting R&D of silicon semiconductor CMOS transceiver technology and amplifier technology using the MEMS vacuum tube.

NICT has been working on R&D of device technologies and integration technologies aiming to realize a wireless communication system at the level of 100Gbps using terahertz waves, and fundamental technologies regarding signal source, detectors, etc.

In order to respond to rapid increase in communications traffic and power consumption accompanying ICT use, NICT has been promoting R&D on all-optical network that realizes networks with ultra high speed and low-power consumption. It is also promoting R&D regarding ultra-high speed optical access networks with extremely low power consumption that can increase "transmission distance multiplied by the number of users" more than a hundred times while at the same time controlling increase in power consumption.

⑥Promotion of mathematical science

As part of activities to use knowledge of mathematics and mathematical science to contribute to the solution of various challenges in science and industry and create new values (mathematics innovation), MEXT has been implementing the "program to promote research for innovation creation in collaboration of mathematics/mathematical science and industries" since fiscal 2012. Choosing tasks for which mathematics promises solutions for important themes including big data, optimization and control mathematics, the program holds workshops for mathematics/mathematical science researchers and other researchers in academia and industry to discuss possibilities of their collaboration, and study groups gathering relevant researchers for concentrated discussion on solutions of individual specific challenges in academia and industry. The program also organizes research exchange meetings of young mathematics researchers and industry, Science Agora lectures to disseminate applications of mathematics/mathematical science to the public and other opportunities to promote collaboration.

(2) Fundamental technologies that have advantages to be a core of new value creation

By incorporating components that use technologies where Japan' is strong in individual systems, the country can ensure its advantage and develop systems that will create new values in response to diverse economic and social needs at home and abroad. As core technologies to create new values in individual systems and function in the real world, the government will strengthen the following fundamental technologies among others.

①Technology for robots, actuators and human interfaces

MIC has conducted R&D to establish technologies for smart networked robots since FY2015. These include a base technology that enables various robots to share information through the network and to operate automatically in real-time, and a communication technology that enables robots to communicate with humans based on an understanding of human feelings as determined through robot sight and hearing and human brain information. In fiscal 2016 the ministry implemented valuation and verification of the technologies through field demonstrations in shopping centers and other places.

The Fire and Disaster Management Agency (FDMA) has carried out R&D on a fire-fighting robots that enter sites where humans cannot approach for information collection and water discharge (See Chapter 3

Section 2 (1)).

②R&D of sensor technology

In the era of big data and the IoT, the utilization of dependable data becomes important. Thus, the sophistication of sensor technology to collect information from all things is also important. MIC has carried out R&D on a terahertz camera that allows see-through imaging on the shapes of materials. METI has carried out R&D on technologies for robot sensing (e.g., sight and hearing) that is not affected by changes in the environment.

③Promotion of R&D in materials and Nano technologies

Nano technology and materials science are fields where Japan is highly competitive. They also serve as foundations to support a broad and diverse range of research and application areas. Because of their cross-functional nature these fundamental technologies will bring about discontinuous innovations through cross-cutting combination of technologies to contribute to solutions of a broad range of social challenges and also create new values in future society.

MEXT has been strategically promoting efforts from basic and pioneering research to technology development with a view toward practical application, while at the same time supporting establishment of R&D centers.

For example, the ministry implemented the Tohoku Innovative Materials Technology Initiatives for Reconstruction, to form a nanotechnology R&D center through industry-academia-government cooperation and develop cutting-edge materials using world-leading technologies in the nanotechnology and materials fields, in which universities and industries in Tohoku excel, for five years from fiscal 2012 to 2016. One of the results of the project is a groundbreaking new soft magnetic material promising energy-saving effects, which is used for the magnetic core of power converters and automobile motors. Tohoku University established a startup to manufacture and sell this new material. The startup is promoting R&D toward practical use by trial manufacturing of motors for home appliances through joint research with a manufacturing company. It is expected that the results of the project will drive the development of the materials industry in Tohoku area and contribute to its reconstruction.

MEXT set up Integrated Materials Development project and started undertakings to demonstrate the effectiveness of a new R&D scheme combining an overview of the entire social system including lifestyle design and basic fundamental research that will generate seeds of materials development technology.

④Promoting R&D on technologies for optical and quantum sciences

Remarkable advances in S&T and sophistication of technologies in various fields have raised the need for materials to be processed at the atomic/molecular level and for material structure and states to be investigated in detail, which was not possible before. Optical and quantum technologies [1] are used broadly from academic research to industrial application in a wide range of fields including information communication, medical care, environment and energy. They have potential to further advance measuring, image sensing, information/energy transfer and processing technologies and create new values in a

1 Optical S&T including laser and quantum S&T including synchrotron radiation, neutron beam and ion beam

super-smart society. They also hold the promise of generating new disciplines and innovations that have not been expected.

Thus, MEXT has been implementing a program for the development of key technologies toward the creation of an R&D center for optical and quantum sciences since FY2008. This program aims at advancing R&D on optical and quantum sciences by using the potential of these sciences to address the needs of various fields through collaboration by diverse researchers from industry, academia and government. The development of future scientists who can further advance these sciences is also promoted. In addition, the quantum science and technology committee was set up at the Council for Science and Technology (CST) for research and examination in this field. In February 2017, the committee published an interim report on new promotion policy for quantum science and technology.

In response to the rising importance of quantum science and technology as fundamental technology to create innovations, the National Institutes for Quantum and Radiological Science and Technology (QST) was established by consolidating the National Institute of Radiological Sciences and a part of the Japan Atomic Energy Agency in April 2016. QST has been conducting research on miniaturization and sophistication of heavy particle radiotherapy apparatuses, materials/life science research using the world's top class laser (J-KAREN) and an ion irradiation research facility (TIARA) and other research to promote quantum science and technologies in an integral and comprehensive manner.

■Table 2-2-1 / Major projects for realization of Society 5.0 (fiscal 2016)

Ministry	Implemented by	Project
MIC	MIC	R&D on next-generation optical network technologies that support the distribution of big data
		Expenses required for R&D on technology using radio waves for radio use financial source
		Expenses required for testing of technologies for addressing the shortage of available frequencies
		Promotion of the Global Communications Plan: R&D on a multilingual speech translation system, including a social experiment
		Development and demonstration of an autonomous mobility system (automated driving technology, automated control technology, and the like)
		Establishment and demonstration of fundamental IoT technologies
MEXT	MEXT	R&D Project for ICT Key Technology to Realize Future Society
		Nanotechnology Platform Japan
		Integrated Materials Development
		Program for the development of key technologies toward the creation of an R&D center for optical and quantum sciences (competitive funds)
		Advanced Integrated Intelligence Platform Project (AIP) -Artificial Intelligence/ Big Data/ Internet of Things/ Cyber security-