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, in the MIRAI program started in fiscal 2017, the 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 (high risk) based on social and industrial needs and clearly identifying targets with economic and social impact (high 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.

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 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

1 Internet of Things

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.

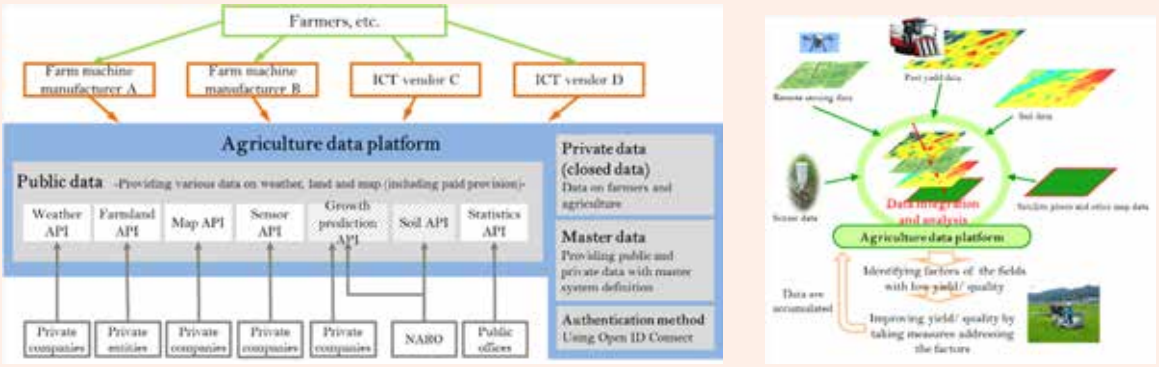
Column 2-2

Build an agricultural data coordination platform – toward realization of Society 5.0 in agriculture

For enhancement of the competitiveness of Japan's agriculture it is important to digitalize experiences and intuition for their utilization. However, data utilization faces challenges due to a lack of coordination among various ICT services and data in the field of agriculture and scattered public data, for example.

In this context, in order to create an environment for farmers to utilize data for productivity enhancement and business improvement, it was decided to build an agricultural data platform with data coordination, sharing and provision functions. WAGRI was established in August 2017, a prototype of an agriculture data platform started operation in December of the same year and farm machine manufacturers and ICT vendors started to import and use weather and other data in their systems through the platform on a trial basis.

Toward full-fledged operation in April 2019, WAGRI will pursue connection with more systems and expand data to provide information including weather, map and soil data. Farmers will be able to obtain various data through the platform and use them for farming. This will enable advanced production management. For example, by constructing big data including crop growth, cultivation management and environmental conditions, identifying factors of the fields with low yield and quality through analysis of the data and taking appropriate countermeasures, farmers can improve yield and quality.



Structure and effects of the agricultural data coordination platform
Source: MAFF

2 Undertakings necessary for the realization

Outline of service platform
Source: Cabinet Office

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."

The Ministry of Internal Affairs and Communications (MIC) is promoting R&D of ultra-realistic image technologies[2] conducted by private businesses as Hospitality Systems in preparation for the 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 hospitals, commercial facilities, railways and taxies. In fiscal 2017 their use was demonstrated in four 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

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 Spatial image technology overcoming distance such as whole-sky image technology to project highly realistic sports and local festival images in dome theaters using planetariums, etc.

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 in universities regardless of whether the fields are humanities or sciences. The aim is to establish an education system for development of 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. The plan also aims to form a practical education network in industry-academia collaboration and promote human resource development responding to the needs of the industry, which includes cyber security specialists, data scientists, people implementing science and technology and other human resources who are in seriously short supply, toward realization of Society 5.0. Furthermore, in light of the rising 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 an expert committee since January 2017. The committee compiled "Approaches to Engineering Education in Universities (Midterm Report)" in June 2017. The report discusses appropriate education systems/curricula of undergraduate and graduate schools for future engineering education and education in industry-academia collaboration, which are necessary for reforming the system to be able to flexibly respond to changes in industrial structure. Based on the report, the committee aims to complete the study on specific system design, etc. within FY2017 and start to implement the design sequentially in FY2018 toward full-scale implementation in FY2019.

In order to develop and secure highly skilled data-related human resources who combine knowledge/ability of advanced utilization of AI, IoT, big data, security, etc. and ability to use the technologies in the real world including business, the "Data-related Human Resource Development Program" has been implemented since FY2017. The program helps doctoral students, PhDs and others learn data science and other skills in addition to their expertise and promote their active participation in various scenes in society.

Ministry of Internal Affairs and Communications (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. 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. In light of the expected utilization of enormous number of IoT devices in diverse fields and business categories, MIC is developing curriculums and holding workshops in industry-academia-government collaboration to train IoT users and human resources who will engage in operation and management of networks.

The Cabinet Office set up the "Committee on New Information Properties" under the Intellectual Property Strategy Headquarters. The committee studied 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, discussed specifics of the support for contracts on data utilization and securing of a fair competition order, development of an environment for facilitation

of data preparation for AI learning, appropriate protection of learnt models and other matters and compiled the result in a report. The direction shown in the report will be reflected in the Intellectual Property Strategic Program 2017. The committee will continue its study of rights with limitations 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.

A. Cyber 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.

The Ministry of Internal Affairs and Communications (MIC) has been promoting R&D of cyber security through the National Institute of Information and Communications Technology (NICT).

B. IoT 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. Furthermore, MIC has been implementing the "IoT Service Creation Support Project", a verification project that uses IoT in disaster prevention, agriculture, sharing economy and other fields familiar to living. Through the project MIC is building a reference model for new IoT services in these fields and clarifying rules necessary for their spread and development.

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 utilization of geospatial information registered in the geographic data base, the Geospatial Information Authority of Japan (GSI) carried out a survey on standard specifications for connection of diverse geospatial information to the basic map information that is the standard of positions.

C. Artificial intelligence technologies

Toward R&D and commercialization of artificial intelligence technologies that are fundamental to realizing Society 5.0, the Cabinet Office, MIC, MEXT, Ministry of Health, Labour and Welfare (MHLW), Ministry of Agriculture, Forestry and Fisheries (MAFF), Ministry of Economy, Trade and Industry

(METI), Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and other relevant ministries are integrally promoting R&D and commercialization of artificial intelligence technologies. In this effort the Artificial Intelligence Technology Strategy Council that was established in April 2016 plays the role of the control tower. The priority fields are: productivity; health and medical/nursing care, spatial movement identified by the "Goals of artificial intelligence R&D and a roadmap for the commercialization" that was formulated in March 2017.

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 that was established at RIKEN (Institute of Physical and Chemical Research), MEXT, other relevant ministries, universities, research institutes and others have been collaboratively developing fundamental technologies of innovative artificial intelligence looking 10 years out, and conducting: (1) elucidation of the principle of deep learning and development of new basic technologies for generic machine learning, (2) R&D on the analysis system using AI and other basic technologies for solutions to social challenges including health care for the elderly, disaster prevention/mitigation and infrastructure maintenance/management technologies by further developing Japan's strength in regenerative medicine, manufacturing and other fields, and (3) research of ethical, legal and social problems arising from the spread of artificial intelligence technologies. In addition, the Japan Science and Technology Agency (JST) has been providing integrated support for unique ideas of young researchers in artificial intelligence and other fields and for challenging research tasks to open the way for new innovations.

METI brought together excellent researchers and technologies at the Artificial Intelligence Research Center (AIRC) established 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 been working to create 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.

D. Device technology

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.

E. Network technology

In order to respond to the rapid increase of network traffic expected in Society 5.0, MIC conducted R&D aimed at practical use of an optical transmission system of over 1 Tbps per wavelength. Toward realization of the 5th generation mobile communication system in 2020 as the ICT infrastructure of a full-fledged IoT society, the ministry has been working on R&D of element technologies including ultra-high speed, multiple connections and ultra low delay technologies, and has been implementing demonstration experiments assuming specific utilization since FY2017 with commercialization of 5G in mind. 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 conducted R&D of silicon semiconductor CMOS[1] transceiver technology and amplifier technology using the MEMS vacuum tube.

NICT worked 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 promoted R&D on all-optical network that realizes networks with ultra high speed and low-power consumption.

1 Complementary Metal Oxide Semiconductor

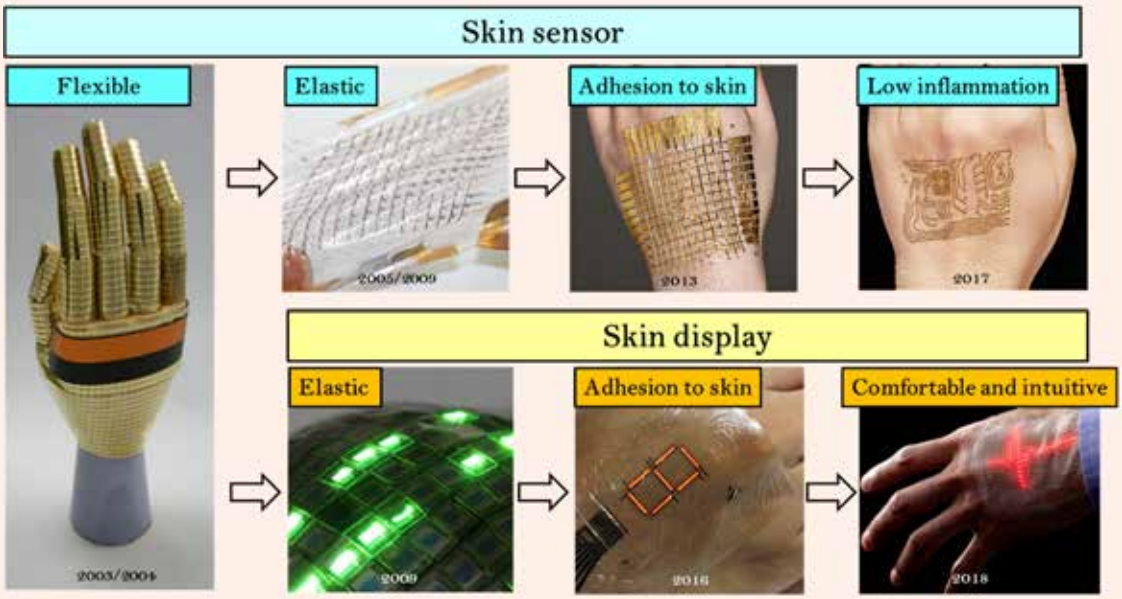
Column 2-3

Development of sensor displays wearable on skin

With the remarkable development of information/communication and electronics technologies in recent years, health management using portable sensors, smartphones, etc. has been spreading. However, most electronics devices were made of hard material.

Dr. Takao Someya, Professor of the Department of Electrical Engineering, School of Engineering, the Tokyo University and other researchers had pushed forward with research on devices made of soft material and closely stuck to skin so that anyone can monitor bio-information easily, anytime and anywhere with support of CREST [1] and ERATO[2] of the Japan Science and Technology Agency and others. The researchers improved elasticity, adhesion to skin, low inflammation and other functions of the device. With support by ACCEL[3] of JSTA since FY2017 they have been advancing development of the Super Bioimager (elastic image sensor) through integration and advancement of technologies they have achieved. Using the Super Bioimager anyone can easily measure a variety of bioinformation by just putting a sheet on the skin.

In 2018 Professor Takao Someya et al succeeded in developing a sensor system that displays moving images of electrocardiogram wave forms measured by thin and flexible low inflammation skin censor directly put on the skin. The display was also directly put on the skin. The system that enables anyone to easily monitor bioinformation anytime and anywhere can be used for many purposes including improvement of accessibility to information of children and the elderly as well as home healthcare. It is expected to become a key in realizing a safe, secure and comfortable society.



Development of skin electronics in harmony with living organisms
Source: The University of Tokyo

1 Among Strategic Basic Research Programs, network-oriented research generating outstanding results leading to ST innovation (team-oriented research) https://www.jst.go.jp/kisoken/crest/index.html

2 Among Strategic Basic Research Programs, Outstanding Research Leaders Strive to generate the seeds of breakthrough new technologies https://www.jst.go.jp/erato/index.html

3 Program aiming to create a flow from distinguished research achievement generated under the Strategic Basic Research Programs to R&D by companies, ventures and other programs through innovation-oriented R&D management by program managers https://www.jst.go.jp/erato/index.html

F. Promotion of mathematical science

As part of the 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 Advanced Innovation powered by the Mathematics Platform (AIMaP) since fiscal 2017. Under the program, the 13 mathematics/mathematical science research centers of universities and public research institutions across Japan form a network and are actively identifying latent needs for mathematics and mathematical sciences and promoting research through the collaboration of mathematics/mathematical science researchers who can solve the tasks with researchers in other scientific fields and industries. Specifically, the program holds meetings to introduce research that uses mathematics and mathematical methods for science and industrial circles, workshops and study groups for discussions toward joint research, and provides forums for knowhow sharing and the lateral spread of collaboration with other science fields and industries.

(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.

A. Technology for robots, actuators and human interfaces

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)).

B. R&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. For example, METI carried out R&D on technologies for robot sensing (e.g., sight and hearing) that is not affected by changes in the environment.

C. Promotion 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 set up Integrated Materials Development Project and has been conducting

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.

The National Institute for Materials Science (NIMS) aims to powerfully advance innovation creation in the fields of nanotechnology and mathematical science and technology. To this purpose the Institute is implementing the Program for Strengthening Innovative Materials Development, or M^3 (M-cube), to establish a forum to create innovative materials by fusing basic research and industrial needs and global centers that gather researchers around the world while developing research infrastructure to make the most of their activities.

D. Promoting R&D on technologies for optical and quantum sciences (optical and quantum technologies[1])

In a society where various economic and social problems are increasingly complex and capital and competitive advantages sharply change, quantum science and technology started to realize quantum state controlling using advanced lasers, component technology of physical elements that enable quantum information processing, for example. There are signs of not only progress of the science but also rapid development of a new technology system with an eye to the solution of social problems and industrial applications toward Society 5.0.

Since FY2008 MEXT had been implementing a program for the development of key technologies toward the creation of an R&D center for optical and quantum sciences. This program had promoted R&D on optical and quantum sciences by using the potential of these sciences in Japan to address the needs of various fields through the collaboration of diverse researchers from industry, academia and government. In light of the development described in the paragraph above, the Quantum Science and Technology Committee, the Subdivision on R&D Planning and Evaluation, Council for Science and Technology (CST) took a panoramic view of the latest research trends of quantum science and technology and started research and examination on their impact on the economy and society and Japan's strengths and challenges in this field in March 2016. Furthermore, the committee formulated a roadmap of expected progress and achievements of research and technologies in the fields of quantum information processing, quantum measuring/sensing, ultrashort pulse laser and next generation laser processing in chronological order. Based on these activities, the committee compiled and published a report on new promotion measures for quantum science and technology in August 2017.

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

1 Science on behaviors and effects of "quantum" and technology to use them

and technologies in an integral and comprehensive manner.

Table 2-2-1 Major projects for realization of Society 5.0 (fiscal 2017)

Ministry	Implemented by	Project
MIC	MIC	R&D on next-generation optical network technologies that support the distribution of big data
		Promotion of the Global Communications Plan: R&D on a multilingual speech translation system, including a social experiment
MEXT	MEXT	Strategic R&D and infrastructure development in the fields of nanotechnology and materials science and technology
		Program for the development of key technologies toward the creation of an R&D center for optical and quantum sciences
	RIKEN, Japan Science and Technology Agency	Advanced Integrated Intelligence Platform Project (AIP) -Artificial Intelligence/ Big Data/ Internet of Things/ Cyber security-