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 as well as the economic and social impact, and provide people who have more creative ideas and the abilities to implement them with opportunities to try their ideas through R&D projects under the jurisdiction of the relevant ministries and agencies.

To this end, in the MIRAI program started in FY2017, 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 Science and Technology Basic Plan (hereinafter referred to as 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, big data and artificial intelligence (AI) and initiatives necessary for building platforms utilizing these technologies.

1 Vision of Society 5.0

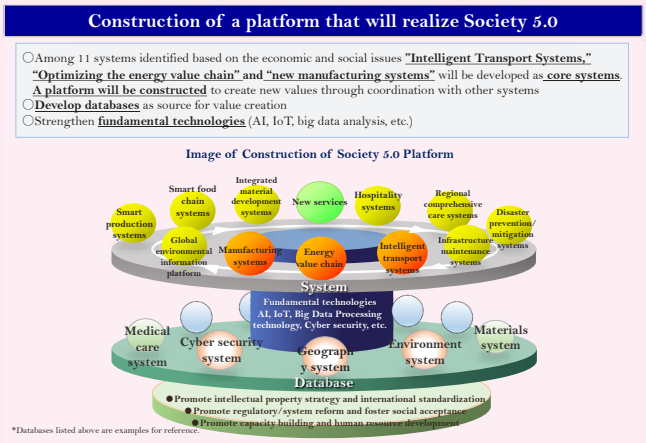
Society 5.0 is the new society following the hunter–gatherer society, agricultural society, industrial society, and information society. For example, Society 5.0 enables "people and life system in communities for Healthy Nation Japan" by securing of transportation means with automatic traveling vehicles, 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 their geographical, economic and social limitations. Efforts to realize Society 5.0

include social reforms that are solutions 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. As a global environment information platform that is one of the 11 systems, MEXT developed Data Integration & Analysis System (DIAS) (see Part II Chapter 3 Section 3-1(3)).

■Figure 2-2-1/Outline of service platform



Source: Cabinet Office

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 promoting R&D of noise suppression technology essential for use of multi-lingual voice translation systems. In order to further improve the accuracy of the technologies through performance assessment in actual scenes of use including hospitals, commercial facilities, railways and taxies, the ministry carried out a large-scale cross-cutting demonstration in FY2018.

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 commercialization of technological innovations including AI, big data and IoT and at the same time development of human resources who can promote structural reform of industries by using the technologies toward realization of the fourth Industrial Revolution and Society 5.0.

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.

To this end, MEXT aims to establish an education system where all students of any department can systematically acquire mathematical thinking and data analysis/utilization abilities which are necessary in Society 5.0. Specifically, the ministry has been spreading mathematical and data science education to universities nationwide by developing and utilizing standardized curricula that systematize basic knowledge necessary for students and methods for evaluation of learning achievements. Furthermore, in order to promote development of human resources who combine deep specialized expertise with extensive knowledge and wide perspectives in engineering fields that have deep relationship with industries, MEXT revised the Standards for Establishment of Universities for promotion of the review of the vertical structure based on departments in June 2018. The Ministry has also implemented the "Program for Development of Education Ecosystem Bases for Commercialization of Science and Technology" to support universities that conduct pioneering development of education programs.

The "Data-related Human Resource Development Program" has been implemented since FY2017 with the aim of developing training programs for doctors in various fields to cultivate abilities to play key roles using data science, etc. in academia and industry.

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 fantastic and 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 Ministry of Economy, Trade and Industry (METI) through the Information-technology Promotion Agency has been implementing the "Program for Discovery and Development of Untapped IT Talents" to discover and train excellent individuals (IT creators) who have original ideas and skills to create innovations taking advantage of IT.

In addition to the human resource development described above, in FY2018 MEXT started the " Project to support research centers for realization of Society 5.0" in order to create advanced core hubs for Society 5.0 demonstration and problem solving by supporting initiatives for social implementation through integration of various research results centering around information science and technologies at universities with a high level of knowledge, information, technology and human resources in cooperation with industry, local governments and other research institutions.

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 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.

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 has built a reference model for new IoT services in these fields and clarifying rules necessary for their spread and development.

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) studied methods 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), METI, Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and other relevant ministries have integrally promoted 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.

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 universities 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. As part of "the program for development of global AI research center" the ministry established "AI Bridging Cloud Infrastructure (ABCI)," a large-scale and power-saving computing system with the world's top level AI processing performance in the fields of information and ergonomics. Operation of ABCI started in August 2018. 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 FY2015 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. In addition, since FY2018 the Ministry has been conducting "integration technology development that will be the core of the next-generation artificial intelligence and robotics" toward sophistication of the energy supply and demand structure. Specifically, MIC has been working on development of a technology for faster detection and identification of gas leak in plant maintenance, omnibus vehicle allocation control to meet large and fluctuating transportation demand and other R&D for early social implementation of AI technology.

Furthermore, under the Meeting to Promote Comprehensive Innovation Strategy chaired by the Chief Cabinet Secretary set up in the office of the Prime Minister in July 2018, relevant ministries have been studying measures for development and strengthening of AI technology strategy, etc. and conducting discussions for formulation of new AI strategies.

D. Device technology/Information processing technology

For efficient use of the massive amount of information that has increased with the advent of IoT society, METI has been working on development of a computing technology pertaining to innovative ultra-low power consumption AI chips that operate on the edge side of the network, a next-generation computing technology that combines high-speed and low power consumption based on a new principle (e.g. brain type computer, quantum computer), optoelectronics technologies, for example. Under the "Innovation Promotion for Acceleration of AI Chip Development," the ministry has been supporting AI chip development by private companies by building an AI chip design center equipped with design tools and verification devices that were necessary for AI chip development.

E. Network technology

In order to respond to the rapid increase of network traffic, diversification of service requirements and complication of networks in Society 5.0, MIC conducted R&D aimed at practical use of an optical transmission system exceeding 5 Tbps per operation unit, and R&D for automation of communication network operation taking advantage of artificial intelligence. 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 with commercialization of 5G in mind. Since FY2018 the ministry has been implementing R&D for reduction of power consumption and downsizing of 5G base stations. 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.

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.

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 FY2017. 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. The ministry has been holding "exchanges between young mathematics/mathematical science researchers in different fields/industries" in cooperation with the Mathematical Society of Japan in an effort to develop human resources who can use mathematics/mathematical science in industry.

In 2018 KASHIWARA Masaki, Project Professor at the Research Institute for Mathematical Sciences, Kyoto University, won the Chern Medal Award for his outstanding and foundational contributions to algebraic analysis and representation theory, which have been sustained over a period of almost 50 years. The Chern Medal was established by the International Mathematical Union (IMU) in honor of Shiing-

1 Complementary Metal Oxide Semiconductor

Shen Chern, a geometrician whose Chern-Simons theory and other achievements had a wide influence not only in mathematics but also in peripheral fields including mathematical physics. IMU also presents the Fields Medal and the Carl Friedrich Gauss Prize. Professor Kashiwara is the first Japanese winner of the medal.

(2) Fundamental 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 fire-fighting robots that enter sites where humans cannot approach for information collection and water discharge. The agency completed robots that can be fielded (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., touch and smell) 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. In FY2018 the institute established the Center for Functional Sensor & Actuator as a

global base to promote basic/generic research for merging of cyber (virtual) space and physical space (real society) toward realization of Society 5.0 ahead of the world.

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

Optical and quantum technologies are generic technologies that can become the core of new value creation, which include ultra high–speed processing of data that have been increasing explosively in recent years. In Western and other countries global R&D on optical and quantum technologies has been intensifying under the catch phrase of "the 2nd Quantum Revolution." Overseas, in the US, Europe and China, in particular, position "quantum technology" is viewed as an important technology that will defy the common wisdom and change society. Their governments have formulated R&D strategies and increased R&D investments. Leading IT companies in the world are also making rigorous investments while venture companies have been established and raising funds.

In view of the technology's innovativeness and its likelihood to become the foundation of all science technologies, the government through the Meeting to Promote Comprehensive Innovation Strategy commenced studies of Japan's comprehensive strategies in the optical and quantum fields in December 2018.

MIC and NICT have been working on R&D of quantum encryption that is impossible for computers to decode and quantum communication technologies based on quantum signal processing that extracts information from a single photon. In the field of quantum communication, NICT implemented a physical layer secret key sharing system in an optical space communication test bed and succeeded in demonstrating the principle of information-theoretically secure key generation in a line-of-sight path. For secret sharing storage network using quantum cryptography, NICT newly implemented a technology to update confidentiality of distributed data. Furthermore, in order to introduce quantum cryptography that has been developed for terrestrial fields to satellite communication, the Institute has been working on R&D for construction of a system that is operable under the restrictive environment of outer space, technology for earth stations to accurately receive light from rapidly moving satellites and technologies mountable on microsatellites.

MEXT at the Quantum Science and Technology Committee, the Subdivision on R&D Planning and Evaluation of the Council for Science and Technology (CST) compiled and published a report on new promotion measures for quantum science and technology in August 2017. In FY2018 the ministry launched Quantum Leap Flagship Program (Q-LEAP). The program has been promoting flagship R&D aimed at demonstration through prototypes based on finely tuned progress management by program directors as well as basic/generic research in the fields of (1) quantum information technology (quantum simulators, quantum computers), (2) quantum metrology & sensing and (3) next generation laser.

With the aim of constructing the world's top class quantum science and technology R&D platform, the National Institutes for Quantum and Radiological Science and Technology (QST) has been conducting research on miniaturization and sophistication of heavy ion medical accelerators and cutting-edge research using quantum beam facilities such as the world's top class laser (J-KAREN[2]) and an ion irradiation

1 Science on behaviors and effects of "quantum" and technology to use them
2 Japan-Kansai Advanced Relativistic ENgineering

research facility (TIARA[1]). In FY2018, QST started basic technology development of quantum life science aiming to create innovations of life science by applying quantum science and technology including quantum metrology and sensing.

In order to ensure superiority of Japan's manufacturing industry by improving processing quality of functional materials, etc. and efficiency improvement of manufacturing processes of auto parts, etc. for the future, since FY2018 METI has been implementing "program for development of high-efficiency and high-luminance next-generation laser technology." With focus on the development of next-generation laser processing technologies including non-thermal processing, the ministry has been constructing a database platform that enables determination of the best machining conditions.

Since FY2016 under the "Cross-sectoral technology development for promotion of IoT" METI has been working on the development of quantum computer (quantum annealing machine) specialized in "combination optimization" issues that are widely present in society. Under the "Development of AI chips and next-generation computing technologies that will enable highly efficient and high-speed processing" that started in FY2018, the ministry expanded the scope of the technology and has been promoting integral development from hardware to software and applications of quantum annealing machine. In addition, toward reduction of power consumption in data centers, which has become a challenge with the progress of cloud computing, METI has been working on development of optoelectronics technology that combines electronic and optical circuits under the "Technology development toward implementation of ultra-low power consumption optoelectronics."

1 Takasaki Ion Accelerators for Advanced Radiation Application

■Table 2-2-2/Major projects for realization of Society 5.0 (FY2018)

Ministry	Implemented by	Project
MIC	MIC	Promotion of the Global Communications Plan: R&D on a multilingual speech translation system, including a social experiment
		R&D and demonstration of advanced dialogue agent technology
		R&D of generic technology for innovative AI network integration
		R&D of innovative optical network technologies that will support new social infrastructure
		ICT human resource development for proper use of a radio utilization system including IoT equipment
MEXT	MEXT	Doctoral Program for World-leading Innovative & Smart Education
		Training of advanced technical talents in response to Society 5.0
		Data-related Human Resource Development Program
		Strategic R&D and infrastructure development in the fields of nanotechnology and materials science and technology
		Quantum Leap Flagship Program (Q-LEAP)
		Support for acceleration of the improvement of school ICT environment
		Project to support research centers for realization of Society 5.0
	MEXT JST	Advanced Integrated Intelligence Platform Project (AIP) - Artificial Intelligence/ Big Data/ Internet of Things/ Cyber security-
METI	NEDO	Next-generation Artificial Intelligence and Robot Core Technology Development
		Development of the integration technology that will be the core of the next-generation artificial intelligence and robotics
		Development of high-efficiency and high-luminance next-generation laser technology
	NEDO	Innovation promotion for acceleration of AI chip development
		Development of AI chips and next-generation computing technologies that will enable highly efficient and high-speed processing
		Technology development toward implementation of ultra-low power consumption optoelectronics

Source: Cabinet Office