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 Japan Science and Technology Agency (JST) 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.

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, big data and artificial intelligence (AI) and initiatives necessary for building platforms utilizing these technologies.

❶ Vision of Society 5.0

Society 5.0 is advocated in the 5th Basic Plan as the 5th society following the hunter-gatherer society, agricultural society, industrial society, and information society. The plan defines it as a "human-centered

society in which economic development and the resolution of social issues are compatible with each other through a highly integrated system of cyberspace and physical space." 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.

The 6th Basic Plan made this social vision more concrete: a "society that is sustainable and resilient against threats and unpredictable and uncertain situations, that ensures the safety and security of the people, and that enables each and every one of them to realize well-being."

❷ 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)).

In order to create pilot cases of Society 5.0 by building a new platform using information S&T. MEXT started "the Research Hub Support Project for the Realization of Society 5.0" in universities and other institutes with high standard in all of the areas of knowledge, information, technologies and personnel in FY2018. The project aims for social implementation by integrating various research results around information S&T in cooperation with the industry, local governments and other research institutes.

In view of the Expo 2025 Osaka, Kansai, Japan, the Ministry of Internal Affairs and Communications (MIC) launched R&D for realization of "simultaneous interpretation" by AI covering also business and international conference discussions by further advancing the multilingual translation technology of the National Institute of Information and Communications Technology (NICT) under the "Global Communication Plan 2025" (March 2020).

R&D of other systems is also conducted in cooperation with the government departments.

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.

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 integrating between cyberspace and physical space in various fields and also consolidation of fundamental technologies necessary for the construction.

❶ 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.

The government formulated the AI Strategy 2019 as a comprehensive policy package in June 2019 in the context of the education reform, R&D, social implementation, etc. related to AI, and implemented follow up of the strategy in June 2020. The following initiatives based on the strategy have been carried out integrally in collaboration between the relevant ministries and agencies. The Cabinet Office set up the "Meeting to Discuss Mathematics, Data Science and AI Education Programs Certification System" under the Council for Implementation of AI Strategies1[1] in cooperation with MEXT and the Ministry of Economy, Trade and Industry (METI) in October 2019. The meeting consisting of experts from universities, high schools, the National Research and Development Agency, and industry, etc. set a goal: "both humanity and science students of universities and colleges of technology of a certain scale (about 250,000 graduates/year) master basic skills of mathematics, data science and AI for application in their respective fields." The meeting conducted studies toward establishment of the Mathematics, Data Science and AI Education Programs Certification System (applied basic level) and compiled a report in March 2021.

With the aim of achieving the goal of the strategy: "all humanity and science students of universities and colleges of technology (about 0.5 million graduates/year) master introductory-level skills" and "students of universities and colleges of technology (about 250,000 graduates/year) master basic skills for application in their respective fields" MEXT developed and is using a model curriculum (literacy level and applied basic level) systematizing the basic concept of mathematics, data science and AI education, learning objectives/skill set, education methods, etc. The curriculum has been spread to universities, etc. across the country through development of teaching materials, and collection and compilation of actual social challenges and real data, which can be used for education. Based on the AI Strategy 2019, the government certifies excellent programs on mathematics, data science and AI education provided in universities and

[1] Council for Strengthening and Promotion of Innovation Policies: AI Strategy (Council for implementation of AI strategy) (decision by the Meeting to Promote Comprehensive Innovation Strategy on September 4, 2018)

colleges of technology. Certification of literacy level will be conducted gradually in FY2021 and the establishment of the certification system for the applied basic level is scheduled within FY2021. This certification system aims to foster an environment where not only the government but the entire society including industry actively evaluate initiatives of individual universities, etc. to improve the quality of education. Furthermore, in order to promote development of human resources who combine deep specialized expertise with extensive knowledge and perspectives based on the industry needs, individual universities have been reforming their education organizations and programs.

The "Doctoral program for Data-Related InnoVation Expert" has been implemented since FY2017 with the aim of developing training programs for top-class experts in various fields in order to cultivate abilities to play key roles using data science, etc. in academia and industry. In addition, MEXT will start The Project for Developing Experts on Statistics in FY2021 with the aims of fostering personnel with advanced statistics skills and building an ecosystem of human resource development on the subject.

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 "The MITOU program" to discover and train excellent individuals (IT creators) who have original ideas and skills to create innovations taking advantage of IT.

❷ 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 order to protect various IoT devices for establishment of safety and security of the whole society, under the Strategic Innovation Promotion Program (SIP) the Cabinet Office has been promoting R&D on "Cyber/Physical Security for IoT Society."

MIC has been promoting R&D in the field of cyber-attack observation and cyber security through the National Institute of Information and Communications Technology (NICT) and other entities.

METI will support construction of cyber security validation technology as the basis of non-face-to-face and remote activities as well as SME's measures in this area. The ministry will also encourage development of software for integrated management of multiple data centers distributed in rural areas and equipment investment to promote SME digitalization.

B. IoT system building 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 response to "Efforts to Strengthen the Capacity for Japan's Maritime Domain Awareness" (decision by the Headquarters for Ocean Policy on July 26, 2016) Japan Coast Guard constructed "the Maritime-domain-awareness Situational Indication Linkages (MSIL)" that centrally gather and share marine information held by ministries, agencies and government-affiliated organs and can stably provide virtually real-time and wide-area information. MSIL started operation in April 2019.

C. Artificial intelligence technologies

Initiatives based on the AI Strategy 2019 have been integrally promoted in collaboration among the relevant ministries and agencies. Specifically, the National Institute of Advanced Industrial Science and Technology (AIST), Institute of Physical and Chemical Research (RIKEN) and the National Institute of Information and Communications Technology (NICT), which are core AI-related centers, established an artificial intelligence research and development network in December 2019 to promote collaboration of universities, research institutes and other organizations that are actively working on AI R&D. The network will promote comprehensive and integrated information dissemination and opinion exchange among AI researchers. 115 domestic universities and public research institutes are taking part in the network as of the end of February 2021. The strategy also will promote fundamental/linking R&D concerning artificial intelligence and develop research infrastructure.

In addition, 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 based on the 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, MEXT has been promoting (1) elucidation of the principle of deep learning and development of basic technologies for

generic machine learning, (2) R&D on AI and other basic technologies for further development of the fields where Japan has its strengths and solutions to social challenges, and (3) research of ethical, legal and social issues arising from the spread of artificial intelligence technologies (ELSI). In FY2020, the ministry promotes R&D on Trusted Quality AI (AI systems capable of explaining the basis for their decisions), R&D using AI technology to address COVID-19 (promotion of behavior change and individual optimization through media and pedestrian traffic flow analysis, etc.) and other R&D based on the AI Strategy 2019, etc. Furthermore, 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 in order to open the way for new innovations (AIP Network Lab).

METI brought together excellent researchers and technologies at the Artificial Intelligence Research Center (AIRC) established at 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 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 the global AI research center" the ministry started the operation of "AI Bridging Cloud Infrastructure (ABCI)" that is a large-scale and power-saving computing system with the world's top level AI processing performance in the fields of information and ergonomics in August 2018 and reinforced its processing capacity to meet the high demand from industry and other users in FY2020. Furthermore, the New Energy and Industrial Technology Development Organization (NEDO) started the Development of Core Technology for Next-Generation AI and Robots Project in FY2015 to integrate artificial intelligence technologies and robot component technologies. Since FY2020, NEDO at the AICT Artificial Intelligence Research Center (AIRC) is working on R&D of AI that can cooperate with human beings, reliable AI in the real world and AI that can be easily constructed and introduced, which will become necessary for widely spreading AI technologies in the real world. 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, the ministry is tackling R&D to accelerate implementation of AI technologies that contribute to sophistication of energy demand and supply, development of fundamental technologies that will greatly accelerate AI introduction and development of AI technologies that will support transmission and efficient use of "skills and tacit knowledge (experience and intuition) of experts," which have been accumulated in design and production sites in the field of manufacturing.

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, ultra-low delay technologies and simultaneous multiple connections, and implemented demonstration experiments assuming specific usage scenes 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, since 2019 MIC has been conducting R&D for further advancement in reliability, energy efficiency, etc. of 5G. In addition, from FY2020 the ministry is implementing development demonstration of local 5G assuming various actual usage scenes. The aim is to enable various entities including local enterprises to construct their own 5G system according to their individual needs.

Toward application of wireless communication infrastructure technology capable of non-compression transmission of ultra-high resolution video using terahertz waves of 252 to 325GHz that are globally outside of frequency allocation, the ministry conducted R&D on ultra-high-definition video interface, beam control and radio signal processing technologies.

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.

Because 5G with further enhanced functions including ultra-low latency and multiple concurrent connection ("Post 5G") is expected to be used for diverse industrial applications including the smart factory and automated driving, METI is tackling the development of Post 5G-compatible information communication systems and related technologies such as the semiconductors used in the system.

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 Mathematics Platform (AIMaP) since FY2017. Under the program, the research centers 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. In the "exchanges between young mathematics and mathematical science researchers in different fields/industries" the ministry held a lecture titled "Mathematical Sciences Fighting against Infectious Diseases" regarding the spread of COVID-19 from the viewpoint of mathematical science in an effort to emphasize the importance of mathematical sciences to the general public. In addition, RIKEN Interdisciplinary Theoretical and Mathematical Sciences Program (iTHEMS) aims to discover and solve social problems through the integration of mathematics, theoretical science and computational science, in cooperation with RIKEN SUURI Corporation which was established in joint investment with the private sector.

(2) Fundamental that has 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 humans cannot approach for information collection and water discharge. The agency completed robots that can be fielded in FY 2018, deployed them at the fire headquarters for demonstration and studied optimization of their functions in order to plan specifications of their production model (See Chapter 3 Section 2-1 (3)).

Toward a future society where autonomous artificial intelligence coexists with human beings, MEXT at RIKEN set up a project to elucidate the mechanism of the mind with focus on human cognitive functions based on computational theory and demonstrate its construction through robot implementation. The

ministry is promoting the project by developing its center in Keihanna[1] area in FY2020.

B. R&D of sensor technology

In a super smart society (Society 5.0) that pursues solution of social issues and creation of new values by using AI, big data and other means, it is important to utilize real data of the real world. This requires innovative sensing technologies that collects enormous amount of highly accurate data from everything. METI implemented "Development of Innovative Sensing Technology for Realization of IoT Society" in FY2019. Specifically, R&D was implemented for measurement of very weak signals that are difficult to detect with existing technologies and microminute sensors taking advantage of the world's most advanced material technology, nanotechnology and biotechnology, where Japan has its strengths, while at the same time developing common fundamental technologies to promote reliability evaluation and improvement of sensing.

C. Promotion of R&D to strengthen materials innovation capability

Japan has strong competitiveness in material science fields. 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.

In light of the importance of the above, MEXT and METI set up a "Preparatory Meeting for the Formulation of a Strategy to Enhancement Materials Innovation Capacity" to conduct study toward enhancement of capability to create materials innovations. In June 2020, the meeting compiled the basic approach toward formulation of the government strategy for the enhancement of materials innovation capacity and the direction of the future initiatives including (1) Creation and enhancement of a data-centric platform for material R&D, (2) Strategic promotion of key materials technologies and implementation areas, (3) Creation of a materials innovation ecosystem, and (4) Training and recruitment of talent to support materials innovation capacity.

Based on the report and with a view to the society and industry visions in 2030, the government at the Council for Integrated Innovation Strategy formulated a strategy to strengthen "materials innovation capacity" that will play an important role in the realization of Society 5.0, achievement of SDGs, overcoming of resource and environmental restrictions, resilient society and industry, etc. ("Materials Innovation Strategy"). Taking Japan's advantage of a large number of diverse researchers and enterprises and the world's top-level R&D infrastructure, and under the shared vision among industry, academia and

[1] Keihanna: Area of Kyoto, Osaka and Nara prefectures

government stakeholders, the strategy will powerfully promote (1) Development and swift social implementation of innovative materials, (2) Encouragement of data-driven R&D leveraging materials data and manufacturing technologies, (3) Sustainable enhancement of international competitiveness and other efforts.

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 is implementing the "Establish Process Science toward Commercialization of Materials (Materialize)" project from FY2019 with the aim of establishing process science as the theory/science basis for solution of process issues in order to facilitate commercialization of materials with innovative functions but without established process technology, by building an industry-academia-government collaboration system at universities, national research institutions, etc.

The "Materials Innovation Strategy" presented the need for the development of an R&D platform centering around data and promotion of utilization of material data. In response, MEXT is working on strategic collection, accumulation and utilization of materials data that are generated using state-of-the-art shared-use facilities across the country by implementing "Advanced Research Infrastructure for Materials and Nanotechnology in Japan" for development of data-compatible facilities and deployment of data personnel to structure data: (1) constructing a new hub & spoke system consisting of hubs with diverse research facilities and spokes with distinctive technologies and equipment around the Materials Data Platform Center of the National Institute for Materials Science (NIMS) and (2) based on the national shared use system of the Nanotechnology Platform Furthermore, in important technical domains of the materials field, which Japan should develop in earnest, MEXT sets research tasks that promise efficient result production, which is highly compatible with data science in addition to high social and industrial needs.

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 M3 (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. Since FY2019 NIMS is implementing activities to transform the research environment into the Smart Laboratory toward acceleration of creation of innovative materials.

In order to ensure social implementation promptly responding to the needs for reduction of environmental burden as well as diverse customer needs, METI promotes digital-driven R&D making full use of computation and information sciences. In addition, the ministry is working for further advancement of the production process technologies that are the core of materials development. Specifically, while constructing a digital-driven materials design system making full use of polymer multi simulators and a highly efficient trial production/measurement systems to develop the "materials development support

center," METI is developing innovative process technologies (flow synthesis, etc.) to realize the on-demand production of many kinds of materials in small quantities. Furthermore, in order to overcome resource constraints, the ministry is tackling R&D for strategic improvement of the supply chain resilience covering rare metals necessary for magnets, motors, etc.

With the aim of accelerating social implementation of the materials developed by SMEs and venture companies, AIST started to develop an environment for collection of production process data in high throughput by introducing state-of-the-art measurement and analysis technologies in its regional centers and by linking the technologies with streamlined production process facilities to promote data-driven materials R&D.

D. Strategic promotion of quantum technology innovation

Quantum science and technologies (optical and quantum technologies[1]) 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, its likelihood to become the foundation of all science technologies and the international trends, the government formulated the "Quantum Technology Innovation Strategy" in January 2020. The strategy sets as future society goals (1) productivity revolution, (2) longevity of a healthy society and (3) safety and security of the country and the people. "Quantum technology innovation" is clearly positioned for their achievement and (1) focused R&D, (2) international cooperation, (3) formation of R&D centers, (4) intellectual property and standardization strategies, and (5) development and securing of excellent human resources are promoted by using Japan's strengths. Regarding (3) formation of R&D centers, "Quantum Technology Innovation Hubs" consisting of eight domestic hubs were launched in FY2020. These hubs consisting of research organizations in a broad range of fields including devices and software composing quantum computers, elements of technologies for their utilization, quantum cryptography and quantum sensors will promote R&D in the respective fields. In addition, related organizations with RIKEN positioned as the core organization join forces to promote a wide spectrum of initiatives across the hubs from basic research to technology demonstration, international cooperation and human resource development. The aim is to accelerate R&D and social implementation of quantum technologies in a concerted effort of industry, academia and governments in order to attract investments from enterprises, etc. at home and abroad.

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

Under the "Cross-ministerial Strategic Innovation Promotion Program (SIP) Second Phase" that has been implemented since FY 2018, the Cabinet Office has been promoting R&D and social implementation of (1) laser processing, (2) optical/quantum communication, (3) optical electronical information processing and a network-type production system that will integrate them. In R&D on the Photonic Crystal Surface. Emitting Laser (PCSEL) of (1), in particular, the office succeeded in the development of a high-performance LiDAR system equipped with PCSEL for the first time in the world and in tackling further intensity and performance toward a very small laser processing system. Furthermore, the office set up the "Quantum Technology Domain" in the "Public/Private R&D Investment Strategic Expansion Program (PRISM)" in June 2020 to support R&D contributing to the expansion of public and private R&D investments.

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 addition, MIC has been promoting R&D of technologies to further extend the distance of terrestrial quantum crypt-communication (long-distance linking and relay technologies) since FY2020. 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 under the Quantum Leap Flagship Program (Q-LEAP) 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. In FY2020 the ministry launched new quantum life and quantum AI flagship projects, set up a new (4) human resource development program field and is promoting development of common core programs for development of education programs aimed at sustained enhancement of quantum technology personnel together with original subprograms.

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 state-of-the-art research using quantum beam facilities such as the world's top class laser (J-KAREN[1]) and Takasaki Ion Accelerators for Advanced Radiation Application (TIARA). In April 2019, QST established a quantum life science institute and has been working on basic technology development of quantum life science aiming to create innovations of life science by applying quantum science and technology including quantum

1 Japan-Kansai Advanced Relativistic ENgineering

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 development and has been promoting integral development from hardware to software and applications of quantum annealing machines. In FY2020, METI started development of interface integrated circuits that connect common software and hardware. 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."