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

1 Vision of Society 5.0

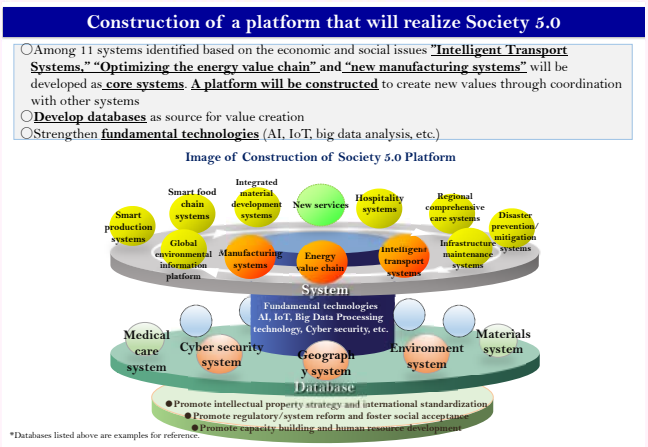
Society 5.0 is the new society following the hunter–gatherer society, agricultural society, industrial society, and information society. For example, Society 5.0 enables "people and life system in communities for Healthy Nation Japan" by securing of transportation means with automatic traveling vehicles, 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 for actual use of multi-lingual voice translation systems as Hospitality Systems, has improved their translation accuracy to a practical level, and promoted performance assessment in actual scenes of use including hospitals, commercial facilities, railways and taxies. The technology has been transferred to private companies.

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.

The government formulated 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. The following initiatives based on the strategy have been carried out integrally in collaboration among the relevant ministries and

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.

agencies. The Cabinet Office in cooperation with MEXT and the Ministry of Economy, Trade and Industry (METI) set up the "Meeting to Discuss Mathematics, Data Science and AI Education Programs Certification System" (October 2019) consisting of experts from universities, high schools, National Research and Development Agency Industry, etc. under the Council for Implementation of AI Strategies[1]. The goal of the meeting is: "all university and college of technology students (about 0.5 million graduates/year) master introductory-level mathematics, data science and AI in their schools." The meeting conducted studies toward establishment of the Mathematics, Data Science and AI Education Programs Certification System (literacy level) where the government authorizes excellent Mathematics, Data Science and AI Education Programs of universities and colleges of technology. The meeting compiled a report in March 2020.

With the aim of achieving the goal: "all humanity and science students of university and college of technology (about 0.5 million graduates/year) master introductory-level mathematics, data science and AI in their schools" MEXT developed and is using a model curriculum systematizing the basic concept of literacy-level mathematics, data science and AI education, learning objectives/skill set, education methods, etc. which are linked with the Certification System (literacy level) mentioned above, so that all university and college of technology students acquire ability to properly grasp, analyze and explain phenomena based on data, namely "cultivate data thinking," in the data-driven society in the future. The curriculum has been spread to universities, etc. across the country. 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, 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. The Institute of Statistical Mathematics is working to cultivate human resources versed in data analysis as well as statistics and mathematical science essential for data analysis.

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 launched the "Project to support research centers for realization of Society 5.0" in order to create advanced core hubs

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)

for Society 5.0 demonstration and problem solving by supporting initiatives for social implementation through integration of various research results centered on 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 has been promoting "Cyber-Security for Critical Infrastructure" and R&D on "Cyber/Physical Security for IoT Society."

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

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 technology development for delivery using automatically running robots, 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

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) compiled a guide book for connection of the basic map information that is the standard of absolute positions (so-called national coordinates) as a common base of geospatial information with relatively high position accuracy.

In response to "Initiatives toward Enhancement of Japan's Ability to Grasp the Ocean Situation" (decision by the Headquarters for Ocean Policy on July 26, 2016) Japan Coast Guard constructed "the Maritime-domain-awareness Situational Indication Linkages (Umisiru)" 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. Umisiru 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. 104 domestic universities and public research institutes are taking part in the network as of the end of March 2020. 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 problems arising from the spread of artificial intelligence technologies (ELSI.) In FY2020, the ministry will promote Trusted Quality AI (AI systems capable of explaining the basis for their decisions) and other R&D based on the AI Strategy 2019. 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 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) have 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.

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 2020 the ministry will implement development demonstration based on local needs in various usage scenes toward introduction of local 5G that various entities can flexibly construct and use.

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.

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 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 also held "exchanges between young mathematics and 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 addition, RIKEN set up the Interdisciplinary Theoretical and Mathematical Sciences Program (iTHEMS) in 2016 with the aim of interdisciplinary fusion and creation of new disciplines based on mathematics and theoretical science and is working for integrated elucidation of sciences and discovery and solution of problems in society toward creation of innovations using mathematical science.

(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)).

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 started "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, nano technology and bio technology.

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 started the "Establish Process Science toward Commercialization of Materials (Materialize)" project in 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 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 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. In FY2019 NIMS started activities to transform the research environment into the Smart Laboratory toward acceleration of creation of innovative materials.

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 international trends, through the Meeting to Promote Comprehensive Innovation Strategy the government formulated "Quantum Technology Innovation Strategy" in January 2020 as a new national strategy beyond short-term technology development, from the medium to long-term perspective of 10 to 20 years with a view to industry and innovation. 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" was clearly positioned for their realization 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 will be

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

promoted by using Japan's strengths.

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.

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. Using quantum cryptography, NICT succeeded in development of a system that increases safety of face authentication and in demonstration experiment to store electronic health records. 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.

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[1]). 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 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,

1 Japan-Kansai Advanced Relativistic ENgineering

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."

■Table 2-2-2/Major projects for realization of Society 5.0 (FY2019)

Ministry	Implemented by	Project
Cabinet Office	Council for Science, Technology and Innovation	"Strategic Innovation Promotion Program (SIP) Second Phase" task
MIC	MIC	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
		Technological study toward introduction of the 5th generation mobile communication system, etc. (5G comprehensive demonstration experiment)
		R&D toward further upgrading of the 5th generation mobile communication system
MEXT	MEXT	Doctoral Program for World-leading Innovative & Smart Education
		Training of advanced technical talents in response to Society 5.0
		Doctoral program for Data-Related InnoVation Expert
		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
		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