Cross-Ministerial Strategic Innovation Promotion Program (SIP)

Research and Development Plan for Intelligent Knowledge Processing Infrastructure Integrating Physical and Virtual Domains

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Director General for Science, Technology, and Innovation
Cabinet Office

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R&D Plan Overview

1. Vision and Development Goals, etc.

While the lives of people are becoming more convenient and rich through progress in science and technology, social issues that need to be solved beyond borders are becoming more complex. This is why international issue-solving efforts are more important than ever. Japan, as a pioneer in tackling social issues, is in a position to be capable of promoting economic growth while addressing social issues at the same time, for the first time in the world. Therefore, the 5th Science and Technology Basic Plan proposed the concept of Society 5.0, as a model of future society to aim for. To realize Society 5.0, Cyber Physical Systems (CPS), which are coordination technologies, must be constructed for collecting and accumulating information on Japan's various high-quality processes (physical space) in an advanced and efficient manner, and integrating that information with virtual (cyber) space to a high degree.

With the aim of constructing the required CPS, it is important to develop coordination technologies based on Japan's strong points, such as hardware technologies and systems focused on enhanced real-time processing, controllability, and ultra-low power consumption, and to systemize the technologies as a new common platform. However, the high cost of physical space processing and Japan's IT professional shortages are major barriers to realization of Society 5.0 by using CPS. Thus, the aim of this project is to significantly reduce the cost of physical space processing and to revitalize Japan's industry, including small and medium-sized companies and newly emerging businesses, by developing an edge-focused platform capable of easily integrating cyber and physical spaces ("edge computing platform"). The edge computing platform, which does not require IT expertise for operation, will remarkably reduce costs such as with the development period and personnel, thereby promoting the entry of new companies and increasing new business opportunities.

Additionally, through commercialization and systematization of the technologies for the low-energy IoT devices and innovative sensors that will utilize Japan's superior material and device technologies, the scope of application of CPS will be widened (for example, technical challenges concerning power supply will be solved, and the environment of physical space where sensors otherwise could not have been installed will be made measurable) and advanced values will be created.

Furthermore, technologies for solving social issues that require construction of edge-focused CPS (such as control management of physical space) will be developed in areas where real-time processing is indispensable, which cannot be achieved in a cloud-based system, thereby disseminating successful results of the project to society.

Toward the maintenance of international competitiveness of solutions using Japan's CPS and contribution to sustainable economic growth, strategies for autonomously maintaining and updating the edge computing platform will be constructed.

Each subtheme of the project will be promoted towards the following goals:

- To develop the world's first platform capable of reducing the development period and/or cost of IoT solutions by 90% or more, compared with conventional methods, as the core technology of Society 5.0.
- To develop technologies for realizing measurement in environments where sensors otherwise could not be installed, including realization of low-energy IoT chips, and innovative sensors which will reduce the energy required for near-sensor processing by 80% or more.
- To demonstrate the effectiveness of the platform and technologies for IoT chips and innovative sensors mentioned above in production and other areas, to create examples of commercialization and establish a route to social implementation.

2. Research

An “intelligent knowledge processing infrastructure integrating physical and virtual domains” that can be utilized in various fields will be constructed as a new common platform, and implemented in society as a front-runner for social issues. Emphasis will be placed on real-time data processing in physical space, usability for non-IT experts, cost reduction, application of the device to undeveloped fields, and advanced thing-to-thing cooperation and coordination.

The program will be divided into the three R&D subthemes listed below. The subthemes will be promoted in mutual intrinsic coordination, to facilitate achievement of the goals.

I. Common edge computing platform technology to develop IoT solutions

II. Technologies for innovative sensors and low-energy IoT chips

III. Technology to disseminate IoT devices for realizing Society 5.0

3. Implementation Structure

Program Director Hideyuki SASO (“PD”) will be in charge of the establishment and promotion of the research and development plan. The Promotion Committee, which is chaired by the PD and is composed of specialists and experts, and for which the Cabinet Office serves as secretariat, will perform general coordination. The PD will order principal investigators who are elected by open application to promote research and development, through utilization of the National Research and Development Agency New Energy and Industrial Technology Development Organization (“NEDO”). Furthermore, business management meetings, for which NEDO serves as secretariat, will be held to share the goals of the project amongst the research themes, manage the progress of each theme, ensure mutual coordination among themes, and to effectively supervise the management of the whole project. The business management meetings will aim to maximize the results of the project through collaboration with a separately established strategy committee, that will be composed of outside experts, and will be responsible for considering edge computing platform strategies. The PD may, if necessary, appoint sub-PDs to support the PD in managing the progress of the research and development.

4. Intellectual Property (IP) Management

An IP committee for managing the intellectual properties of the entire project will be established in NEDO, or in any of the institutes to which the selected principal investigators belong (entrusted institutes), to understand and manage the trends of background IPs possessed by each entrusted institute and foreground IPs generated through the program, to properly manage handling of such IPs, and to coordinate relationships among stakeholders.

5. Evaluations

Prior to the evaluation made by the Governing Board at the end of each fiscal year, the principal investigators will conduct self-inspections, and the PD and management agency will also conduct self-inspections. Evaluation results will be reflected in plans for subsequent years, and will be used to organize research teams as necessary, thereby maintaining the level of research and development.

6. Strategy for Commercialization

The program will construct an environment in which information from Japan’s high-quality physical space will be easily and effectively utilized through standardization of the state-of-the-art edge computing platform. Opportunities for creation of new businesses by various industries will be enhanced through the results of the program, to aim at economic growth and the solution of social issues under the concept of Society 5.0.

For that purpose, in addition to development of the edge computing platform, social implementation of near-sensor low-energy devices and innovative sensor systems, in which Japan has a competitive edge, as well as IoT devices, including robots capable of solving social issues, will be strategically promoted through specific verification. Companies which are expected to actually engage in commercialization will be selected as partners for each of the subthemes, and efforts for prompt commercialization in the industry will be made, with private capital being invested in the promotion of the R&D subthemes.

An intelligent knowledge processing infrastructure integrating physical and virtual domains will be made to develop as an attractive platform through combination with the existing results of PRISM, ImPACT, and various ministries and agencies (including three research organizations for artificial intelligence), as well as with the results from the related SIP projects “Big-Data and AI-Enabled Cyberspace Technologies” and “Cyber Physical Security for IoT Society.” This will continue to enhance new business opportunities and promote the entry of the industry even after completion of the program, through construction of systems for maintenance and update (such as consortia), and aim to maintain and enhance Japan’s competitive edge and economic growth.

1. Vision and Development Goals, etc.

(1) Background and Domestic/International Context

While the lives of people are becoming more convenient and rich through progress in science and technology, social issues to be solved beyond borders are becoming more complex due to an increase in demands for energy and food, an increase in greenhouse emissions, and ever-increasing population aging.

As a result of the growing importance of international efforts to solve these issues, expectations are running high for efforts toward “digital innovation,” utilizing new technologies such as IoT, Big Data, and artificial intelligence (AI) to solve social issues.

Japan, as a pioneer in tackling social issues, is in a position to be capable of promoting economic growth and addressing social issues at the same time, for the first time in the world. Therefore, the 5th Science and Technology Basic Plan proposed the concept of Society 5.0, as a model of future society to aim for.

The concept is expected to lead to a human-centric society in which every human and thing will be mutually connected via IoT, various items of knowledge and information will be shared, and artificial intelligence (AI) and robots will be utilized so that the required amount of things and services will be delivered at the right time to people requiring such things and services. In such a society, everyone can lead a comfortable, energetic, high-quality life.

In addition, to realize Society 5.0, Cyber Physical Systems (CPS)[1] must be constructed, which are coordination technologies for collecting and accumulating information on Japan’s various high-quality processes (physical space) in an advanced and efficient manner, while integrating the information with virtual (cyber) space to a high degree.

[Image]

According to a survey by the Ministry of Internal Affairs2, however, only 64.5% of companies in Japan are considering the introduction of any IoT solution by FY2025, far less than in other countries, such as the U.S., Germany, and China. (Figure 1-1)

[1] Collection, processing, and utilization of data obtained from actual society and humans will enable advanced human-to-thing and thing-to-thing coordination and collaboration, and contribute to the enhancement of efficiency of every social system, creation of new industries, and improvement of intellectual productivity.

[2] “International questionnaire survey of companies concerning economic contribution of ICT in Japan, and attitudes toward IoT at home and abroad”(2016).

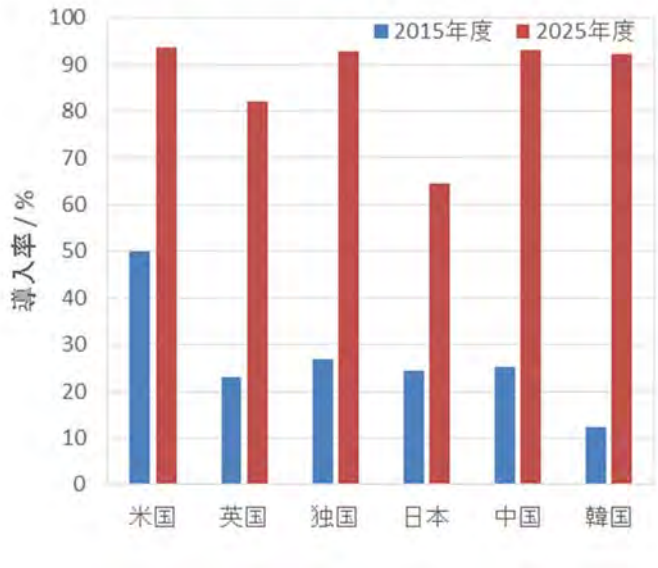

Figure 1-1. Expected Rate of Companies Introducing IoT Solutions

In addition, according to a survey by the Ministry of Economy, Trade and Industry[3], Japan requires 1.17 million IT professionals[4] as of 2018, but lacks 243,000. The supply of IT human resources will start to decline after reaching a peak in 2019. If the IT market continues rapid growth, the number of required IT professionals will reach 1.325 million, and the shortage will be 790,000 in 2030. A severe shortage of IT professionals is predicted (Figure 1-2). Among IT workers, system engineers in particular are in short supply, but are needed for incorporating social issues into CPS and AI human resources for efficiently processing data from physical space.

Toward the realization of Society 5.0, it is essential to solve social issues through the advanced merger of cyber and physical spaces, in addition to solving the issue of a shortage of human resources.

[3] "Results of the survey on the latest trends of IT professionals and future projections" (2016).
[4] Total number of human resources belonging to IT companies and information system divisions of user companies.

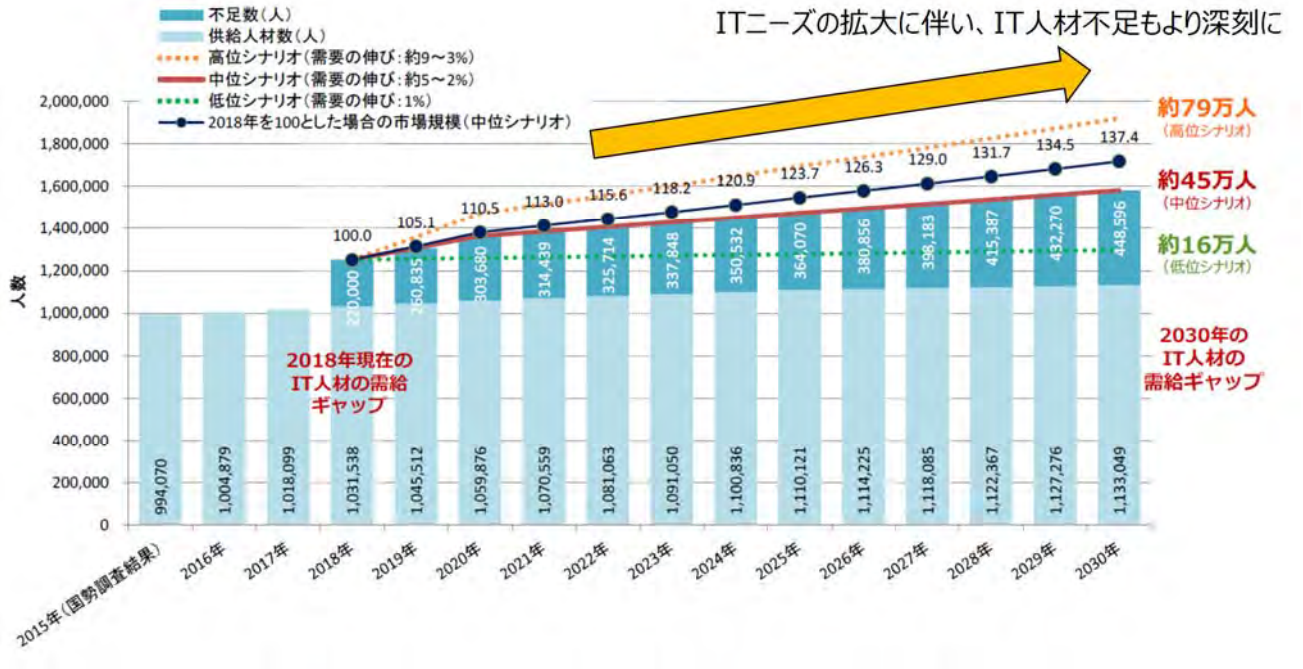

Figure 1-2. Results of Major Trial Calculations

Concerning the Supply and Demand of IT Personnel

(2) Significance and Strategic Importance

In response to the proposals in the 5th Science and Technology Basic Plan, the Center for Research and Development Strategy of Japan Science and Technology Agency (JST-CRDS) has proposed two research and development areas towards the realization of an advanced information processing system required for CPS: 1) the development of technologies for vertical integration of software and hardware, and verification of performance of the technologies, 2) the systematization of new common core technologies, and the enhancement of each technical layer. The Center insists that technical development vertically integrating the algorithm and software for realizing various services for solving social issues and individual technologies of technical layers such as circuits, architecture, devices, and materials is important for the realization of CPS. The Center also insists that it is important to construct a strategy for vertically integrated technical development. Especially in connection with development of IoT systems, it is expected that coordination technologies based on Japan's strong points (such as hardware technologies and systematization) will be developed with a focus on real-time processing, controllability, and ultra-low power consumption, and will be systemized as a new common platform[5].

Based on the proposals above, with the aim of widely applying CPS to the real world, this program will construct an "intelligent knowledge processing infrastructure integrating physical and virtual domains" that can be utilized in various fields as a front-runner for social issues, with emphasis put on real-time data processing in physical space, usability for non-IT professionals, cost reduction, application of the device to undeveloped fields, and advanced thing-to-thing cooperation and coordination.

The platform will be the first in the world to solve social issues due to shortage of workforce or human resources (such as the social issues faced by Japan) by, for example, installing low-energy IoT devices and innovative sensors for providing access to information that otherwise could not be obtained on the edge platform, for analyzing and controlling physical space to a high degree, and applying the edge platform to workplaces that suffer labor shortage, thereby remarkably improving productivity.

[5] Strategic proposal "Innovative computing --- Calculation domain-oriented creation of core technologies" (2017)

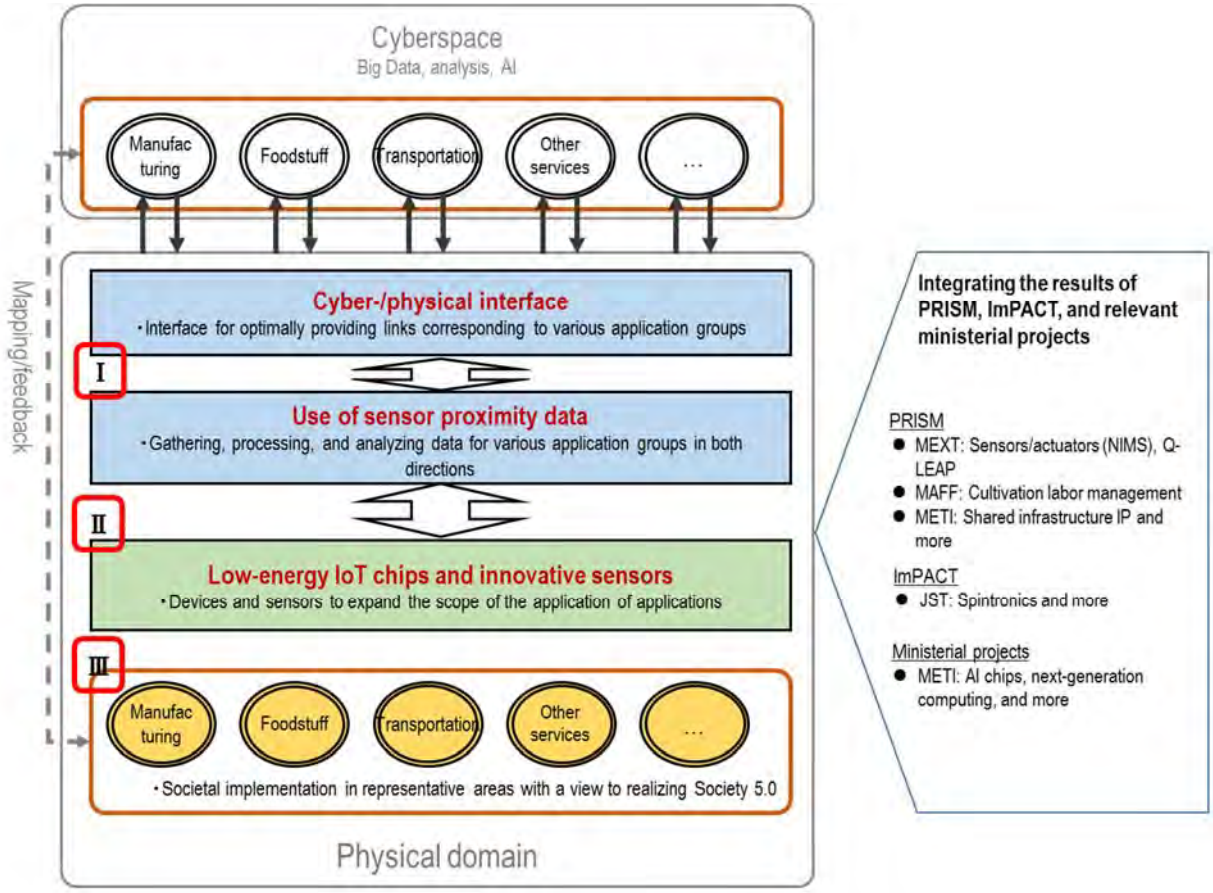

Figure 1-3. The Overall Picture of the Intelligent Knowledge Processing Infrastructure Integrating Physical and Virtual Domains

(3) Objective/Aim

i. Achievement of Society 5.0

- In order to realize Society 5.0, it is necessary that various next-generation technologies related to digital innovation be implemented in actual industries and social life, be widely utilized, and therefore the research and development should take concrete commercialization strategies into consideration.
- In the Hyper Connected World that will be realized as a result of the achievement of this project, every human and thing will be connected to every other human and thing, and such connectivity will drive a society in which every individual can live an active, comfortable, and full life.
- This project will develop the low-energy IoT devices and sensors required for efficient digitization of physical space, centered on the core technology (edge computing platform) for enabling every individual to realize CPS solutions, which is essential to the realization of Society 5.0. This project will also demonstrate the effectiveness of these technologies in production and other areas, create multiple examples of commercialization, and establish a route to social implementation.
- The project will contribute to the realization of Society 5.0 by constructing a successful model of improvement of productivity in a society with a decreasing labor population, for the first time in the world.

ii. Social Objectives

This project will enable “human-to-human,” “human-to-thing,” and “thing-to-thing” coordination and linkage in the various fields mentioned in Society 5.0, especially by integrating cyber and physical spaces to a high degree, and will solve social issues (such as improvement of productivity) due to Japan’s shortage of labor force and human resources, thereby creating a richer society.

iii. Industrial Objectives

- This project will facilitate the introduction of IoT solutions by reducing barriers to such introduction, and will increase the rate of introduction of IoT solutions by companies to 90% or higher, which is the level required for global competition, in FY2025.
- The impact of IoT and AI on economic growth (indicated by the market size) was 1.07 quadrillion yen in 2016, and will be 1.222 quadrillion yen in 2030, if the base scenario continues to apply, which means that the impact will not grow significantly under the base scenario. However, under a growth scenario where the creation of new industries is actively promoted, an impact as great as 1.495 quadrillion yen can be expected. The difference between the economic growth scenario and the base scenario is especially large in the “manufacturing,” “commercial and logistics,” and “service and others” industries (WHITE PAPER Information and Communications in Japan [2017 edition]: Ministry of Internal Affairs and Communications). This project will develop a digital data processing platform with which even individuals who are not specialized IT professionals can easily utilize AI/IoT technologies, and disseminate such a platform within the industries mentioned above, thereby giving many players more opportunities to materialize their ideas and facilitate the creation of new industries, with an aim to enhance Japan’s economic growth and international competitiveness.

iv. Technical Objectives

- To establish technologies with a low barrier to entry and high international competitiveness by constructing the edge computing platform through the development of technology for performing advanced real-time mapping of physical space, even with small near-sensor computing resources, and by coordinating the technology for stably and smoothly coordinating with minimal effort the many various devices on site with cyberspace and the technology for utilizing data from digital areas, without requiring expertise in advanced ICT and AI, etc.
- To achieve social implementation of low-energy IoT devices and innovative sensors for the first time in the world. To develop compact, low-cost, innovative sensors that can mine the various high-quality data on site, and then use that for robots, etc., and IoT chips for processing said data with ultra-low power consumption, and also implement them in society, toward the realization of Society 5.0.
- To develop technologies for real-time analysis and control management of physical space, which cannot be achieved by cloud-based systems, mainly in robots used in the manufacturing industry and services directly related to the lives of individuals, and establish technologies for evolving the technologies mentioned above until they can be widely utilized in areas such as food, transportation, nursing care, and other services where the labor shortage is severe but development has been difficult, and implement those technologies in society.
- With a productivity revolution being sought for, digitization of industrial machinery is required in Japan’s manufacturing industry (production sites). However, different data exchange and communication methods have been adopted in production

sites, and no technology for mutual linkage amongst industrial machinery has been established. It is essential to accelerate the connection of various types of industrial machinery to networks, as well as interconnection and data exchange among industrial machines, and to utilize the collected real data for further improvement of productivity.

v. Objectives Pertaining to Institutional Systems

- The physical space common platform to be developed in this program will be made available for utilization by many players in the industry, by making the interface standard, and the results of the platform freely available. In addition, individual rights obtained by principal investigators through this program will not be treated as exclusive technologies, but will be licensed to third parties that intend to utilize them for an appropriate fee.
- Problems in connection with solutions by CPS, including the improvement of the working environments of industrial workers and the rise of the acceptance level of ICT, will be made clear and incorporated within systems.

vi. Strategies in Light of Global Benchmarks

- Industry 4.0 is an effort in Germany to use IoT to optimize production and inventory management, mainly in the manufacturing industry, beyond the framework of individual plants and companies, thereby promoting economic development, and it has spread to other European countries and developing countries. Under the concept of Society 5.0, Japan is trying to be the first in the world to solve social issues arising from the decrease of the population (such as aging and the decrease of the working population) by connecting various factors in social systems (thing-to-thing, human-to -machinery/system, human-to-technology, companies in different industries, humans in different generations, manufacturer-to-consumer, etc.).
- Applications for utilizing digital data for industrial purposes include platforms focused on data linkage on the cloud, such as the “Mind Sphere” of Siemens AG and “Lumada” of Hitachi, Ltd., the “FIELD System” led by Fanac Corporation, etc., and the edge computing “Edgecross,” led by Mitsubishi Electric Corporation. All of them are vertically integrated systems, characterized by their connection of products, plants, systems, and machines for management. Microsoft’s “Azure” was formerly focused on enclosure of data in the cloud, but recently started to enhance response and linkage in on-premise environments, advancing to the edge side.
- Japan, strong in device technologies, has a share of 38% in the global market for electronic components (2016), and leads the world in the level of research. However, Japan’s share has significantly declined due to fierce competition with overseas companies in recent years. In addition, there are issues concerning industrial application, such as commercialization and inclusion of devices in CPS in the industry, especially in small and medium-sized companies and venture businesses.
- On the other hand, horizontally specialized platforms which, while using a generic cloud platform, incorporate devices and sensors and enable agile developmental responses to social issues have not been developed to the level fully capable of industrial application anywhere in the world. Development of such platforms will become more important as we head towards the future.
- The positioning in the edge computing platform to be constructed in this project and benchmarks are shown in Figures 1-4 and 1-5.

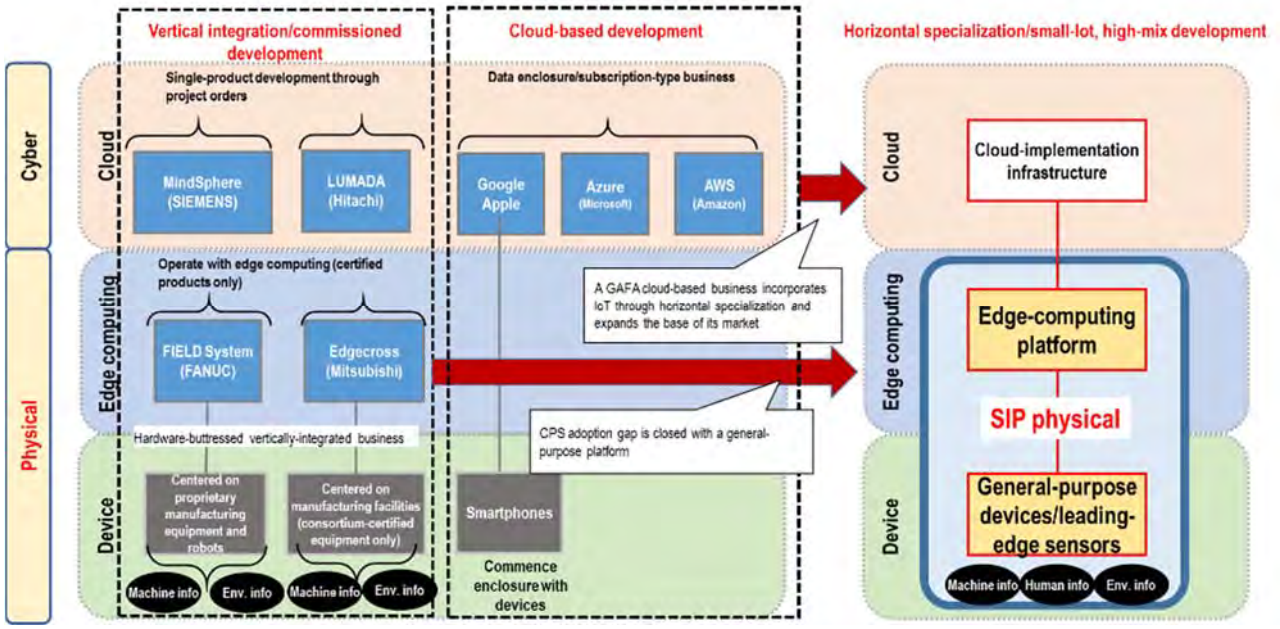

Figure 1-4. Positioning of the Intelligent Knowledge Processing Infrastructure Integrating Physical and Virtual Domains

Name	Developed by	Platform classification	App-linking policy	Target classification	Edge-computing platform/purpose
MindSphere	Siemens	Vertically integrated: Implementation through an in-house order	Data linkage in the cloud	Manufacturing/solutions	Used for in-house orders; streamlining of in-house development
Lumada	Hitachi	Vertically integrated: Implementation through an in-house order	Data linkage in the cloud	Manufacturing/solutions	Used for in-house orders; streamlining of in-house development
FIELD SYSTEM	FANUC	Vertically integrated: Implementation through an in-house order	Data linkage in the cloud	Plant machine tools	Used for in-house orders; streamlining of in-house development
AWS	Amazon	Cloud-based: API release for user development purposes	App add-on in the cloud	Cloud-based platform as a service (PaaS)	Commencement of the provision of specific devices; enclosure for data acquisition
AZURE	Microsoft	Cloud-based: API release for user development purposes	App add-on in the cloud	Cloud-based platform as a service (PaaS)	Commencement of the focusing of efforts on communication security; protecting the integrity

Figure 1-5. Outline of IoT Platforms

vii. Collaboration with Local Government, etc.

In connection with research themes planned for the future, feasibility studies will be conducted through collaboration with and implementation in universities, municipalities, and in small and venture businesses to explore and promote the concrete realization of Society 5.0 in local communities.

2. Description of R&D Activities

There is no doubt that in the society which the concept of Society 5.0 aims at, the focus of technologies will transfer from centralized data processing systems in the cloud to ultra-autonomous distributed and coordinated control systems, with the focus put on the edge in physical space (Figure 2-1). In this trend, Japan, with its internationally competitive technologies (such as devices and sensors) and high-quality manufacturing sites, will be required to establish the edge technology for controlling said technologies and sites, in order to take advantage of its international competitiveness in the future. However, taking into consideration the severe shortage of IT professionals, it is essential to construct a platform enabling anyone to easily realize the advanced edge-based CPS at a low cost.

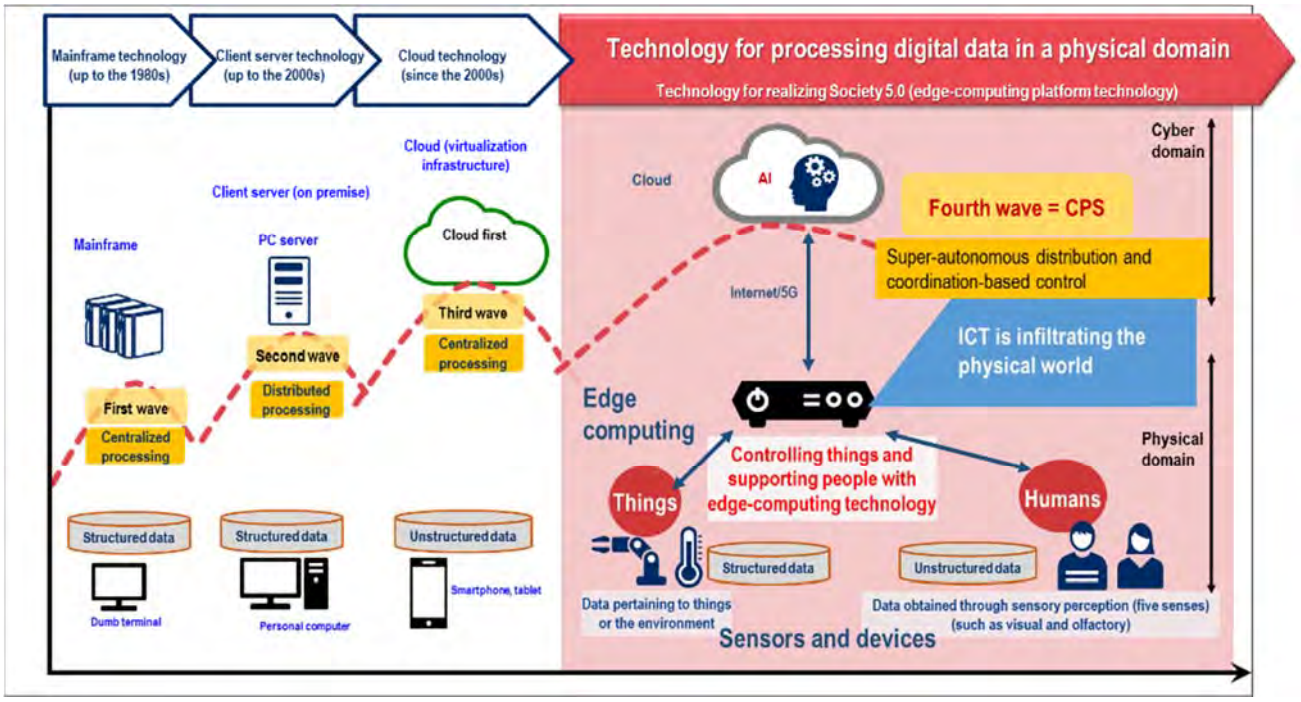

Figure 2-1. Positioning of CPS Seen from the ICT Perspective

Thus, this project will set the three R&D subthemes below, and construct the platform through promotion of efficient and effective research and development with these subthemes intrinsically linked with each other.

R&D Subtheme I: Common Edge Computing Platform Technology to Develop IoT Solutions

Under this subtheme, we will develop the technology for safely analyzing vast amounts of various types of data in physical space from diversified and integral perspectives with small computing resources, within the required time period, the real-time, low-cost edge processing technology, and the technology for linking with cyberspace. Furthermore, by facilitating the construction and operations of systems, we will provide an edge computing platform that many players in the industry can easily utilize. This subtheme also includes the following initiatives:

- We will designate research themes relating to multiple element technologies that are essential for the edge computing platform to be worked on by Japan as areas of cooperation, and perform development in said areas.
- Each research themes will survey and consider the design and standardization of various interfaces in close collaboration with the responsible individuals of all the three R&D subthemes.

- We will establish joint ventures and committees for considering more strategic construction of the ideal state of the edge computing platform, toward the realization of Society 5.0. Strategies for vertical integration and horizontal specification of the edge computing platform will primarily be considered, and output provided to each R&D subtheme as deemed appropriate. Based on said output, the R&D subthemes will appropriately adjust the direction and course of their research and development.
- We will promote commonization and construction of the edge computing platform (common edge computing platform) by incorporating elemental technologies and the results of considered strategies and achieve this goal by FY2020.

R&D Subtheme II: Technologies for Innovative Sensors and Low-Energy IoT Chips

Under this subtheme, we will develop and commercialize technologies for low-energy IoT chips and innovative sensors capable of enlarging the scope of application of CPS (assuming that the technologies can be utilized for the edge computing platform in the first R&D subtheme). This subtheme also includes the following initiatives:

- In order to enlarge the scope of application of CPS through development of low-energy IoT chips and sensor devices, in which Japan excels relative to other countries, the prospects for commercialization of said devices will be ensured by FY2020, and technological verification will be conducted in collaboration with the third R&D subtheme, eyeing the possibility of actual operations and commercialization, during and after FY2021.
- During the entire period, information on interfaces, etc., will be shared, coordinated, and proposed beyond the borders of R&D subthemes, for the purpose of promotion of research.

R&D Subtheme III: Technology to Disseminate IoT Devices for Realizing Society 5.0

Under this subtheme, we will develop technology for the social implementation required for the construction of CPS, including the real-time processing and control management of physical space, which cannot be achieved by centralized data processing based on cloud systems, toward the realization of Society 5.0. This subtheme also includes the following initiatives:

- After concrete systems for solving social issues faced by Japan are made clear, the system design and elemental technologies will be developed, and information will be provided to the necessary technologies of the second R&D subtheme by FY2020. Social implementation incorporating the first and second R&D subthemes will be verified during or after FY2021.
- During the entire period, information on interfaces, etc., will be shared, coordinated, and proposed beyond the borders of R&D subthemes, for the purpose of promotion of research.
- A preliminary investigation will be made with the aim of revitalizing and disseminating the advanced IoT solutions achieved through the realization of Society 5.0 in Japan’s various regions, and for creating new industries.

The edge computing platform to be constructed in this project is shown in Figure 2-2. Efforts will be made to complete the edge computing platform, while coordinating with results and activities of other SIPs, devices developed by other government ministries, and OSS (“open source software”), etc.

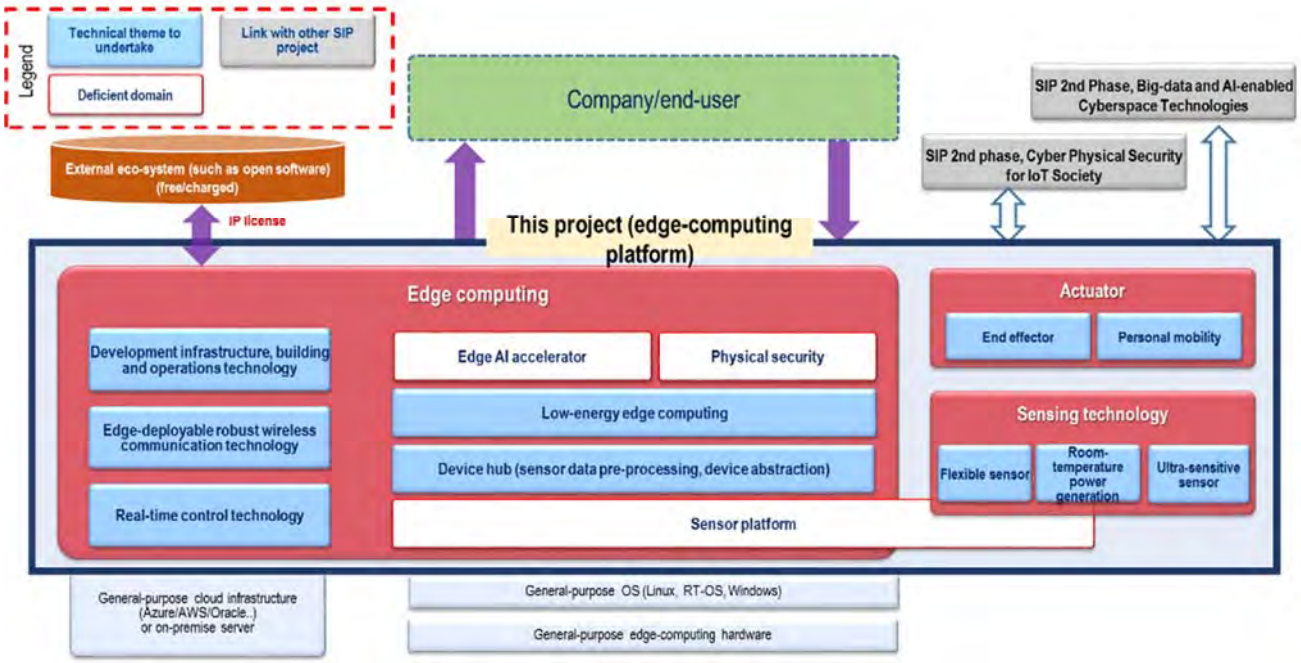

Figure 2-2. Edge Computing Platform to Be Constructed in This Project

In this project, technologies will be stacked in the configuration shown in Figure 2-3. As a result, CPS solutions will be constructed without the requirement to develop systems from scratch, so the period and costs for development will be reduced.

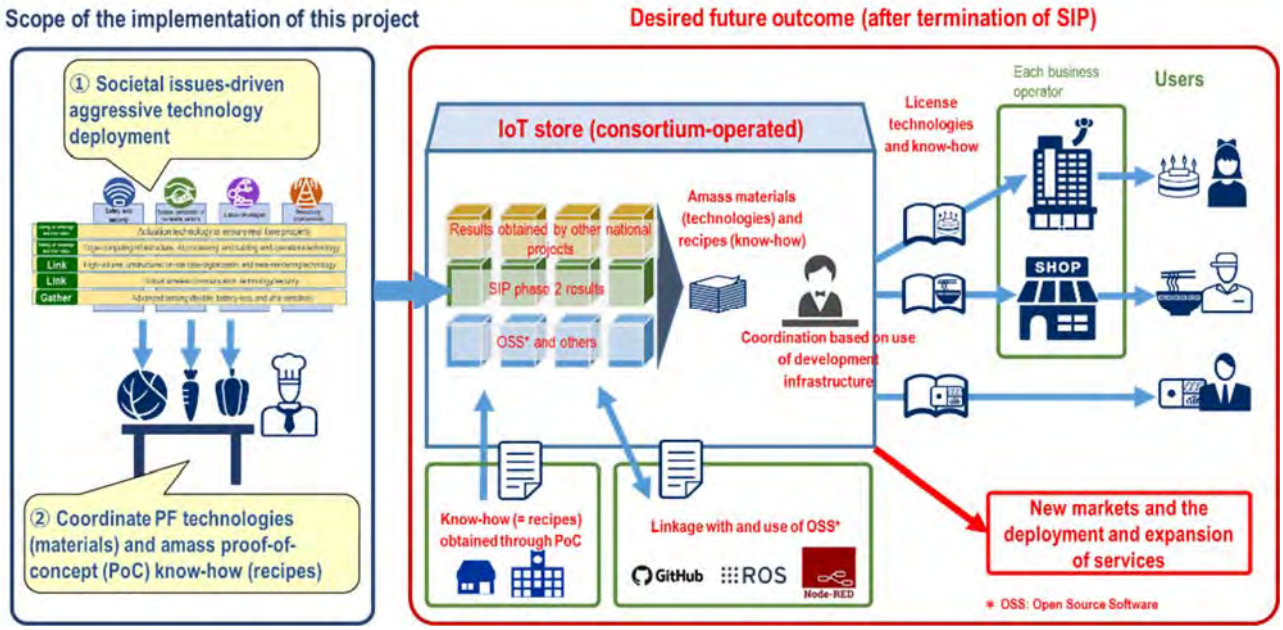

Figure 2-3. Scheme for Operations, Maintenance, and Utilization of the Platform

The ecosystem and business model for the edge computing platform are shown in Figure 2-4. As for the edge consortium that will form the core of the ecosystem, the edge working group (WG), which is the predecessor of the consortium, will be established in

FY2019, and efforts will be made to incorporate it by FY2021. The WG will be established at Kyushu University (Ito Campus), which is the research operator, and will be operated by Kyushu University and NEC. It will be operated with the SIP budget for several years after the establishment of the consortium. The consortium will use the open/closed strategy to practice innovation, making results of the SIP project open to the public, while keeping technologies specific to each company confidential.

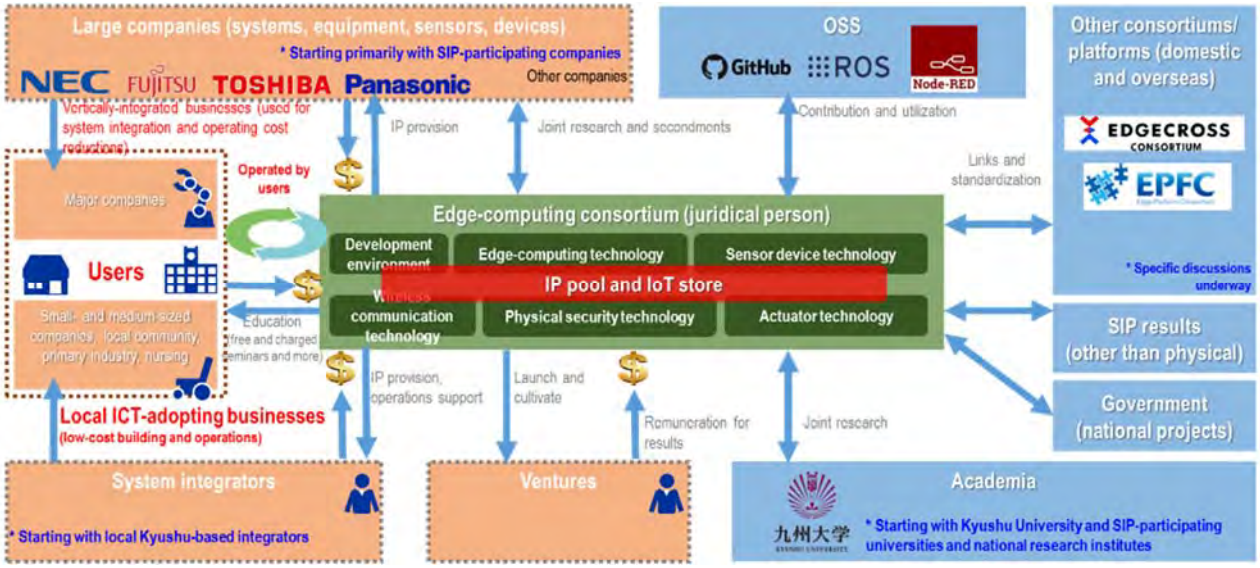

Figure 2-4. Ecosystem and Business Model of the Edge Computing Platform (Proposed)

The estimated timeline of research and development activities of each R&D subtheme is shown in Figure 2-5.

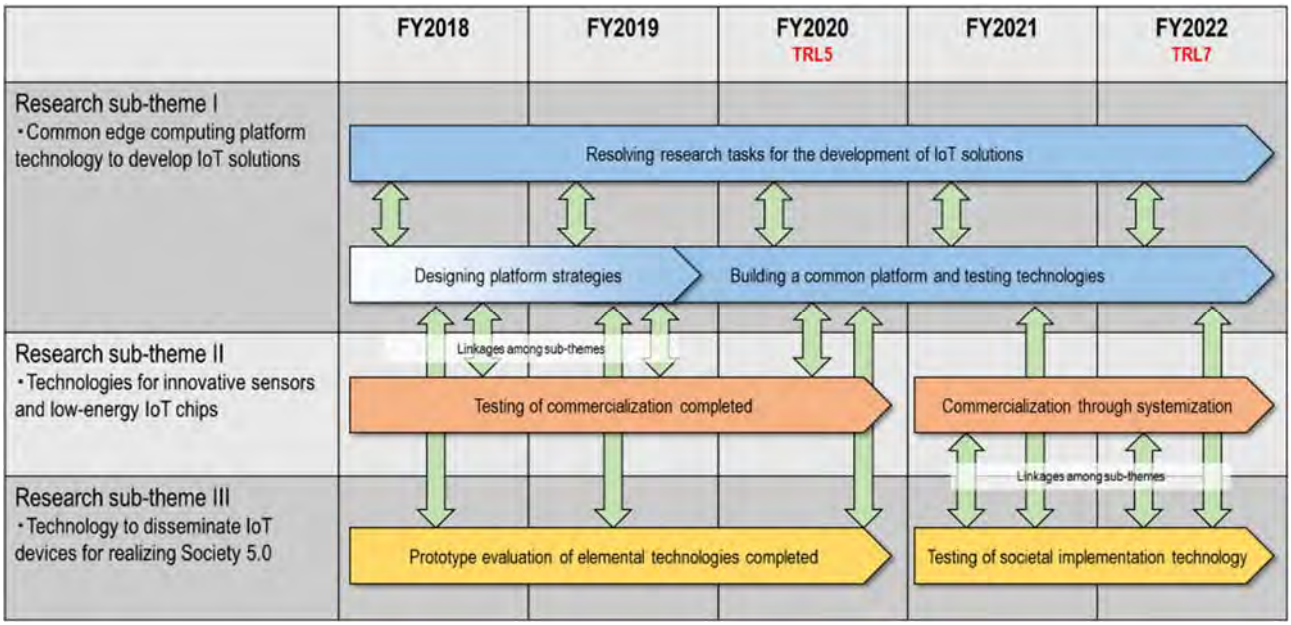

Figure 2-5. Estimated Timeline for Each R&D Subtheme

Figure 2-6 shows the operation structure of this project.

The PD and sub-PDs will perform effective management by regularly holding business management meetings to share the goals of the project amongst the research themes, and to manage the progress of each theme and mutual collaboration amongst themes. The

sub-PDs will perform the more practical management of each theme, keeping in close contact with the PD.

A strategy committee and edge computing platform consortium will be formed under the strategy coordinator to establish concrete strategies for commercialization of the edge computing platform. The strategy coordinator will consider the composition of elemental technologies, and clarify functions toward social implementation which are lacking. Based on this, the strategy coordinator will adjust additional functions, integrate and propose additional business, and take measures for open application for the business in the process of promotion of the project, thereby proposing measures to the PD that are appropriate for the dissemination and promotion of the results of this project.

The PD will perform management toward the construction of the intelligent knowledge processing infrastructure integrating physical and virtual domains, in cooperation with the sub-PDs and the strategy coordinator.

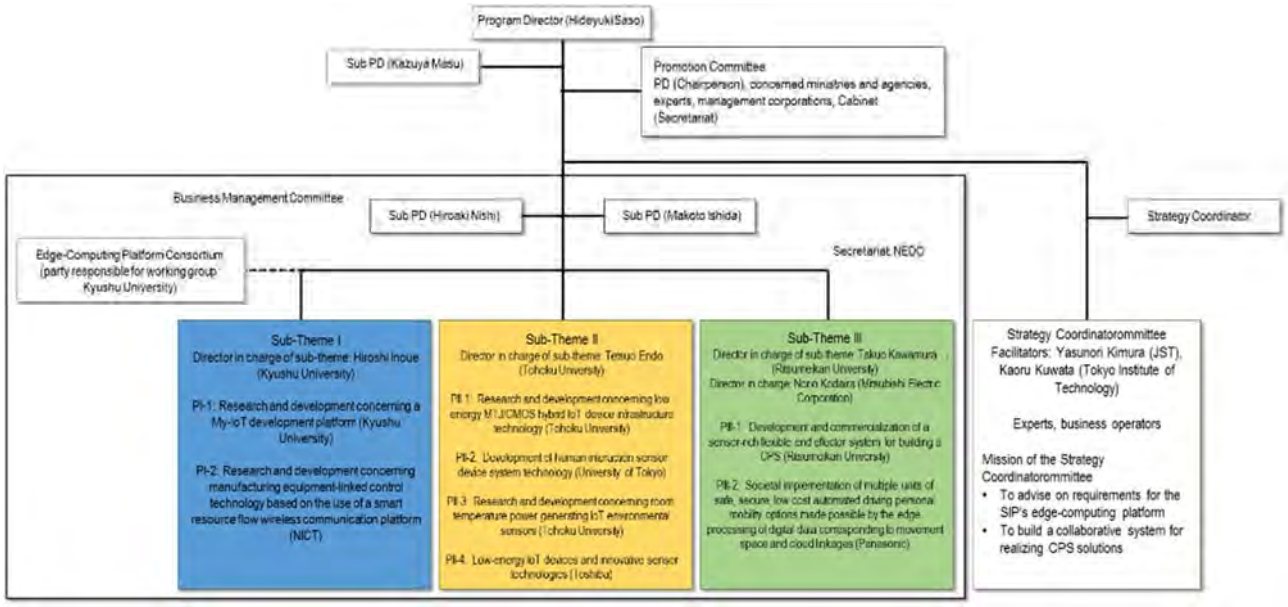

Figure 2-6. Operation Structure

The strategy committee will establish strategies concerning areas for social implementation, dissemination, and promotion of the edge computing platform, which is the goal of this project. In addition, it will construct the system of cooperation required for realization of CPS solutions.

The strategy committee will:

[Goals of the Relevant Fiscal Year]

- Inquire about requirements for the SIP edge computing platform.
- Construct the system of cooperation for realization of CPS solutions.

In FY2018, the research project was implemented to clarify issues and targets concerning dissemination of IoT in Japan, as part of consideration of strategies. The research project to clarify dissemination strategies for the edge computing platform to be developed, as well as policies for internationalization of the edge computing platform, will be implemented in the future. Below is an outline of the research results for FY2018.

Research project for considering strategies: Proposal of the "local IoT platform" based on the IoT coordination platform CPaaS.io

Director of the research project: the University of Tokyo.

Research was conducted to construct a PF capable of solving social issues in Japan, which is facing such issues earlier than any other country, with the use of IoT, AI, and data science, and of revitalization of the Japanese economy. Many of the social issues of Japan that will be dramatically resolved through CPS solutions occur in rural areas. Thus, 10 plans for industrial creation projects in the actual municipalities and regions were made on the basis of low-cost IoT service models (which corresponds to Japan's rural economy) and supporting platform systems, as well as the method for the management changes required for social implementation of said models (Figure 2-7). Each project is planned on the basis of situations of the area which was used as the model, and the possibility and methods of application of the project to various areas of Japan. As a result, it was suggested that the keys for coping with factors that inhibit revitalization of local communities of Japan using IoT and AI are (1) the situations of compact, low-cost IoT service

models and platforms, and (2) the method of changing management for reforming organizations and services. In addition, issues concerning (3) creation of local industries using localized versions of IoT platforms were extracted and organized.

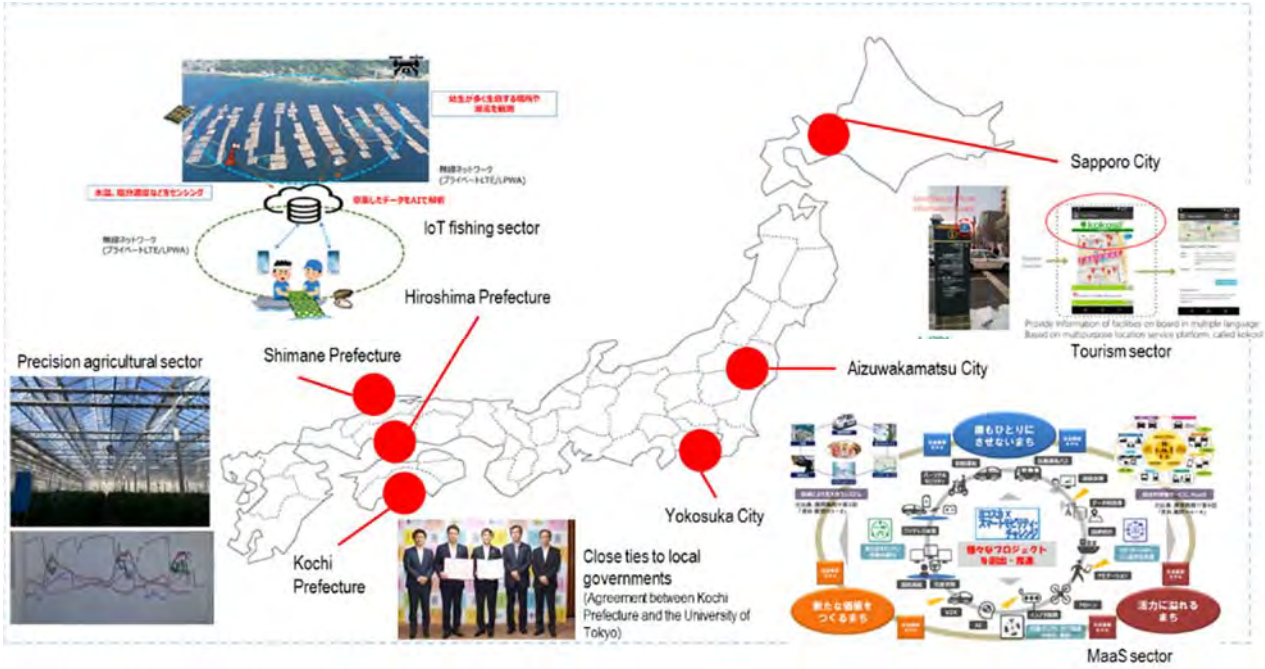

Figure 2-7. Overview of Industrial Creation Projects

Research Overview	Results of the research for strategic planning are as follows: (1) Trend research In order to look into industrial creation in local communities using IoT, a literary survey and a domestic survey were conducted (mainly on the regional business creation process in Kochi Prefecture). As an overseas survey, a trend survey was conducted in Germany (cities of Berlin and Cologne). (2) Planning of industrial creation projects The following 10 plans for industrial creation projects were proposed, utilizing IoT based in various areas of Japan. 1. IoT agriculture/data-driven agriculture (Kochi Prefecture) 2. IoT fishery (Sendai City, Kochi Prefecture, and Hiroshima Prefecture) 3. IoT forestry (Kochi Prefecture) 4. Regional electronic *boshi-techo* [mother-and-baby notebooks] (Kochi Prefecture) 5. IoT personnel development (Kochi Prefecture) 6. IoT logistics (Yokosuka City) 7. Open data distribution (Sapporo City) 8. IoT snow removal (Izumo City) 9. Distillery x IoT (Izumo City) 10. Sandbox (Hiroshima Prefecture)

Extracted Issues	IoT solutions and IT/ICT solutions, which are the first step of IoT solutions, have not become popular in rural areas of Japan. This is mainly because solutions appropriate for the size of the issues that often exist in rural areas (approximately several million yen per solution) cannot be provided. The causes for such a situation include not only inappropriate business models and corporate structures, but the high cost of solution development due to environments for IoT system development and system architectures which are technically undeveloped. In addition, venture businesses with technical and business ambitions in local areas should be developed and supported.
Future Policy	Issues revealed by this research are clearly tangible in various rural areas of Japan, but it should be noted that they are not the problems of local areas, but the ones of the overall IoT and AI areas, where it is customary to provide a solution optimized for each client. SIP does not cover business issues or business models, but should promote research and development of biosystems architectures and environments for system development, and conduct research centered on system architectures and software engineering. This should include improvement of efficiency of software development, as well as the testing and refurbishing processes required for such development, enhancement of reusability of software, support for deployment management, and high-level development environments and parallel processing languages for distributed systems based on server-edge coordination. All of the tasks above should be promoted through utilization of local technical venture businesses.
Matters to Be Considered	In particular, it is necessary to analyze the number of workforce in the development process of actual products and solutions, and to consider whether horizontal expansion of one solution can be made as close to reproduction of a system as possible (which will reduce the cost to zero), whether the solution can be expanded to various applications, and if not, what is the technical cause, etc., focused on the production process of IoT solutions.

Figure 2-8. Outline of the Research, Issues, Policies, and Matters to Be Considered

Based on the research results, development targets for commercialization of the edge computing platform are shown in Figure 2-9. Vertically integrated systems, which are the most commonly used today, cost tens of million yen, and most CPS are designed for the automotive industry and the infrastructure. However, many companies in Japan are small and medium-sized ones, and few industries can construct a system of this scale. Thus, strategies for commercialization target areas that may be utilized by small and medium-sized companies.

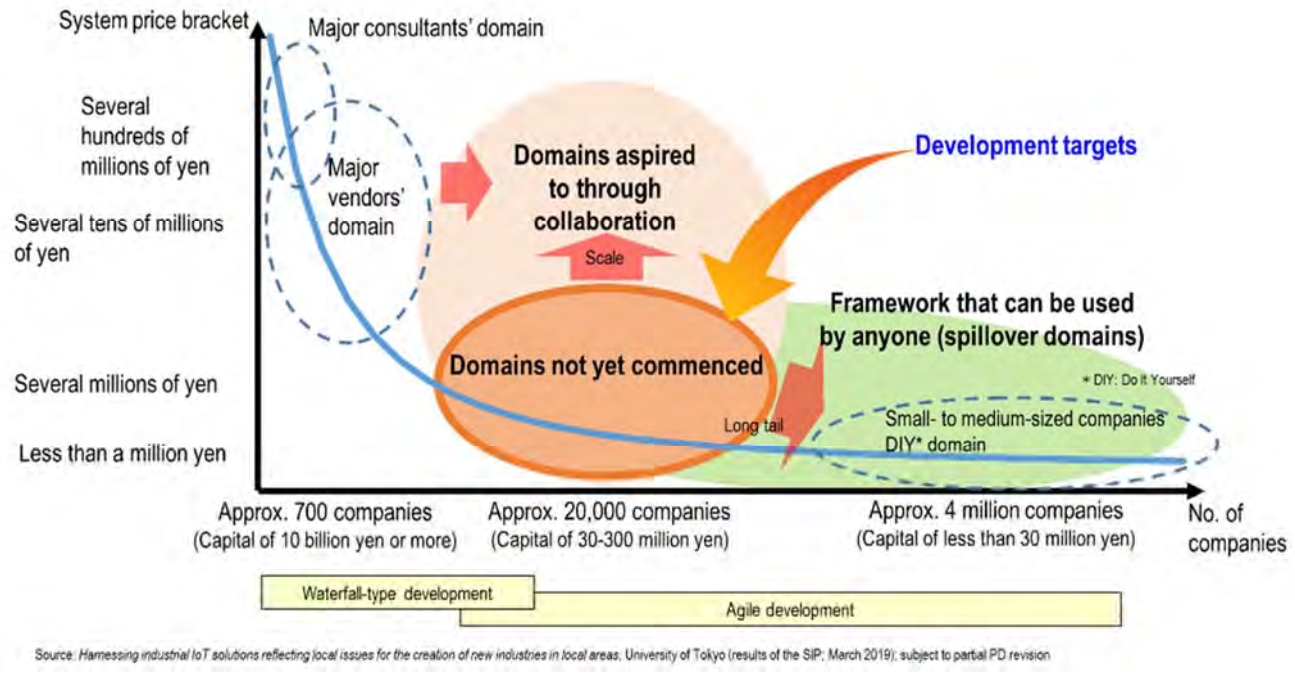

Figure 2-9. Development Targets

In underdeveloped areas, there are a great number of social issues that should be solved toward the realization of Society 5.0. It is important for Japan, which is among the first in the world to face such issues, to have strategies for constructing the edge computing platform in areas where utilization of IT technologies can lead to dramatic solution of the issues, thereby promoting growth in such areas and enhancing international competitiveness. Therefore, on the basis of retrospective deduction from issues in Society 5.0, (1) safety and security, (2) participation of the disadvantaged in society, (3) shortages of human resources, and (4) improvement of productivity due to the decreasing birthrate and aging population, and resulting labor shortage, will be designated as focus areas of social issues, and specific development activities will be conducted (Figure 2-10).

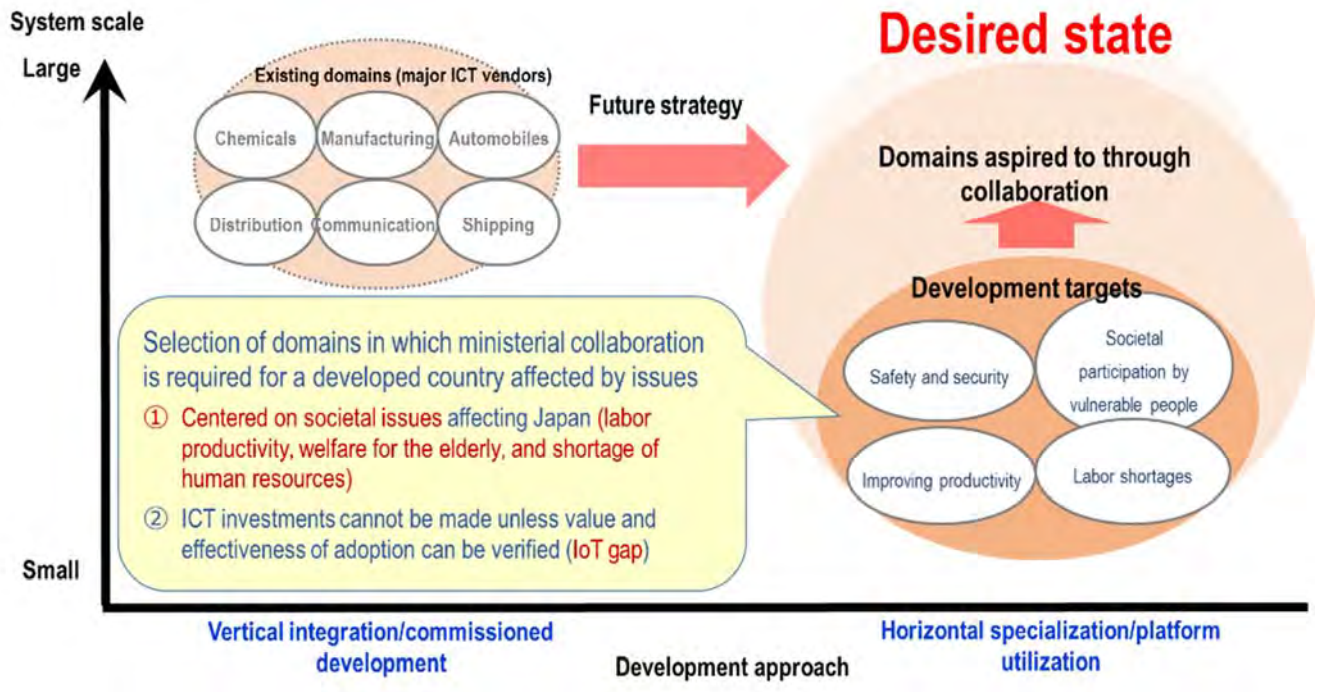

Figure 2-10. Development Targets and Areas to Be Dealt with in Future

Consequently, the overview of the edge computing platform to be constructed by this project is shown in Figure 2-11. The project will be operated on the basis of mutual collaboration of social issues for commercialization as the vertical axis, and technical requirements that are commonly required as the horizontal axis.

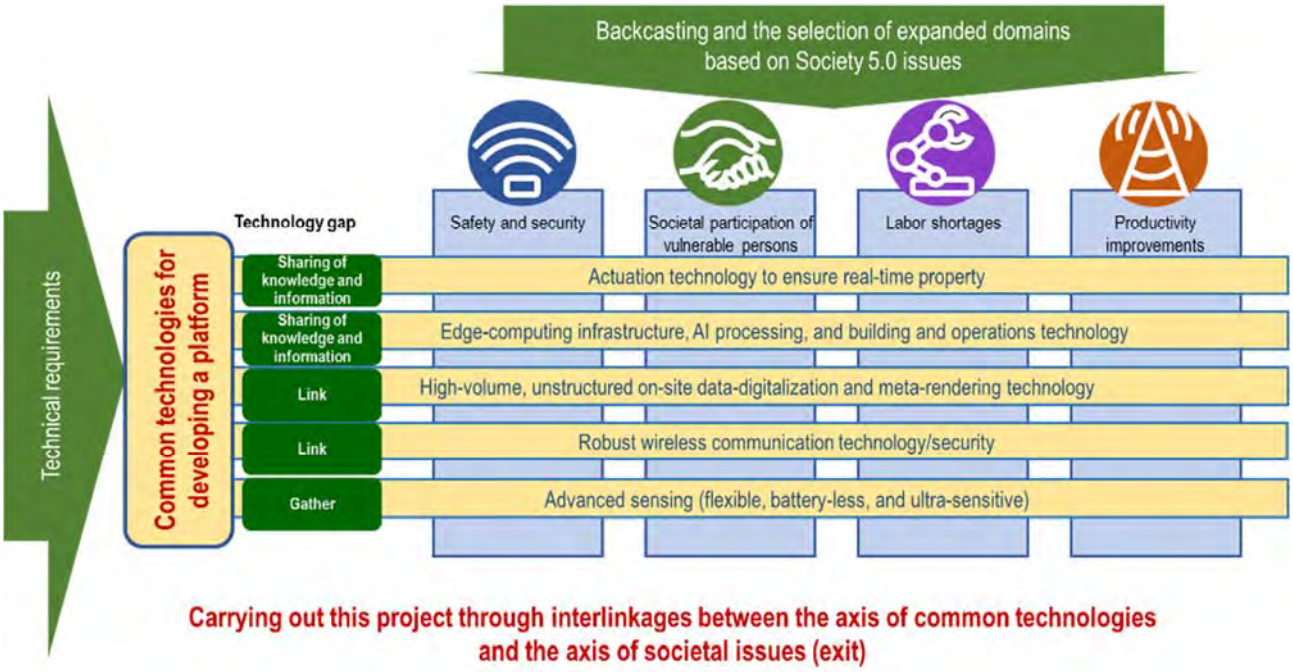

Figure 2-11. Overview of Progress Towards

the Intelligent Knowledge Processing Infrastructure Integrating Physical and Virtual Domains

Commercialization strategies for the research operators participating in this project are shown in Figure 2-12. Each research operator will construct need-driven technologies within the set social issue towards social implementation.

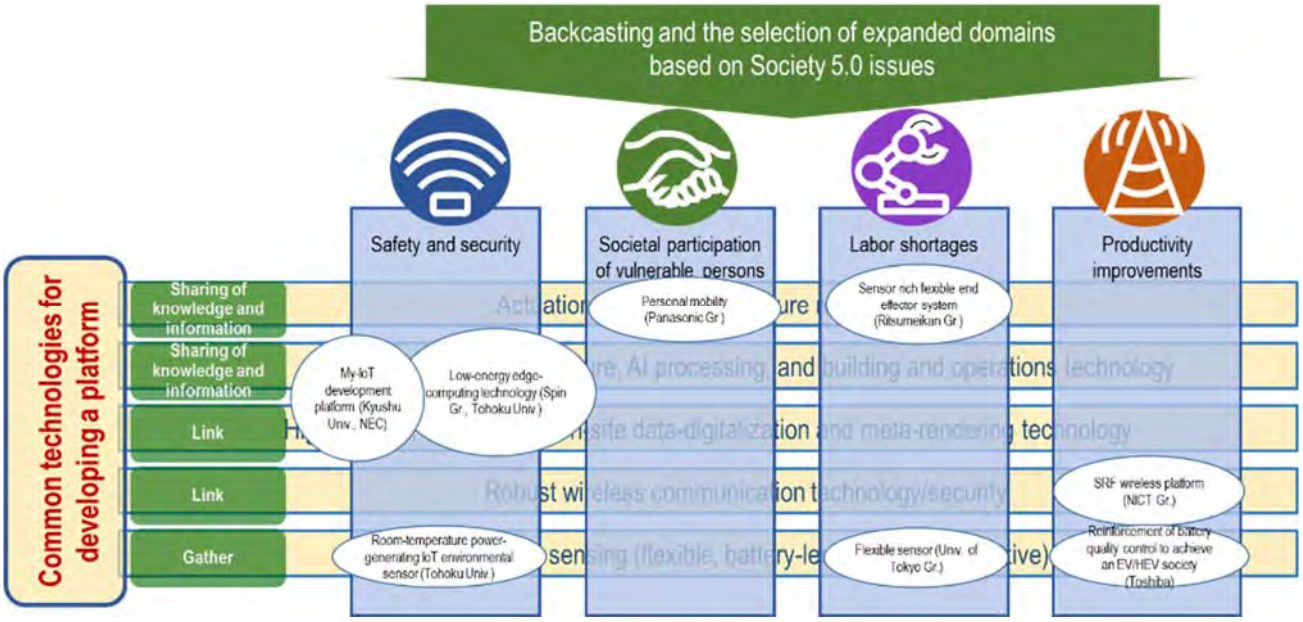

Figure 2-12. Commercialization Strategy Mapping for Technologies/Research Operators

The edge computing platform will be constructed on the basis of a stack of common technologies. Common technologies are centered on (1) real-time actuation technology, (2) technology for processing, constructing, and operating the edge computing and AI, (3) technology for digitizing and overviewing the vast amounts of unstructured data obtained from manufacturing sites from higher perspectives, (4) robust wireless communication technology/security, and (5) advanced sensing [flexible, batteryless, and ultra-high sensitivity] (Figure 2-13).

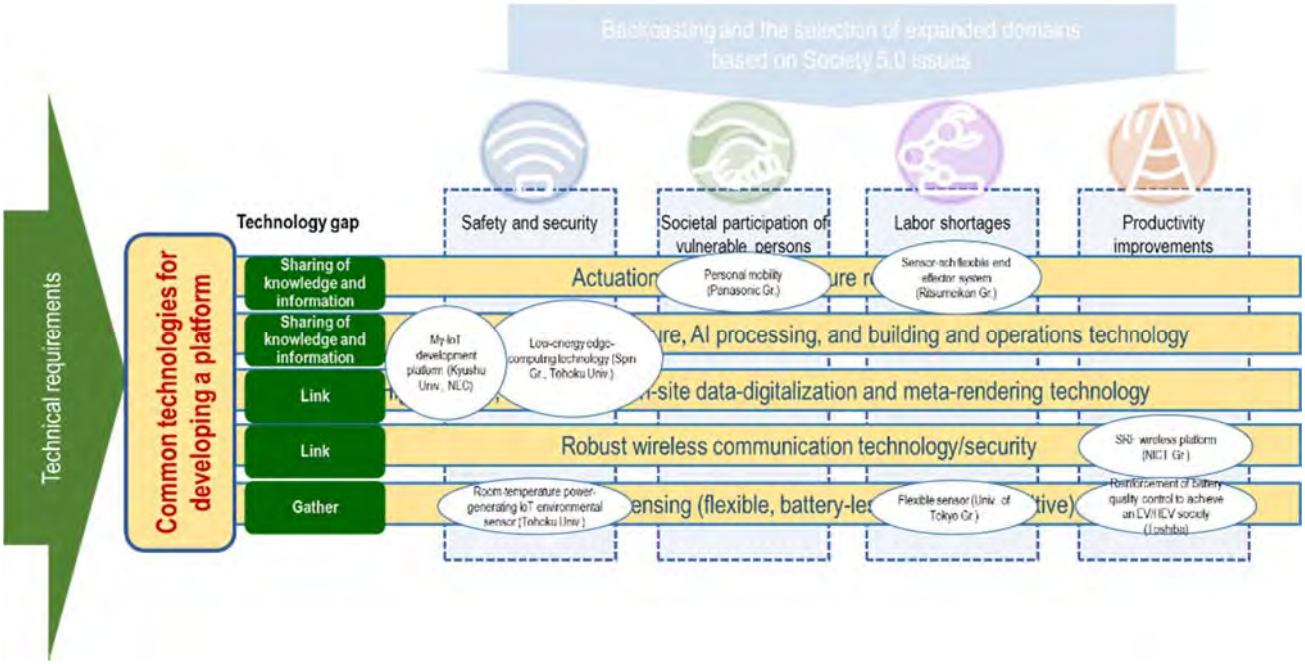

Figure 2-13. Development Technologies/Research Operators

Mapping of the Common Technologies That Constitute PF

Toward the resolution of Japan's social issues, universities located in the region will be designated as the "forum of co-creation" for each subtheme, and will be utilized to apply the edge computing platform to social issues, and to consider social implementation (Figure 2-14, Figure 2-15). Integration with the corresponding SIP issues "Big-Data and AI-Enabled Cyberspace Technologies" and "Cyber Physical Security for IoT Society," and coordination with existing research and development, including PRISM, ImPACT, and the related research and development conducted by government ministries and agencies, are important to the accelerated promotion of this program. Thus, review meetings composed of stakeholders will be held as appropriate to promote collaboration.

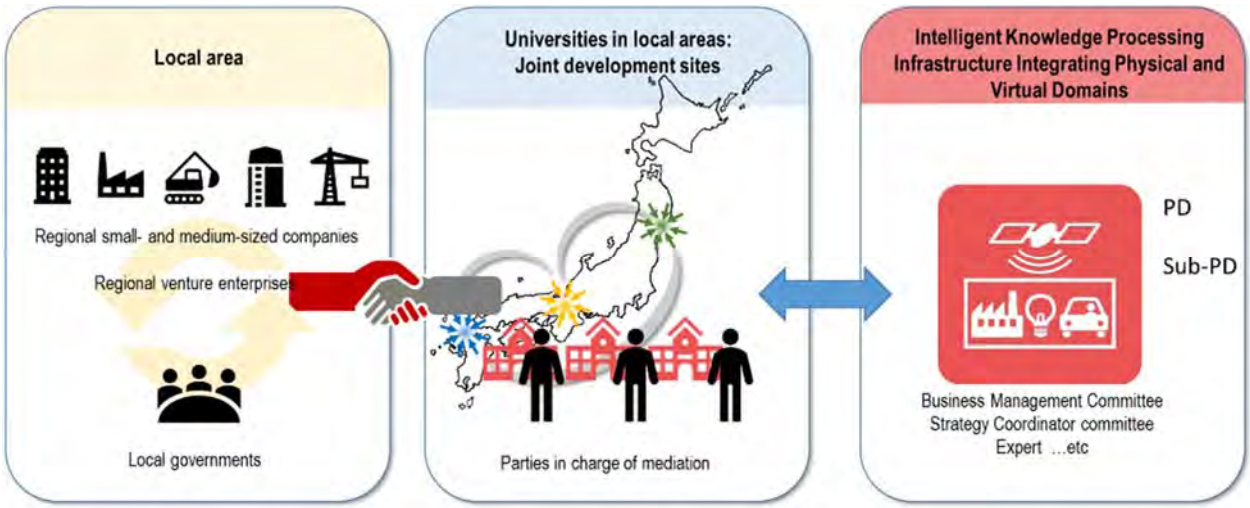

Figure 2-14. Plan for Operations of the Forum of Co-Creation at Universities Located in the Region

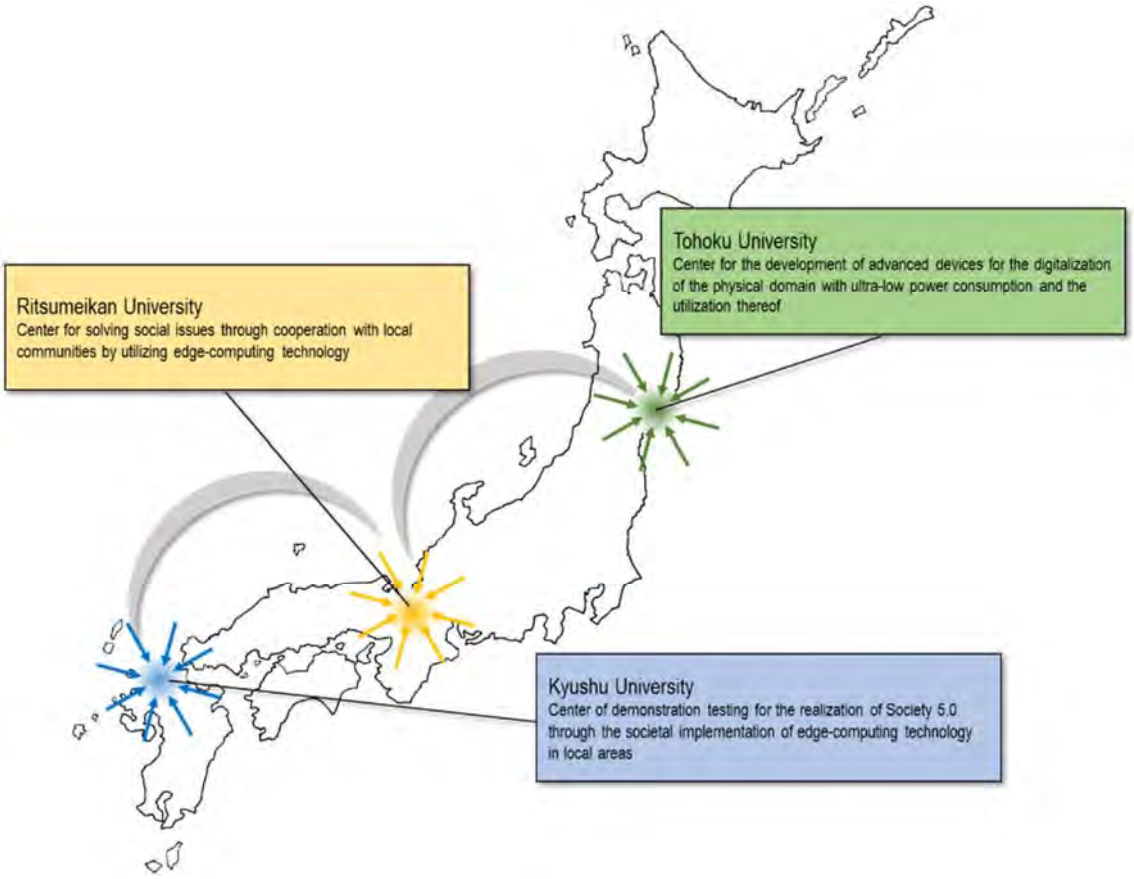

Figure 2-15. Bases for the Realization of Society 5.0 in Local Communities

I. Common Edge Computing Platform Technology to Develop IoT Solutions

Director in Charge of the Subtheme: Koji INOUE (Professor at Kyushu University)

This subtheme is composed of two research and development projects, and the platform strategy working group. Below are the common points and individual descriptions of said components.

Goal of the R&D Subtheme

In the first R&D subtheme, the edge computing platform for realizing and maintaining state-of-the-art CPS will be developed. Specifically, we will develop the technology for collecting vast amounts of diversified information in physical space (while concurrently performing control via sensors) with small near-sensor computing resources, within the required period of time, and digitizing the information to be used for ICT through learning type distributed multi-modal analysis and the technology for reliably connecting, controlling, and coordinating actuators on site in response to requests from cyber-space. We will also develop the technology for stably and smoothly linking many various machines on site through the connection control applied to each site and provide these technologies as the edge computing platform, in combination with technology for making the construction and operation of systems easier.

Currently, most CPS are individually developed to meet specific system requirements, and there are issues concerning the development period, costs, and human resources. One of the purposes of the edge computing platform is to automate or semi-automate (to the extent possible) specialized IT professionals' know-how on how to use sensors, etc., effectively, and the tasks required for construction of IoT solutions, and to provide such and other know-how to Japanese companies in various industries, thereby enabling them to easily construct CPS. Consortiums, etc., will be constructed for continuously maintaining, updating, and providing the edge computing platform even after completion of this research, which will make efforts to increase opportunities for Japan as a whole (including small and medium-sized companies and venture businesses) to enter new businesses using CPS, and expand the scope of application of CPS.

Utilization of incorporated OS that works with small computing resources will realize the real-time processing of the entire edge computing platform. Furthermore, in addition to general-purpose devices, and the results of related projects of various government ministries and agencies, the technology for low-energy IoT devices having an interface developed in the second R&D subtheme, and innovative sensor technology, will be flexibly incorporated into the edge computing platform to enable deployment to the third R&D subtheme.

For the systematization of the edge computing platform which is essential to social implementation, this R&D subtheme requires (1) mapping of physical space (the technology for appropriate digital analysis of physical space to generate situation information [context] of the physical space), (2) coordination with cyberspace (the edge computing platform technology for implementing coordination of cyberspace and physical space, aiming at real-time processing), and (3) facilitation of construction, deployment, and operations (realization of schemes to encourage IT professionals to utilize the edge computing platform in various layers), as shown in Figure 2-16.

(1) Mapping of Physical Space

The task of collecting human behavior/status and the condition/status of things in physical space, analyzing the information from

diversified and integral perspectives via algorithm, and digitizing it to enable the condition of physical space to be accurately sensed and utilized for ICT (mapping) will be achieved.

In this R&D field, we will develop a device for collecting sensor information, a gateway for aggregating information from the device in the cloud, middleware for analyzing data at the edge, and an interface for accessing cyberspace. Functional blocks will be individually developed in mutual close coordination.

(2) Coordination with Cyberspace

The task of providing functions for identifying IoT equipment and others in physical space, in response to requests from cyberspace based on mapping of physical space, and for translating and transmitting the requests from cyberspace (coordination) will be achieved.

In this R&D field, we will develop an interface for accessing cyberspace, middleware for identifying devices in response to requests from cyberspace, a gateway for transmitting information from the middleware to the device with immediate responsiveness, and an interface module for translating and transmitting the received information to an actuator and others. Functional blocks will closely coordinate with one another.

(3) Facilitation of Construction, Deployment, and Operations

In an attempt to support efficiency, acceleration, and cost reduction of social implementation, a framework for facilitating utilization of the edge computing platform will be provided. Furthermore, hardware and software, which will serve as the foundation for development and deployment toward the realization of (1) and (2), will be constructed.

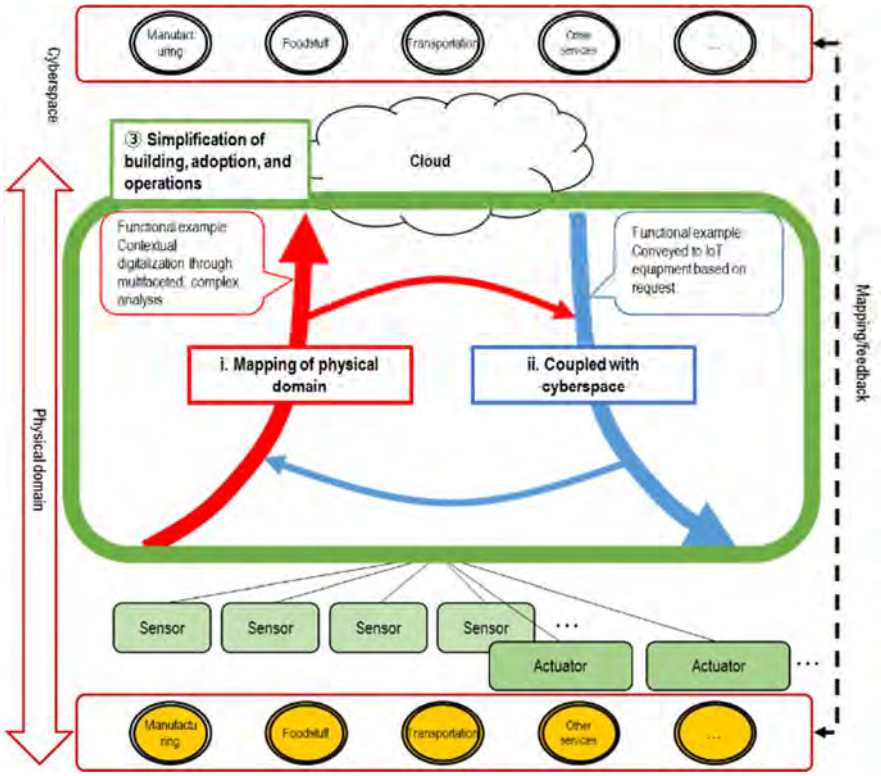

Figure 2-16. The Overall Picture of the Common Platform Technology

This R&D subtheme will designate the most advanced edge computing platform in the world as a theme in the cooperation area, and will promote research and development in advance in fields (1) and (2), and will design the edge computing platform which can be utilized by various technicians in field (3). The research operators will work in collaboration and cooperation with the joint ventures and committees mentioned above.

Research Project No.: PI-1

Research Project Name: R&D of My-IoT Platform

Research and Development Manager: Graduate Schools of Kyushu University

Co-Proposer: NEC Corporation

Research Overview: Based on the concept that IoT gaps, which refer to the conflict between the diversity (required by users) and uniformity (required by providers) of IoT systems, are the essential cause for deterrence of distribution of IoT systems, research for solving this issue will be conducted. Thus, a “My-IoT platform” on which users can easily develop and operate their own IoT system will be constructed, and towards the realization and dissemination of said platform, (1) research and development of virtual system architecture, (2) research and development of next-generation edge computing, (3) research and development of environmentally friendly edge actuation, (4) research and development of auto-configuration and development environments of the edge platform, (5) experimentation and verification of application of use cases, and (6) formation and operation of communities will be performed.

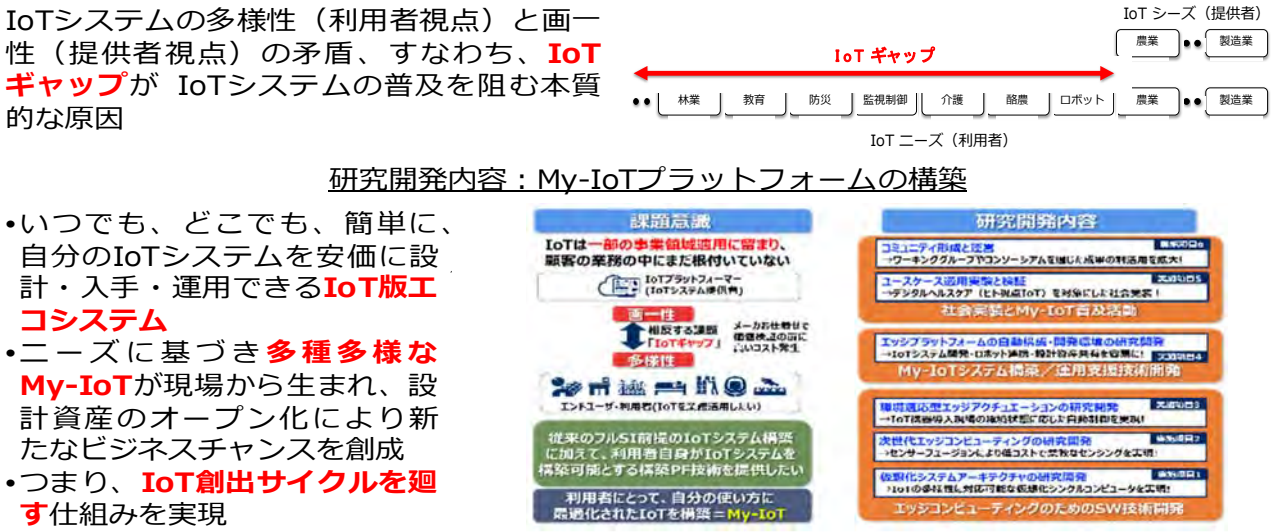

Figure 2-17. Research and Development Overview

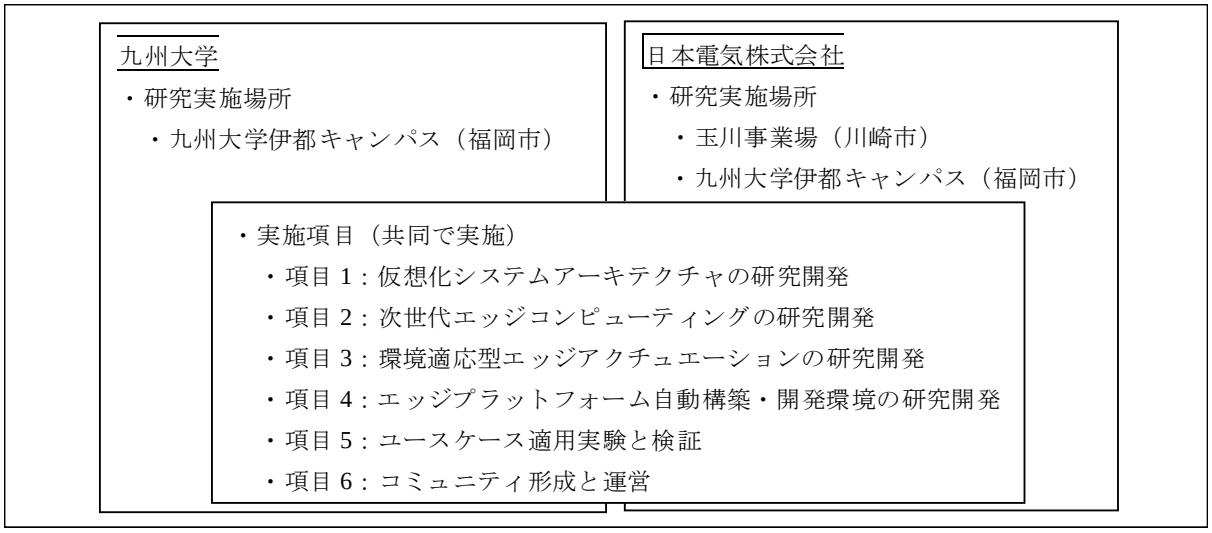

Figure 2-18. Research Organization Scheme

Issues	Present IoT (Internet of Things) systems are either vertically integrated and enclosed by equipment manufacturers with their own products or data-enclosing systems by mega-clouds such as GAFA. On the other hand, although utilization of information from human perspectives (such as human behavior and vital data, and knowledge in small and medium-sized companies) is a pressing issue in Japan, no technologies have been developed for such utilization at a low-cost, and for quickly constructing IoT systems. Thus, it is difficult to convert systems for utilizing collection of data on things mainly at manufacturing sites into collection and utilization of human data in a daily life setting. If no measures are taken, Japan's human data may be directly collected and utilized by GAFA via the smart devices that have become widespread in our domestic market, and the realization of Society 5.0 from human perspectives may be greatly affected. On the other hand, there are a great number of social issues from human perspectives in Japan, such as a decrease of the labor force and an increase of medical expenses, so it is urgently necessary to develop edge construction technologies that are capable of efficiently collecting human data, as well as data on actual environments and things.
Positioning of Research and Development	This My-IoT development platform can be positioned in two ways. On one hand, technologies will be developed for easily constructing an edge system capable of efficiently collecting human-related data, in addition to physical data on things and environments which have been aimed at by the conventional IoT systems. In connection with this technical development, one major objective is to be the first in the world to develop the edge automatic setup technology enabling users who are computer-literate enough to use PCs to construct IoT without employing or arranging for dedicated constructors, and single computer technology (edge virtualization technology) enabling users to effectively utilize their own idling resources as the resource of the edge. On the other hand, if the edge actuation technology that can lead to real-time control on actuators (such as robots and drones) in the real world is developed on the basis of information collected on things, environments, and humans through this edge, IT (information technology) and OT (operational technology) will be able to intrinsically coordinate with one another, using the edge constructed with this edge construction technology as the hub. Completion of this research and development will lead to establishment of an environment in which users can perform demonstration experiments on their own at a low cost, so many users will be able to become demonstrators on their own. Results obtained from such demonstration experiments will not be enclosed in conventional vertically integrated systems, but will be shared worldwide as social knowledge through a mechanism that will be prepared for that purpose. With the aim to work on a pressing issue in Japan, which is support for the socially underprivileged (such as dementia patients and elderly people) and their co-existence with society, focus will be put on "digital healthcare" as a social issue theme to be solved. With commercialization taken into account, with the consent of the subjects and the attendance of third-party experts, the effectiveness of the technologies will be verified through demonstration experiments of the sensing of human vital information, and observing robots.
Advantages	Cloud-side functions for realizing IoT are already provided as PaaS throughout the world, but automatic setup functions have not been provided, and the existing functions do not enhance the efficiency of the edge-side development. In addition, a mechanism for constructing a simple IoT system with a single smart device has not been provided. Construction of IoT systems conventionally requires dedicated equipment, or assumes the use of the cloud as a precondition, so cost reduction is difficult. In contrast, this research and development is original and advantageous because it will deploy the new virtualization technology to respond to the diversity of IoT systems, and to construct an ecosystem for the development and dissemination of an IoT system based on said technology, and its technologies will be easy to personalize. In addition, the promotion of research and development through various demonstration experiments using the university campus, with a better focus on social deployment, will also be a major advantage. [Originality and advantages: (1) cutting-edge virtualization technology, (2) sensor integration technology, (3) environmentally friendly operational technology, and (4) automatic construction technology.]

Others	Results of this research and development will enhance the efficiency of development, deployment, and operation through the deployment and utilization by the “IoT promotion consortium,” which was established to construct the system for developing new technologies based on industry-academia-government participation and collaboration, and other industrial consortia (such as IVI and Edgecross Consortium), and through the utilization in domestic and overseas projects related to IoT and the edge, as well as in local IoT demonstration programs. The results are also expected to contribute to the acceleration of IoT research and development, because the fields where IoT gaps exist are related to various government ministries and agencies. Furthermore, the results are expected to be spread through the formation of communities which are centered on the university.

Figure 2-19. Issues, Positioning, Advantages, and Other Aspects of the Research

[Goals of the Relevant Fiscal Year]

To complete part of the development of the required elemental technologies, and construct part of the prototype system. To establish a working group, and commence activities towards the dissemination of results.

[Interim Goal] (As of the end of FY2020)

To complete implementation of use cases under the existing IoT environment.

[Final Goal] (As of the end of FY2022)

To complete coupling evaluation on My-IoT, complete demonstration experiment cases through use, and confirm the reduction of deployment costs for IoT systems by 90%.

Research Project No.: PI-2

Research Project Name: R&D of Coordination Control Technology for Manufacturing Equipment by Using Smart Resource Flow Wireless Communication Platform

Research and Development Manager: National Institute of Information and Communications Technology

Co-Proposers: Sanritz Automation Co, Ltd.

Mobile Techno Corporation

NEC Corporation

Research Overview: Systems for making mutual coordination of manufacturing equipment adaptive and smooth by using the “Smart Resource Flow (SRF)” wireless platform. This is the technology for optimizing wireless communication within space, which will be developed in manufacturing areas through realization of feedback based on information collected with IoT equipment on the assumptions of actual production lines, toward the realization of an internationally competitive CPS.

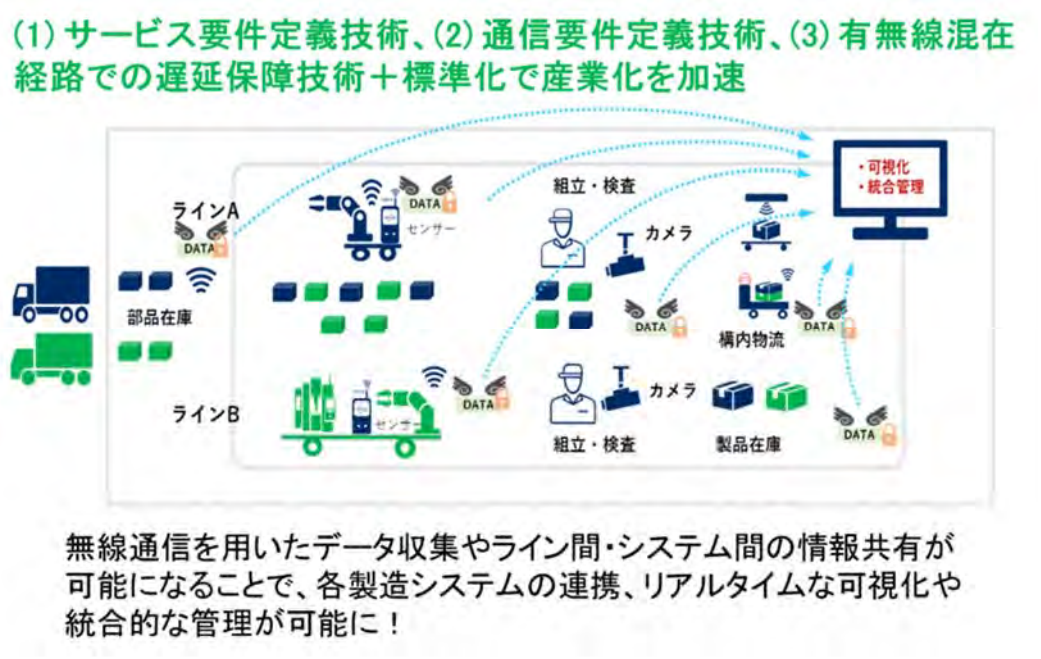

Figure 2-20. Research and Development Overview

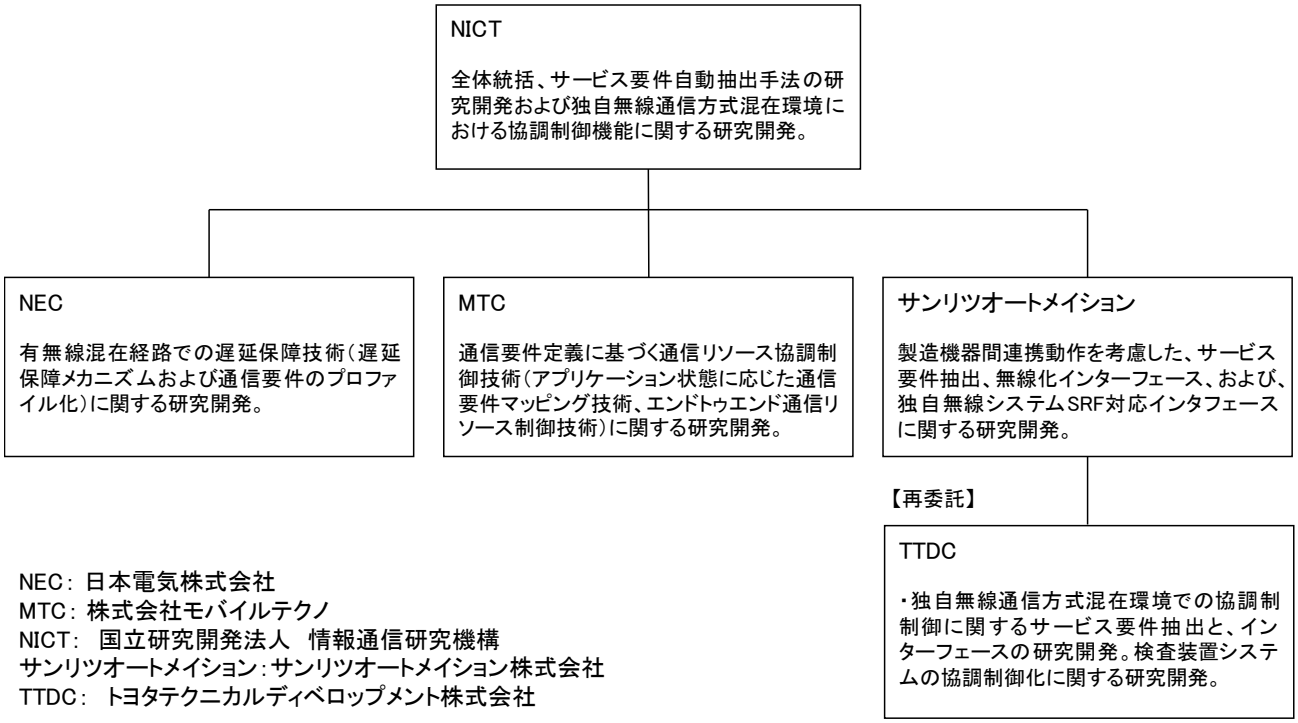

Figure 2-21. Research Organization Strategy

Issues	At manufacturing sites, there is a mix of old and new machinery of various generations and types, and production lines are frequently modified due to the recent trend of high-mix low-volume production. Thus, there are high hopes for utilization of wireless communication technologies for information collection and control required in IoT solutions, especially wireless communication technologies in the bandwidths for which no license is required. On the other hand, data delivery within the delay time that each element of manufacturing equipment or application permit allows is essential at manufacturing sites. However, the existing wireless communication technologies do not provide users with any guarantee against delay in data

	transmission in the bandwidths for which no license is required. This is one of the reasons why manufacturing sites have been slow to deploy IoT. As a result, it is difficult at the present manufacturing sites to share information that is useful for improvement of productivity in each line, and to perform real-time visualization and integrated management.
Positioning of Research and Development	• Coordination, real-time visualization, and integrated management of different manufacturing systems will be realized through the realization of data collection via wireless communication at manufacturing sites, and information sharing among the lines. • This research has great novelty in its wireless resource coordinated control for warranting the communication quality (against delay and others) in the unlicensed bands where various communication systems coexist. • Even individuals other than communication experts can easily construct a system by extracting and mapping the communication requirements of the various systems that exist at the manufacturing site. • The technologies to be developed are very practical, not only at manufacturing sites, but also in medical settings and social infrastructure fields, including airports and railways, where wireless communication is anticipated to be deployed in the future. • The technologies can be applied to warehouses, hospitals, stations, airports, etc., as well as to manufacturing sites. Results of this development will be applied to various systems at low implementation costs and low demonstration costs, as a result of the standardization of interfaces, and protocols for coordinating functions. • The risk of instability of wireless communication within systems of vendors selling wireless systems, manufacturing equipment manufacturers, and manufacturing system integrators will be reduced, user expectations will be met, and market opportunities will be increased.
Advantages	• Japan is taking the lead in activities concerning deployment of wireless communication at manufacturing sites and, thanks to promotion of the standardization with this timing, a globally competitive platform will be established for the first time in the world. • Developed products will be globally deployed with ease, because they target the bandwidths which are commonly secured for all nations, and can be used with no license. • Interoperability amongst the equipment of different vendors will be secured through the standardization, and the market size will be increased. On the other hand, protection of the core part of wireless resource coordinated control by intellectual property rights will ensure a competitive advantage.
Others	The purpose of the research and development of technologies for effective utilization of frequencies for frequency dense utilization in narrow space (Ministry of Internal Affairs and Communications) is to establish functions for optimizing wireless communication in narrow space such as plants to effectively utilize frequencies, and the research and development of SRF wireless platforms (PF) is being performed. In this research and development, the three technologies required for application of SRF wireless PF to the entire system will be established, which are (1) the method for defining requirements for services that correspond to upper-layer applications, (2) the method for defining communication requirements, and (3) the method for guaranteeing against delay in routes which include a wireless section. The functions of the SRF wireless PF will be completed, and demonstration experiments towards social implementation will be jointly performed. Efforts will be made to achieve commercialization and social implementation without missing market opportunities, in collaboration with the standardization activities of FFPA (Flexible Factory Partner Alliance), a group promoting the standardization, and others, in relation to wireless technologies at manufacturing sites.

Figure 2-22. Issues, Positioning, Advantages, and Other Aspects of the Research

[Goals of the Relevant Fiscal Year]

To create a primary prototype of the function for extracting service requirements with the assumptions of a specific system, and complete verification of the function.

[Interim Goal] (As of the end of FY2020)

To perform partial demonstration experiments by combining the technology for mapping communication requirements, depending on the status of application with the end-to-end communication resource control technology, and to make improvements to solve extracted issues.

[Final Goal] (As of the end of FY2021)

To complete the proposal to the FFPA standards.

[Final Goal]

The world’s first platform capable of reducing the development period or cost of IoT solutions by 90% or more, in comparison with conventional methods, will be developed as the core technology of Society 5.0. Through such development, it will be ensured that Japan’s various industries (including small and medium-sized companies and venture businesses) will use CPS to utilize digitized data to solve social issues, and construct an environment in which new businesses can be created.

II. Technologies for Innovative Sensors and Low-Energy IoT Chips

Director in Charge of Subtheme: Tetsuo ENDO (Director of Center for Innovative Integrated Electronic Systems, Tohoku University)

This subtheme is composed of four research and development projects. Below are common points, and individual descriptions of said components.

[Goal of the R&D Subtheme]

In the second R&D subtheme, technologies for practical application of low-energy IoT chips and innovative sensors will be developed, with the aim of expanding the scope of application of CPS.

Towards the realization of Society 5.0 through the advanced CPS, it is necessary to utilize high-quality data sources existing in the fields of production improvement, mobility, and medicine and nursing care (unique to Japan). For that purpose, it is important to develop devices capable of responding to underdeveloped environments where there is no power supply, or to the situation of manufacturing sites that cannot be understood using conventional sensing technologies. To continuously operate such devices, it is necessary to solve issues connected with social implementation such as reducing energy use on the backend side from obtaining sensor signals until uploading information, downsizing sensors, and practical application of energy harvesting technology.

Thus, in this R&D subtheme, focus will be put on development of low-energy IoT devices and innovative sensors, and basic technical development of uncommercialized new methods will be conducted, with the aim of retrieving data that has not been collected, and utilizing such data at manufacturing sites. The development will include organization of the design environment toward commercialization, and organization of the industrial infrastructure for commercial transition. As for technologies that have, after three years of development, reached the stage where commercialization can be anticipated, operational verification in a production environment (including collaboration with the first and third R&D subthemes) will be conducted toward social implementation, in a close industrial-academia-government collaboration. This research and development will validate results such as the information sensing that has not yet been realized, and the reduction of power consumption required for massive data processing in physical space, to maximize the results, and industrialize the advanced technologies in which Japan has a competitive edge.

Research Project No.: PII-1

Research Project Name: Research and Development of Ultra-Low Power IoT Devices and Their Technical Platform with MTJ/CMOS Hybrid Technologies for Society 5.0

Research and Development Manager: Tohoku University

Co-Proposers: NEC Corporation

Keihin Corporation

Keysight Technologies International Japan G.K.

Research Overview: In this proposal, through the use of the MTJ/CMOS Hybrid technologies in which CMOS technologies are merged with magnetic tunnel junctions (MTJ), using spintronics elements that have been developed by the proposers, every IoT device will be merged not only with the arithmetic processing function, but also with the non-volatile function (the function for retaining information even after power-off) to resolve the conventional dilemma between power consumption and arithmetic processing performance, and the core technologies will be constructed for IoT devices having dramatically low-energy performance (reduction from the conventional ones by 80-90%), which is required in physical space. In addition, core technologies for systemization will be

developed which will facilitate social verification through development of verification examination. This SIP will enable Japan to take the lead in achievement of the great revolution through innovative low-energy IoT devices, thereby contributing to the realization of Society 5.0.

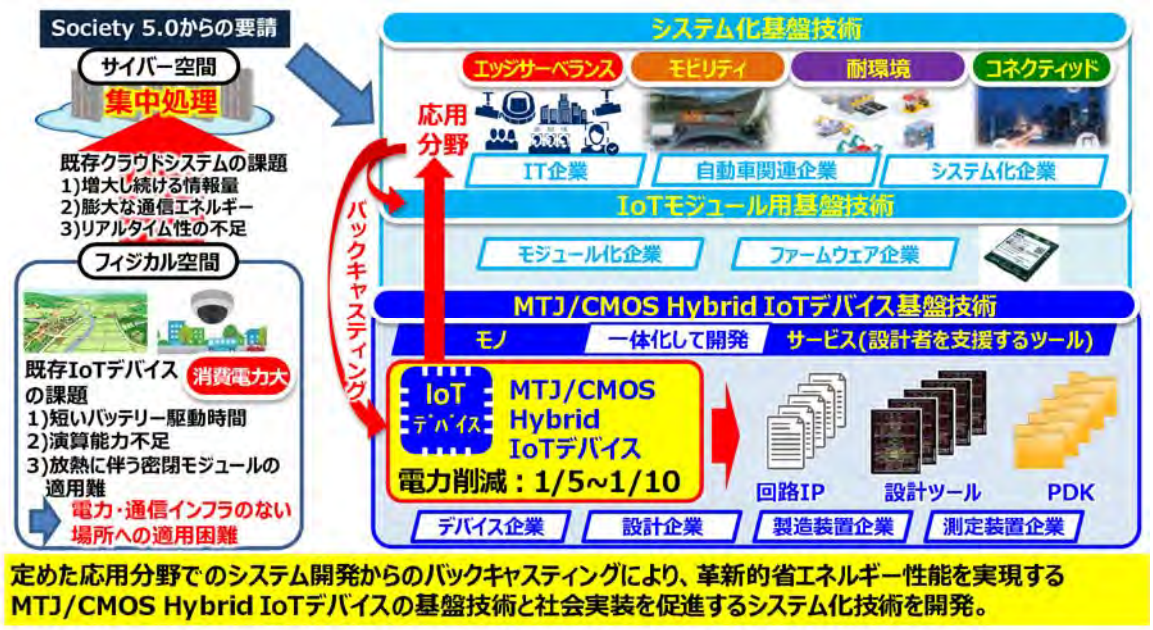

Figure 2-23. Research and Development Overview