# Cross-Ministerial Strategic Innovation Promotion Program (SIP)

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

**July 25, 2019**

**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).

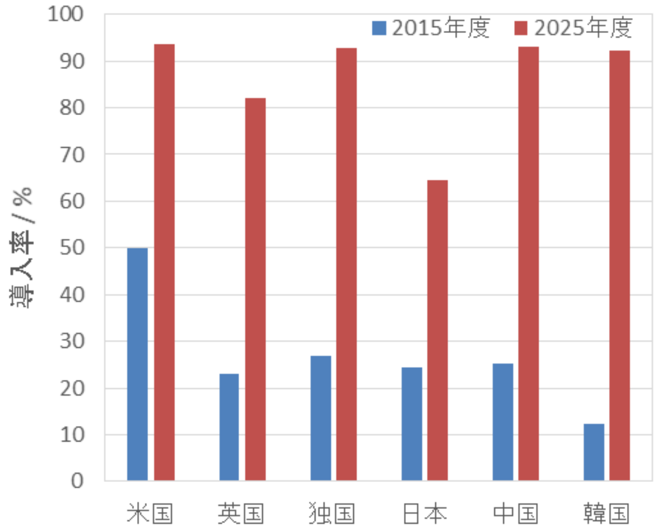


**Figure 1-1. Expected Rate of Companies Introducing IoT Solutions**

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.

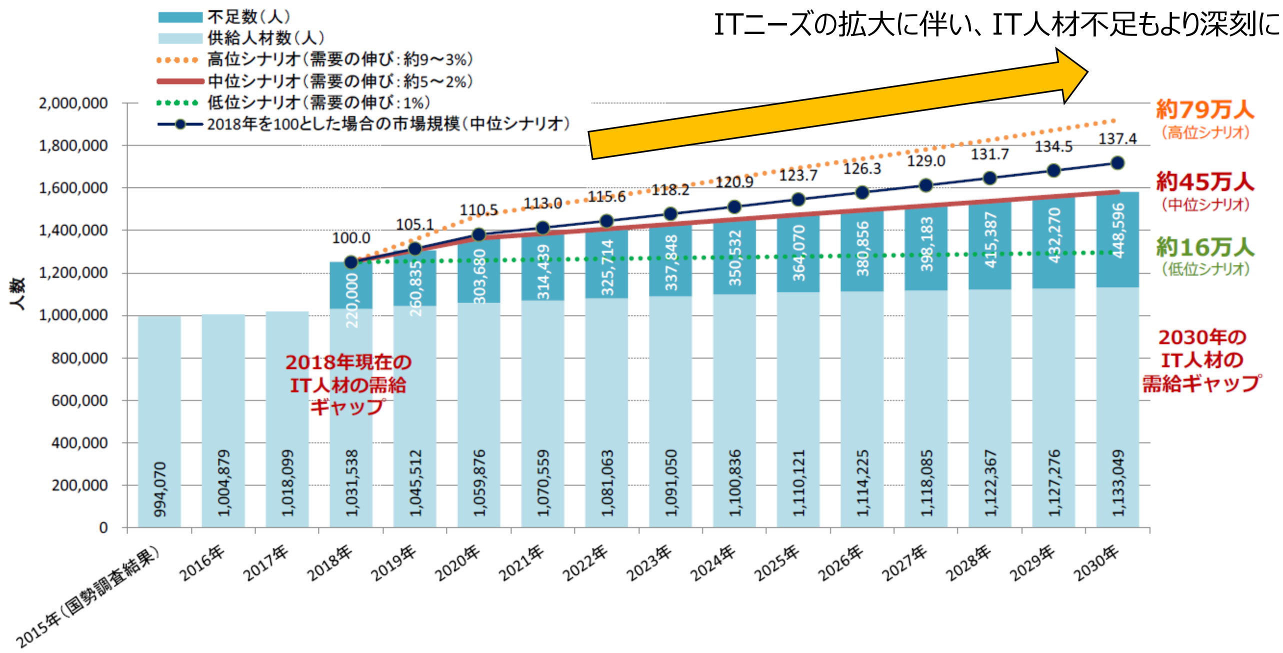


**Figure 1-2. Results of Major Trial Calculations**

**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)

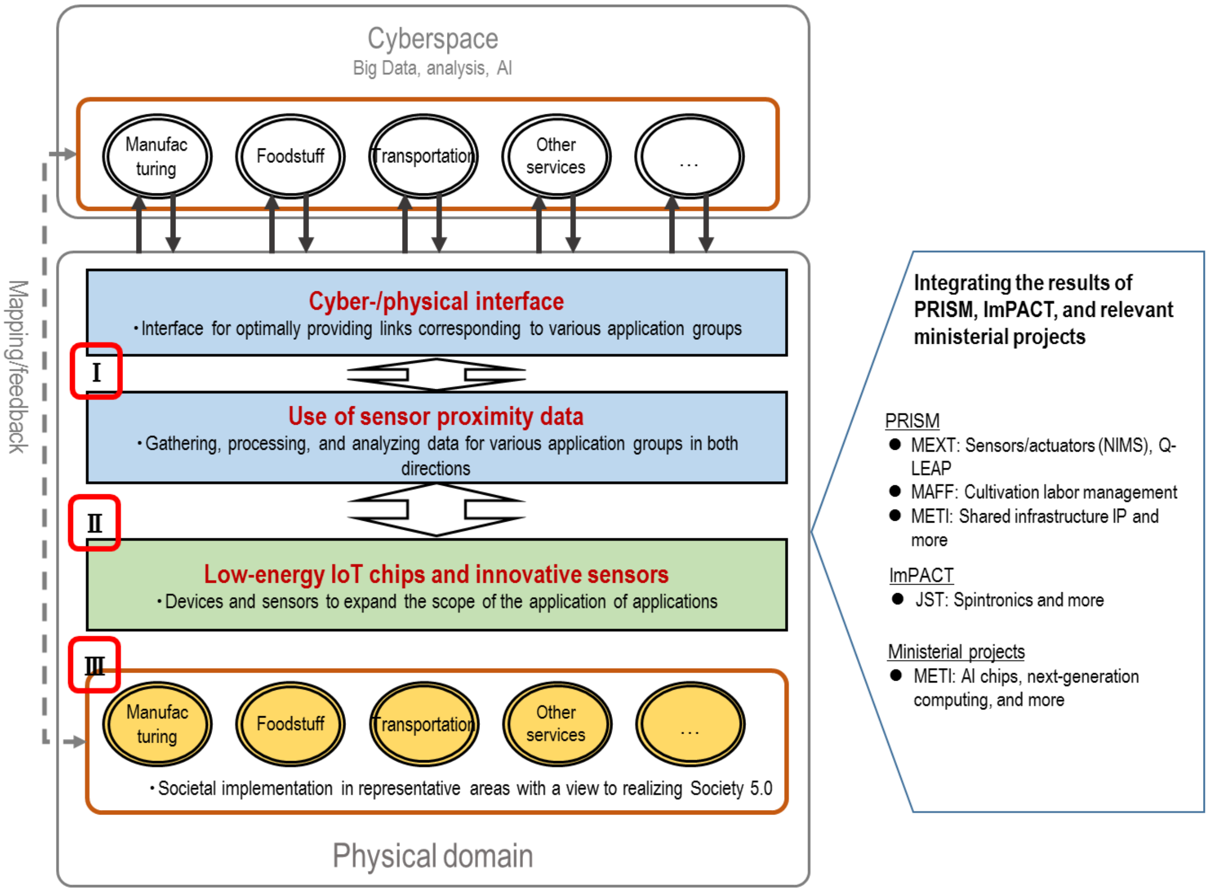


**Figure 1-3. The Overall Picture of the Intelligent Knowledge Processing Infrastructure Integrating Physical and Virtual Domains**

### (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.

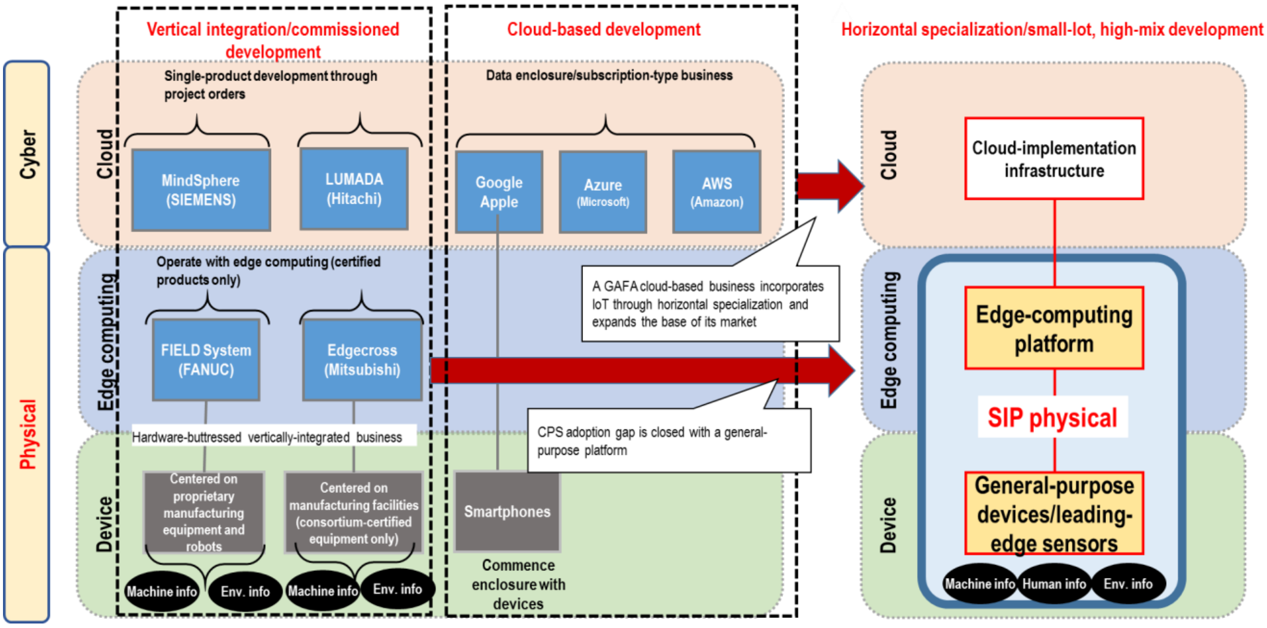


**Figure 1-4. Positioning of the Intelligent Knowledge Processing Infrastructure Integrating Physical and Virtual Domains**

| 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.

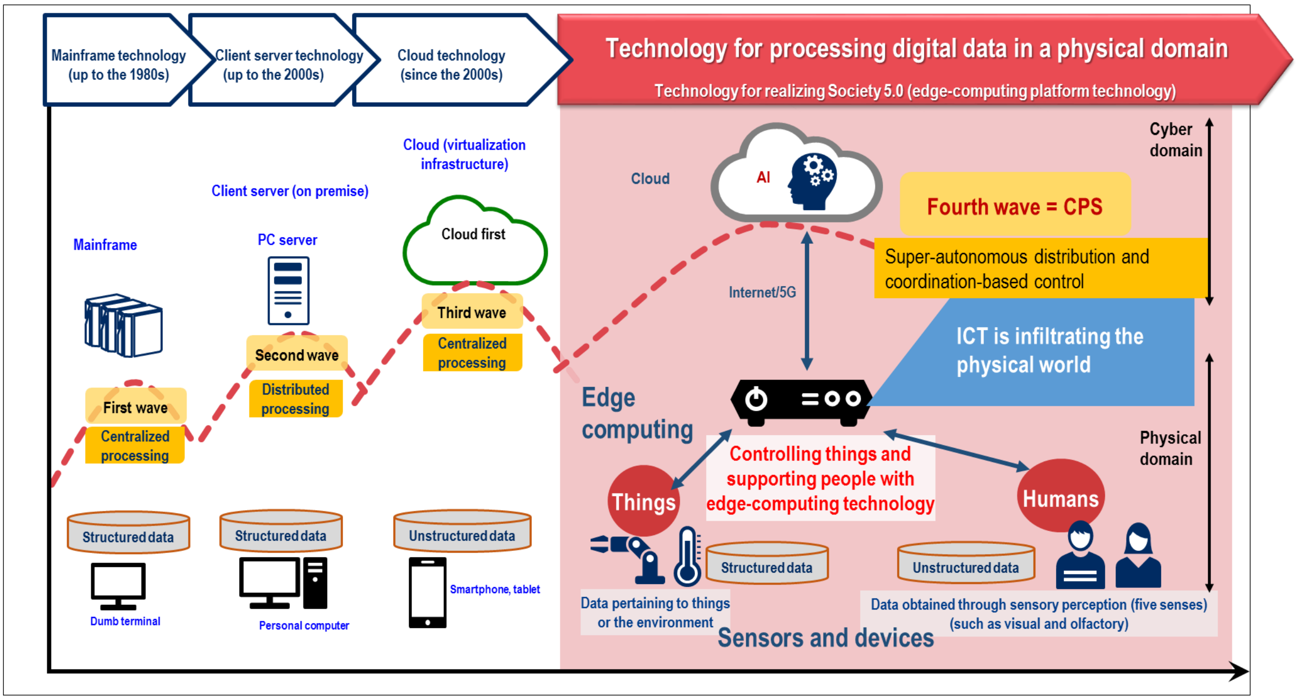


**Figure 2-1. Positioning of CPS Seen from the ICT Perspective**

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.

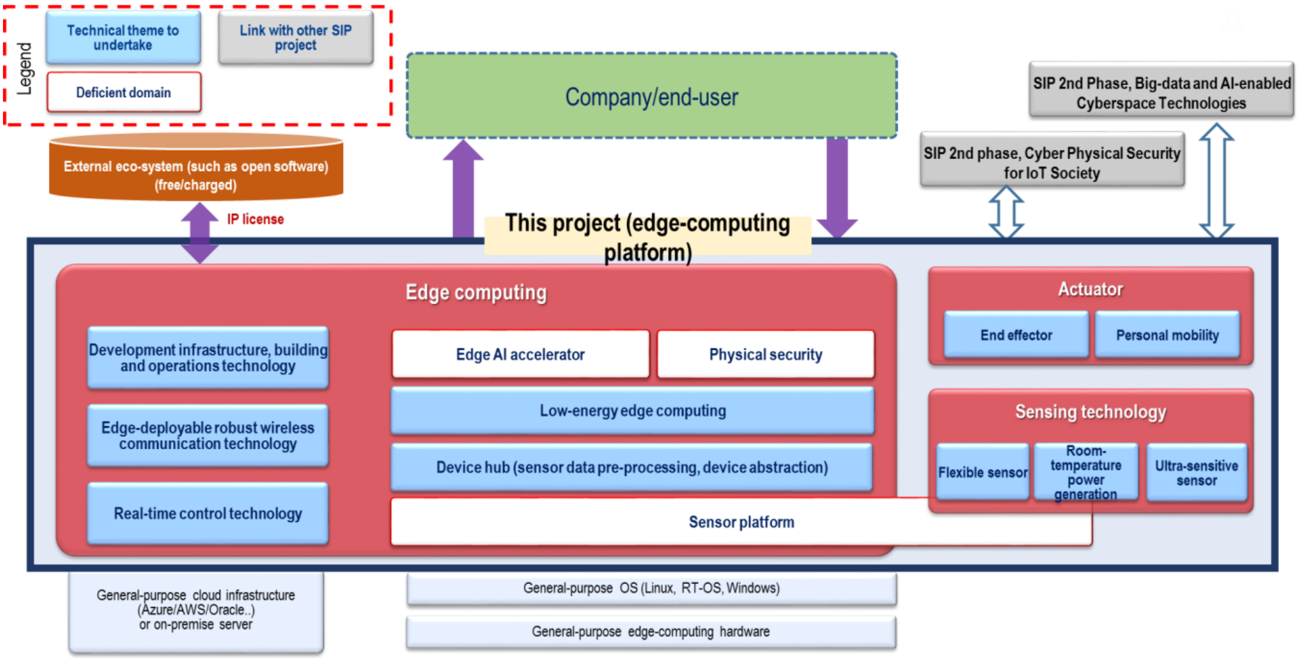


**Figure 2-2. Edge Computing Platform to Be Constructed in This Project**

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.

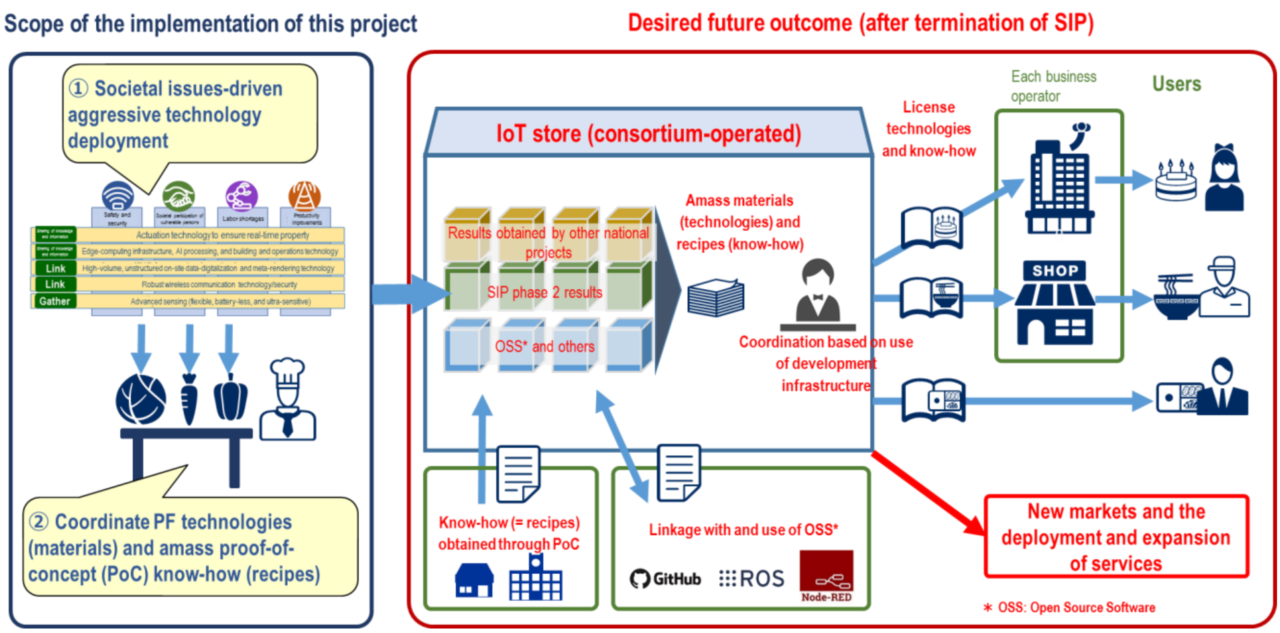


**Figure 2-3. Scheme for Operations, Maintenance, and Utilization of the Platform**

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.

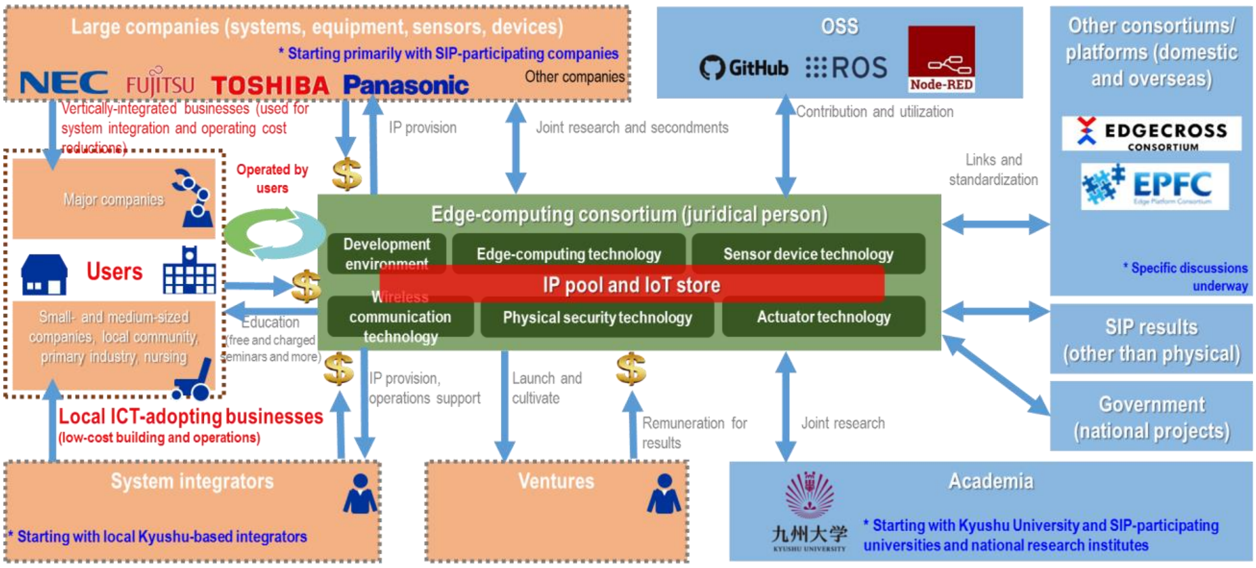


**Figure 2-4. Ecosystem and Business Model of the Edge Computing Platform (Proposed)**

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

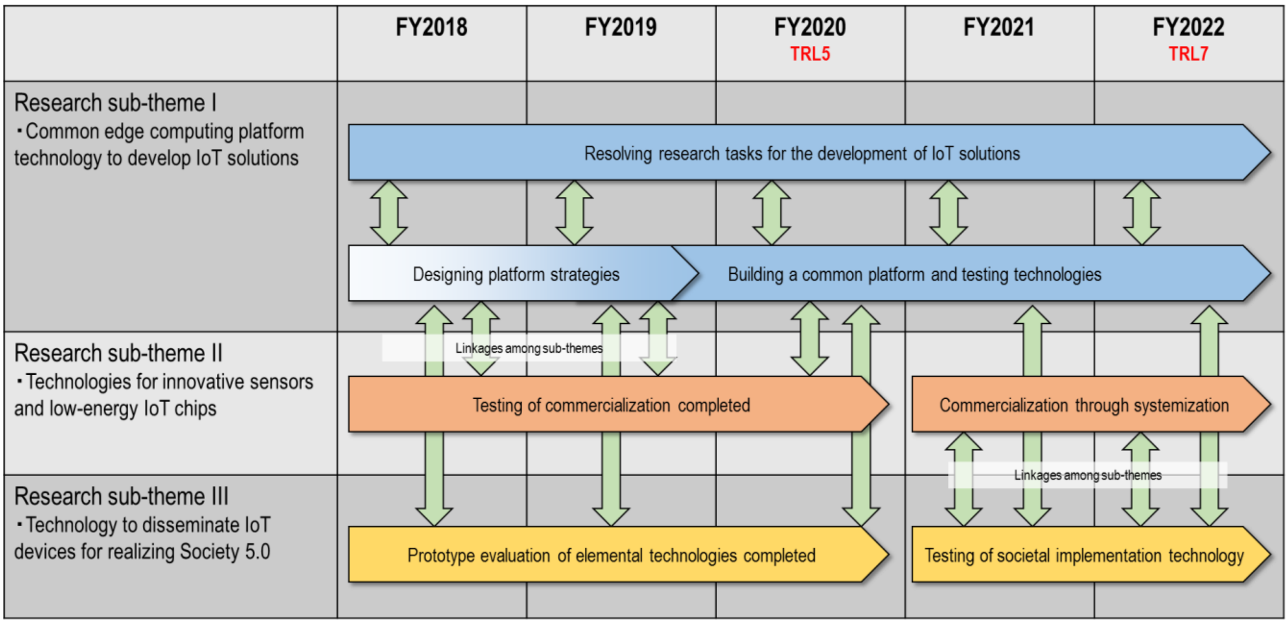


**Figure 2-5. Estimated Timeline for Each R&D Subtheme**

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.

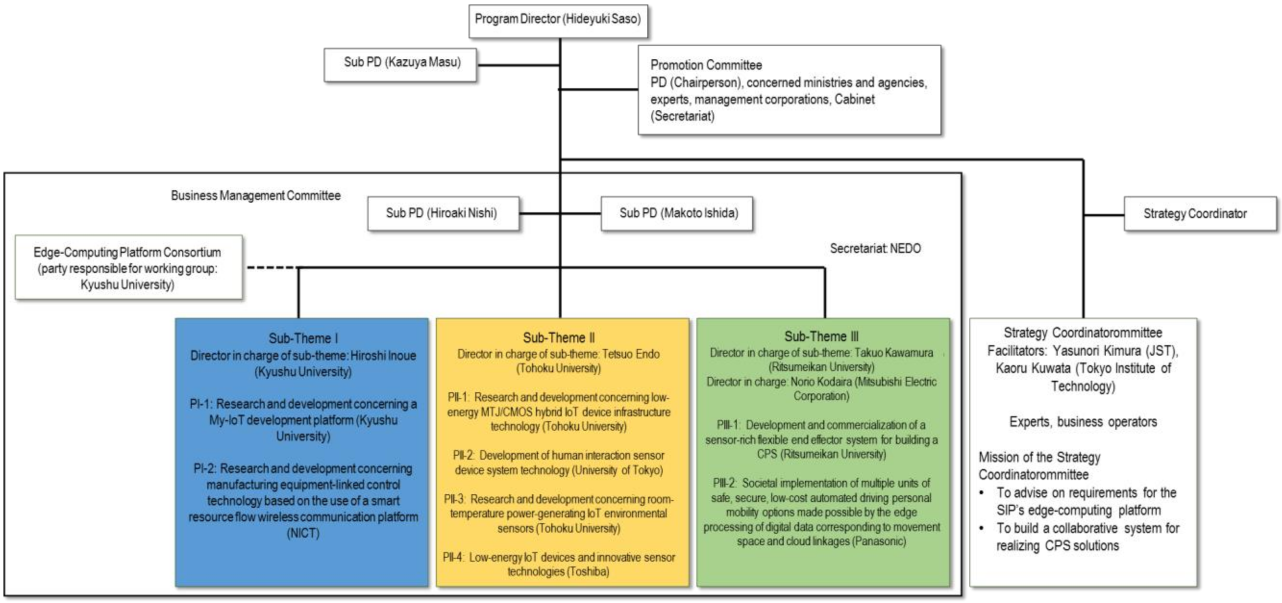


**Figure 2-6. Operation Structure**

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.

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

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.

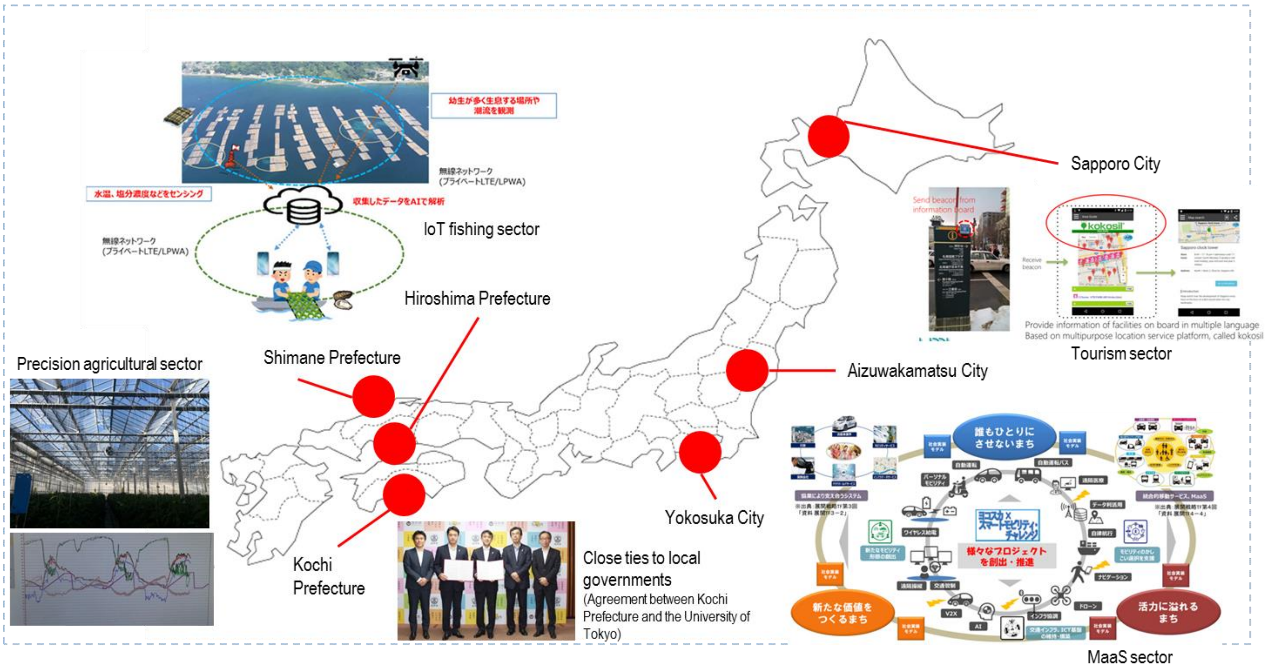


**Figure 2-7. Overview of Industrial Creation Projects**

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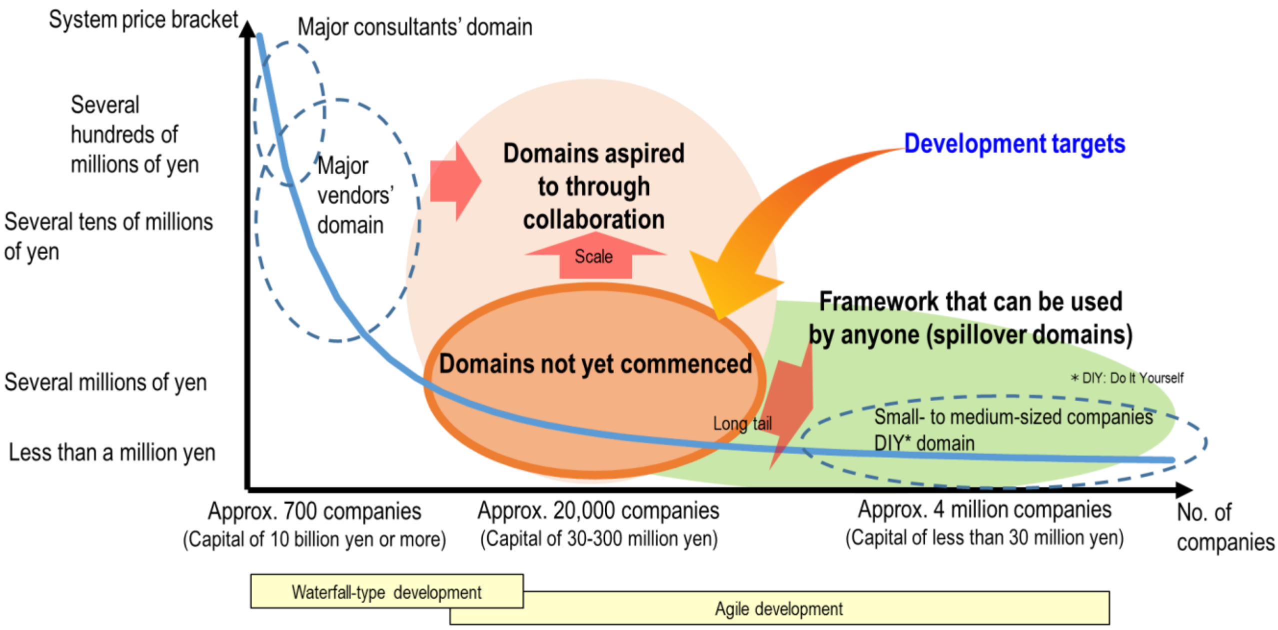
|---|---|
| Research Overview | Results of the research for strategic planning are as follows:<br>(1) Trend research<br>In order to look into industrial creation in local communities using IoT, a literary survey and a domestic survey were conducted (mainly on the regional business creation process in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




Source: *Harnessing industrial IoT solutions reflecting local issues for the creation of new industries in local areas*, University of Tokyo (results of the SIP; March 2019); subject to partial PD revision

**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).

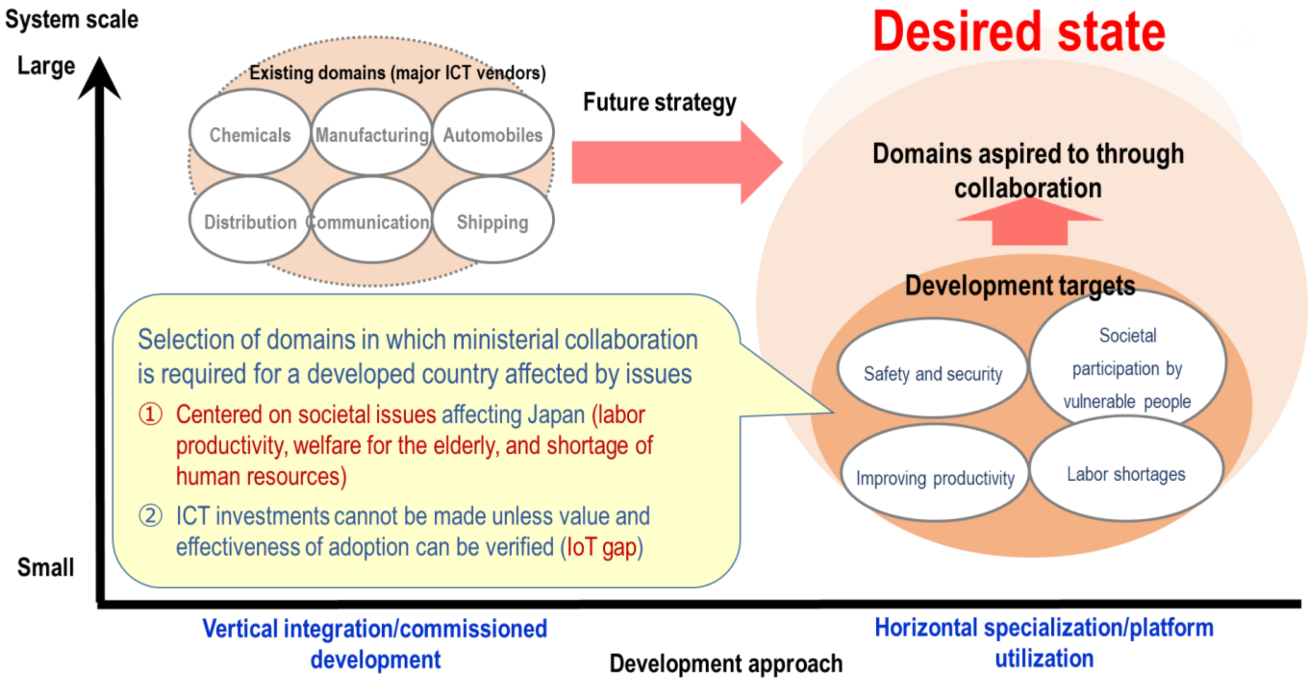



**Figure 2-10. Development Targets and Areas to Be Dealt with in Future**

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.

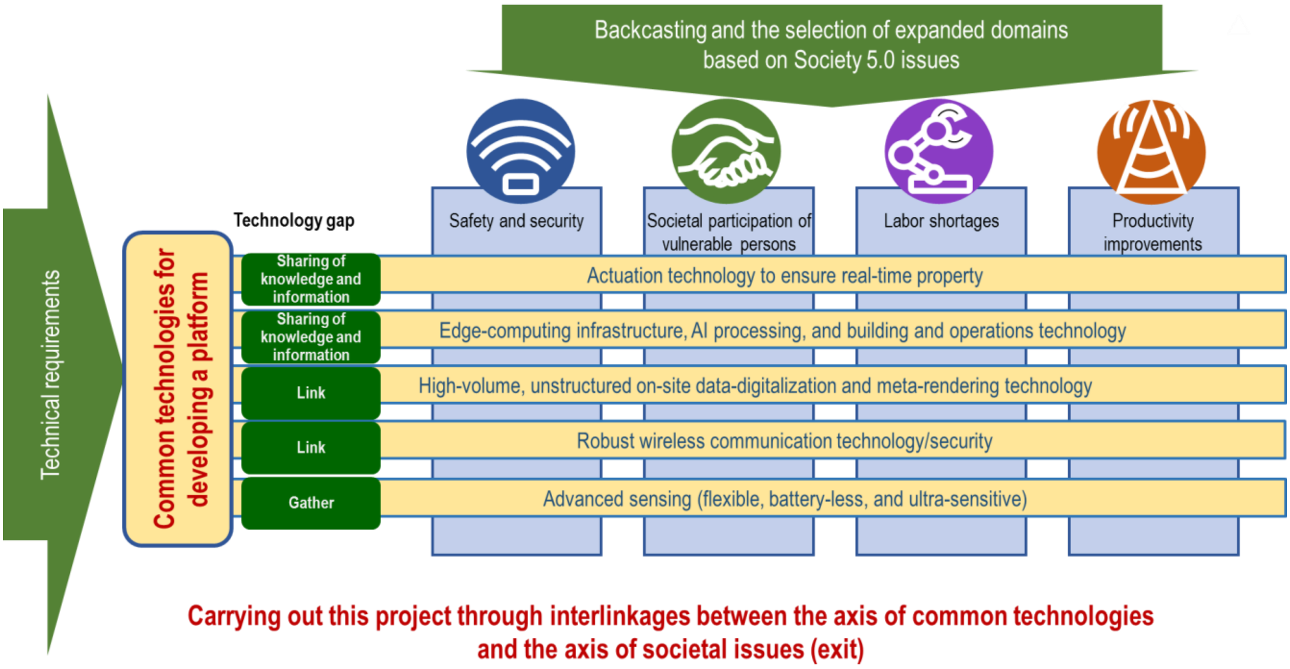



**Figure 2-11. Overview of Progress Towards**

**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.

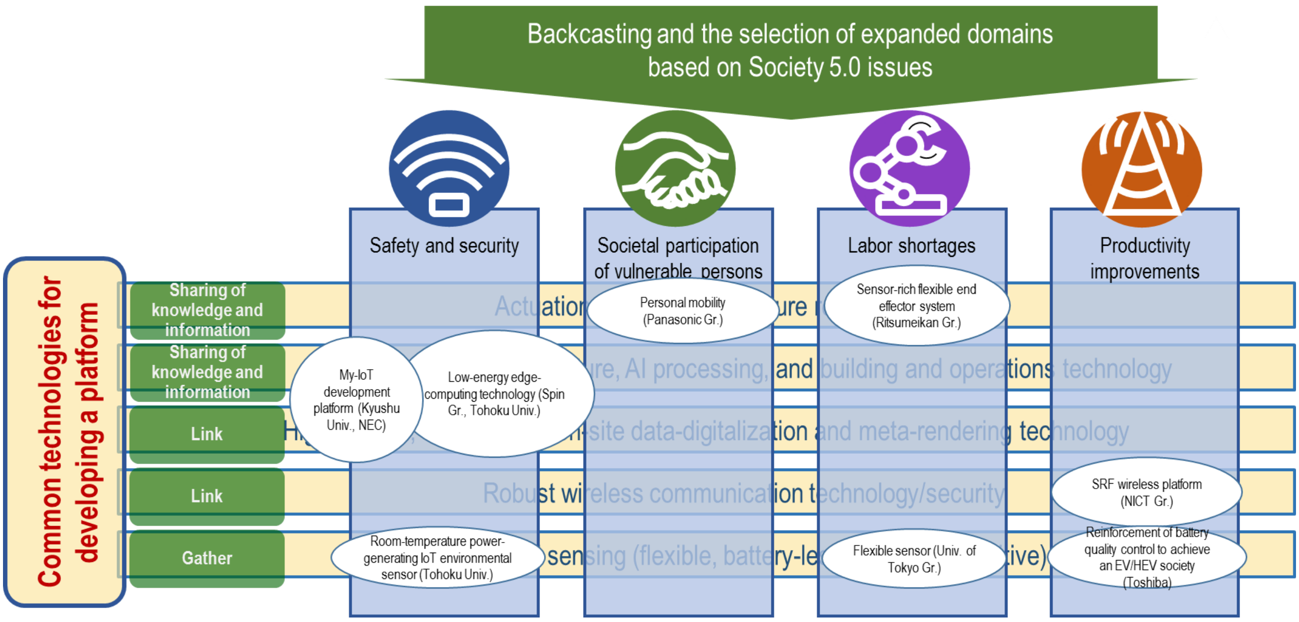



**Figure 2-12. Commercialization Strategy Mapping for Technologies/Research Operators**

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).

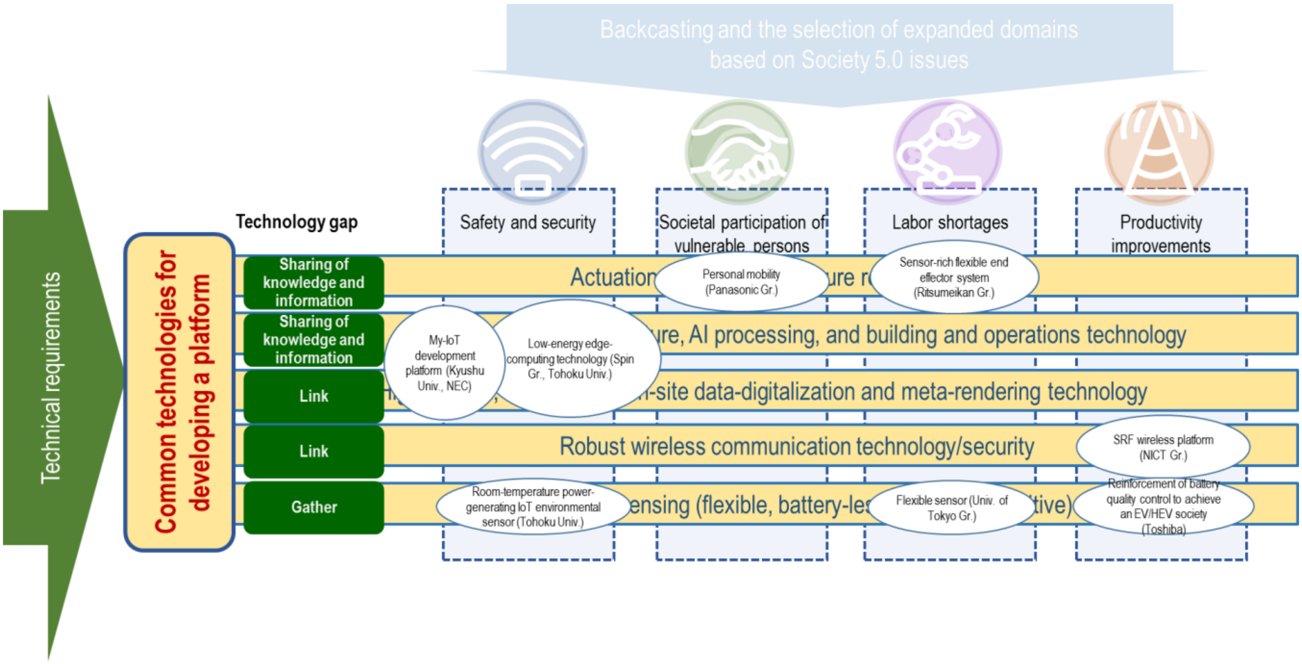



**Figure 2-13. Development Technologies/Research Operators**

**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.

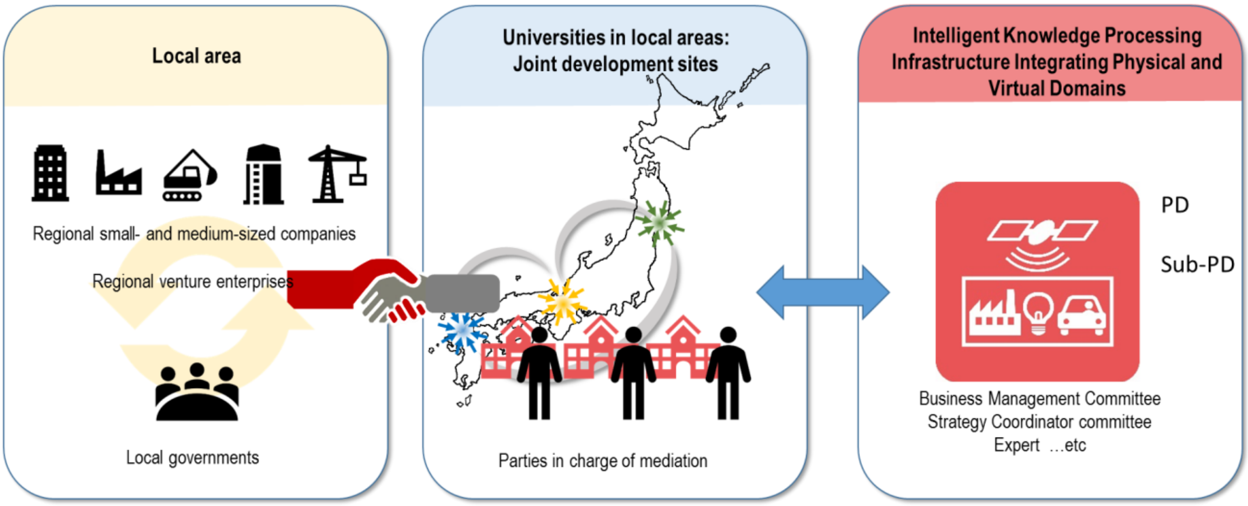



**Figure 2-14. Plan for Operations of the Forum of Co-Creation at Universities Located in the Region**

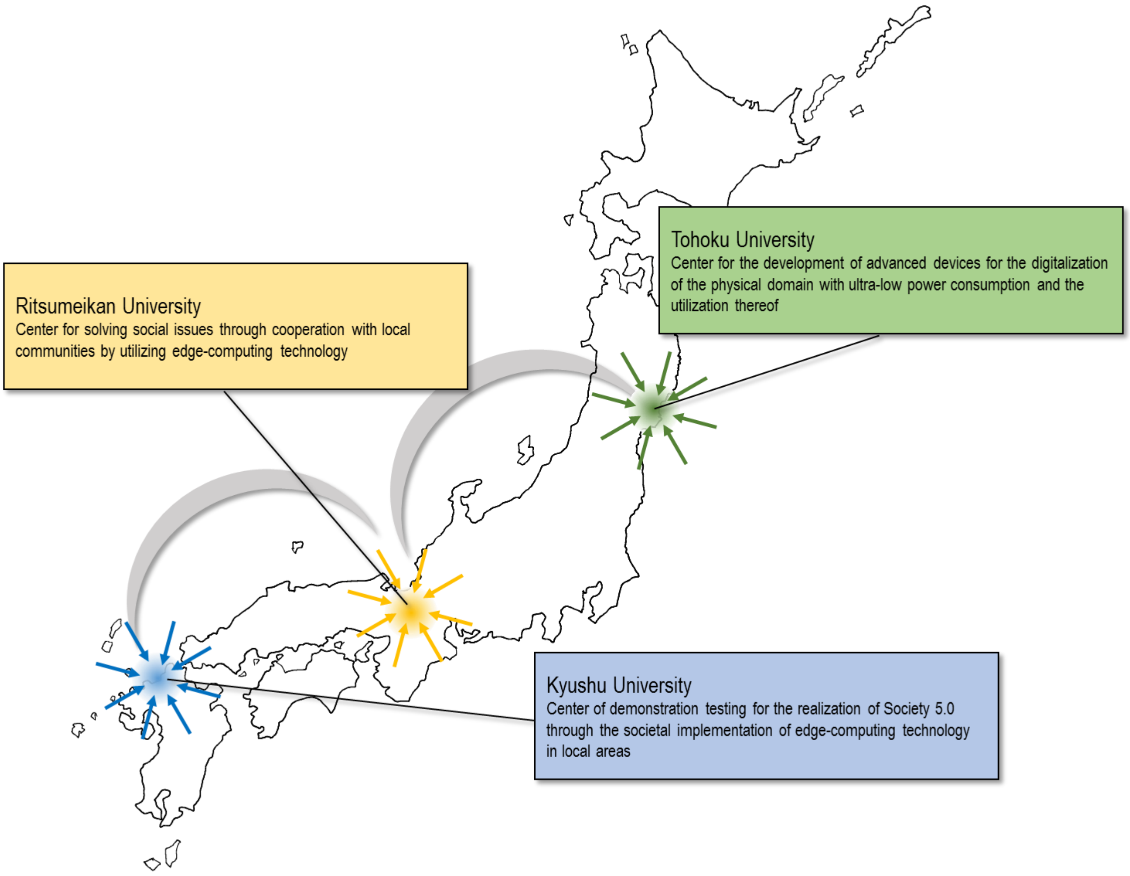



**Figure 2-15. Bases for the Realization of Society 5.0 in Local Communities**

**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.

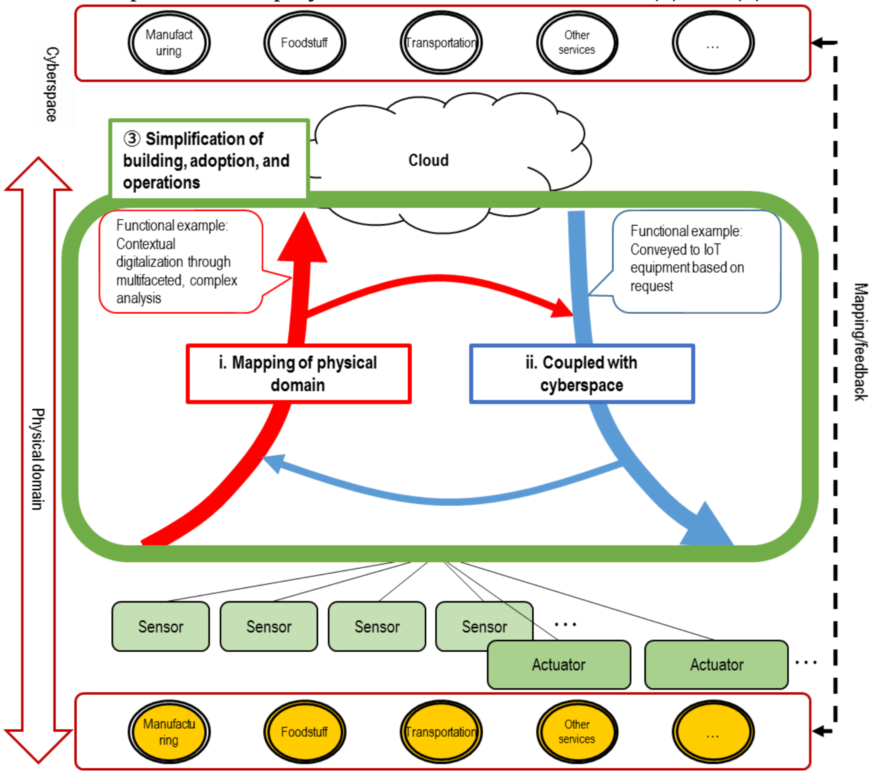



**Figure 2-16. The Overall Picture of the Common Platform Technology**

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.

<u>Research Project No.: PI-1</u>

<u>Research Project Name: R&D of My-IoT Platform</u>

Research and Development Manager: Graduate Schools of Kyushu University

Co-Proposer: NEC Corporation

Research Overview: The contradiction between the diversity (required by users) and uniformity (required by providers) of IoT systems, called the “IoT gap,” makes it challenging to spread IoT technologies. The goal of this research is to solve such an essential issue by introducing and developing the “My-IoT platform” on which users can easily design and operate their own IoT system. Towards the realization and dissemination of the platform, (1) research and development (R&D) of virtualization techniques for IoT systems, (2) R&D of next-generation edge computing techniques for IoT systems, (3) R&D of edge actuation technologies for IoT systems, (4) R&D of auto-configuration and development environment for IoT systems, (5) Use case demonstration and verification of IoT systems, and (6) establishing and operating an IoT community, will be performed.

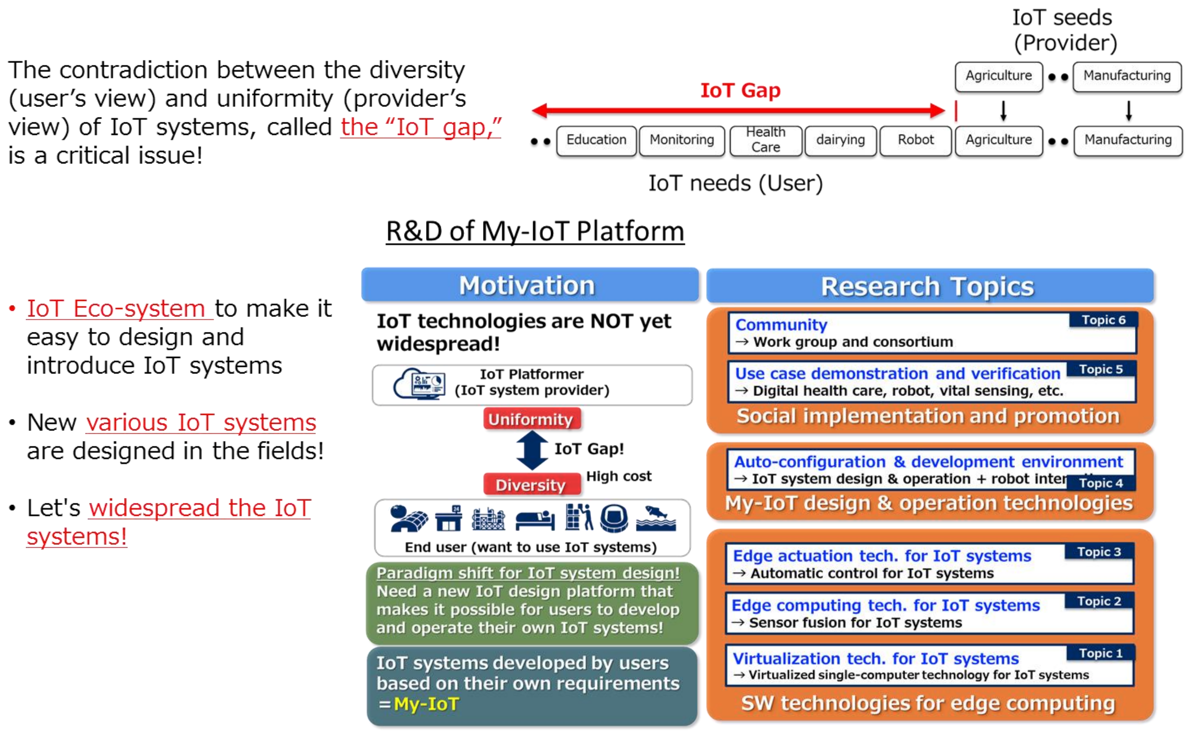



**Figure 2-17. Research and Development Overview**

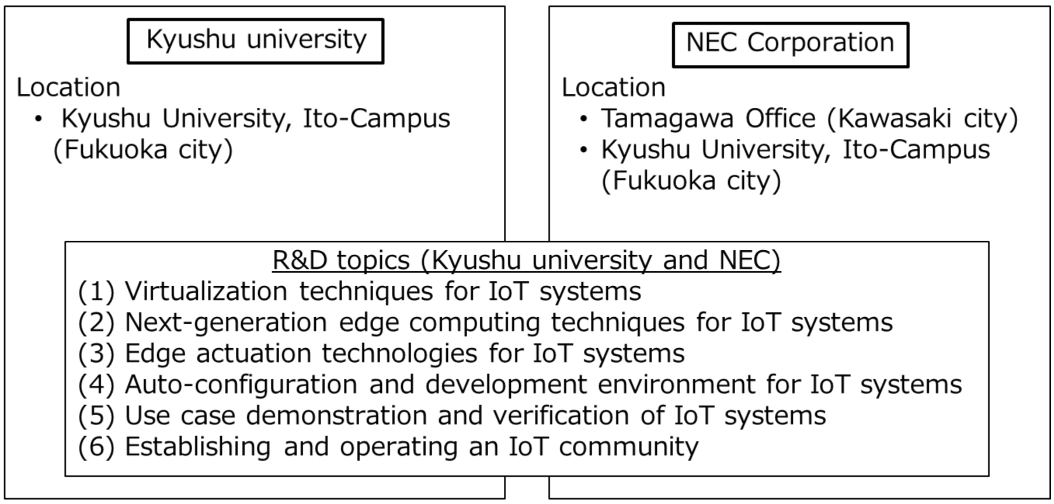



**Figure 2-18. Research Organization Scheme**

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| Issues | Present IoT (Internet of Things) systems tend to take either a vertically integrated implementation style by traditionally manufactured products or a data-driven network implementation style by using mega-clouds such as GAFA. On the other hand, the utilization of information from human perspectives (such as human behavior and vital data, and knowledge in small and medium-sized companies) is an essential challenge in Japan. Unfortunately, no technologies have been developed that make it possible to quickly construct desired IoT systems with a low-cost to improve such information utilization remarkably. Although many methods for collecting and utilizing data have so far been developed in the area of manufacturing, it is difficult to directly exploit (or convert) such systems for personal data collection and utilization. If no measures are taken, they may be directly collected and utilized by mega-cloud vendors via smart devices that have become widespread in our domestic market. The realization of Society 5.0 from human perspectives may be significantly affected. |

| | |
|---|---|
| | On the other hand, there are a significant number of social issues from human aspects in Japan, such as a decrease in the labor force and an increase in medical expenses. Therefore, it is urgently necessary to develop edge construction technologies that are capable of efficiently collecting personal 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.<br>[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 on Coordination Control Technology for Manufacturing Equipment by Using Smart Resource Flow Wireless Platform

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

Co-Proposers: Sanritz Automation Co., Ltd.
Mobile Techno Corp.
NEC Corporation

Research Overview: The system to provide adaptive and smooth coordination controls for manufacturing equipment will be developed by using "Smart Resource Flow (SRF)" wireless platform which is the technology for optimizing wireless communication systems in factory space. In the System, feedback controls for the information collected by IoT devices are performed based on the assumptions of actual production lines, toward the realization of a globally competitive CPS in the manufacturing field.

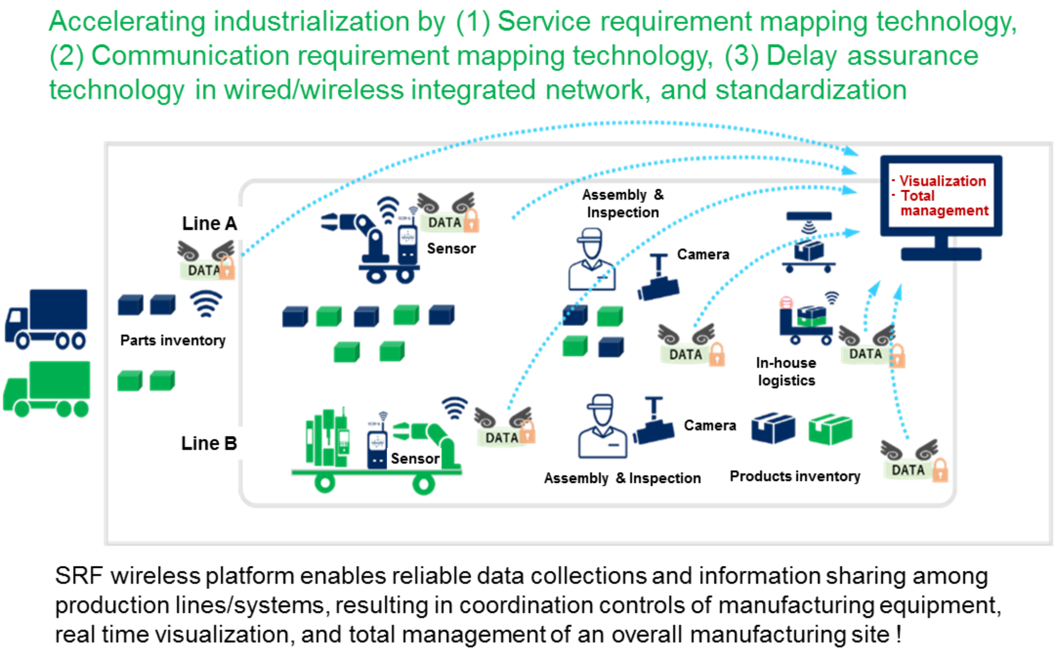


**Figure 2-20. Research and Development Overview**

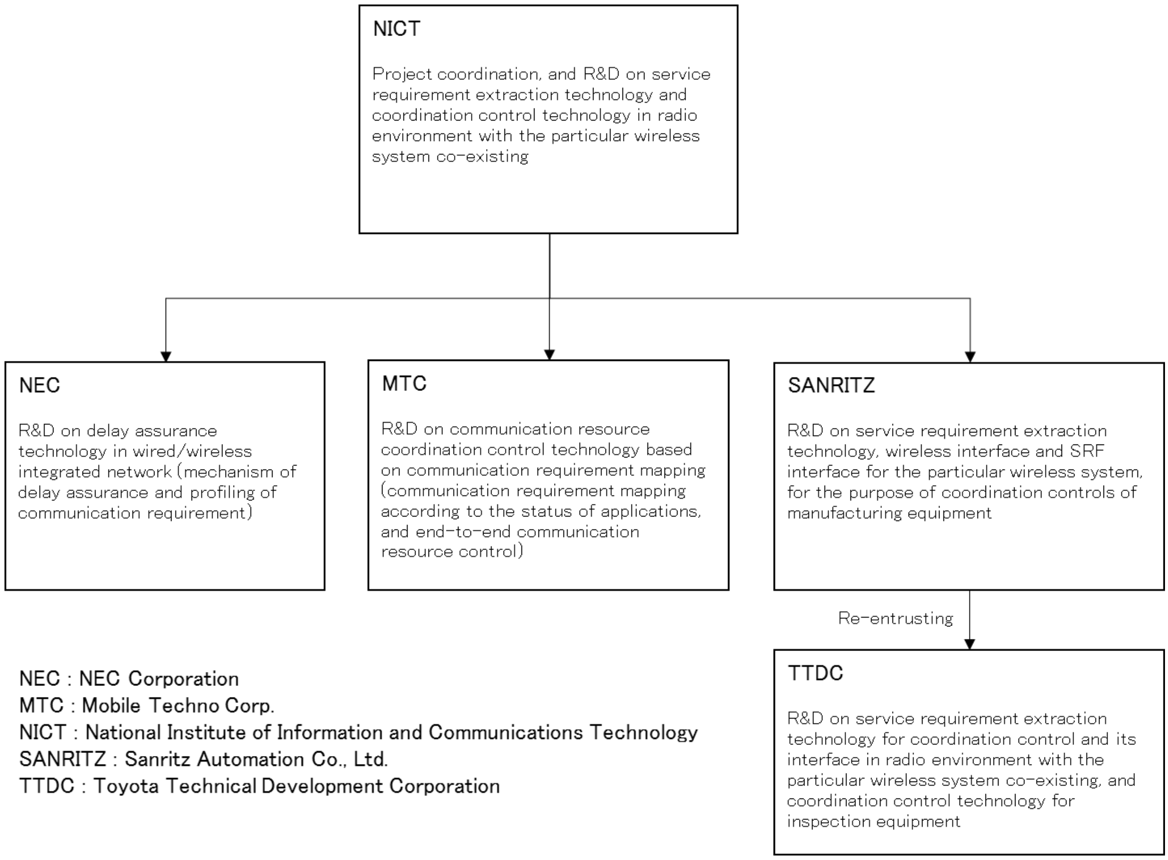


**Figure 2-21. Research Organization Strategy**

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|---|---|
| Issues | In manufacturing sites, it is common for old and new equipment to exist together with 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 unlicensed bands. On the other hand, data delivery within the tolerable delay required by manufacturing equipment or applications is essential. However, the existing wireless communication technologies do not provide users with any assurance against the tolerable delay of data transmission in unlicensed bands. This is one of the reasons why the progress to deploy IoT has been slow in manufacturing sites. As a result, it is difficult to share information that is useful for improvement of productivity in production lines and to perform real-time visualization and total management. |
| Positioning of Research and Development | • Coordination controls of manufacturing equipment, real-time visualization, and total management of an overall manufacturing site will be realized through the realization of data collections and information sharing among production lines by using wireless communications.<br>• This research has great novelty in its radio resource coordination control to satisfy the required communication quality (delay and others) in the unlicensed bands where various wireless systems are coexisting.<br>• Non-experts of communication technologies can easily construct a system by mapping the extracted communication requirements of various systems in manufacturing sites.<br>• The technologies to be developed are very practical, not only in manufacturing sites, but also in medical settings and social infrastructure fields (airports, railways, etc.) where wireless communication is expected to be deployed extensively in the future.<br>• 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 testing costs, as a result of the standardization of interfaces and protocols between functions.<br>• The risk of instability of wireless communication for 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 (our project) is taking the lead in activities concerning deployment of wireless communications in manufacturing sites. Promotion of the standardization with this timing leads to a globally competitive platform established for the first time in the world.<br>• Developed products will be globally deployed with ease, because they target the frequency bands which are commonly used as unlicensed bands for all nations.<br>• The standardization which ensures interoperability among different vendors' devices will enlarge the market size. On the other hand, protection of the core technologies of radio resource coordination control by intellectual property rights will ensure a competitive advantage. |
| Others | Ministry of Internal Affairs and Communications has been conducting the research and development on SRF wireless platform (PF) for the purpose of establishing functions to optimize wireless communications in narrow space such as factories, and realizing efficient spectrum utilization. On the other hand, in this SIP research and development, the three technologies required for applying SRF wireless PF to the entire system will be established, which are (1) the service requirement mapping method according to upper-layer applications, (2) the communication requirement mapping method, and (3) the delay assurance method in wired/wireless integrated network. Furthermore, the functions of SRF wireless PF will be completed, and demonstration experiments towards social implementation will be jointly performed.<br>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 in relation to wireless technologies in manufacturing sites, and other relevant activities. |

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

[Goals of This Fiscal Year]

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

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

To perform partial demonstration experiments consisting of communication requirement mapping technology according to the status of applications and 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 standardization.

[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 its 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 that was integrated our core technologies of magnetic tunnel junction (MTJ) with CMOS technologies, by providing the IoT device with nonvolatile function (not losing information even when the power is turned off) in addition to the processing function, the standby power is drastically reduced and the dilemma between the conventional power consumption and the processing performance is eliminated. In this way, we aim to establish a platform technology for innovative IoT devices with ultralow power consumption (1/5 - 1/10 compared to conventional) required for physical space. In addition, the system technologies will be developed which will accelerate the social implementation through the verification examination. Japan will take initiative in the revolution brought by innovative low-power IoT devices for the realization of Society 5.0 through this SIP.

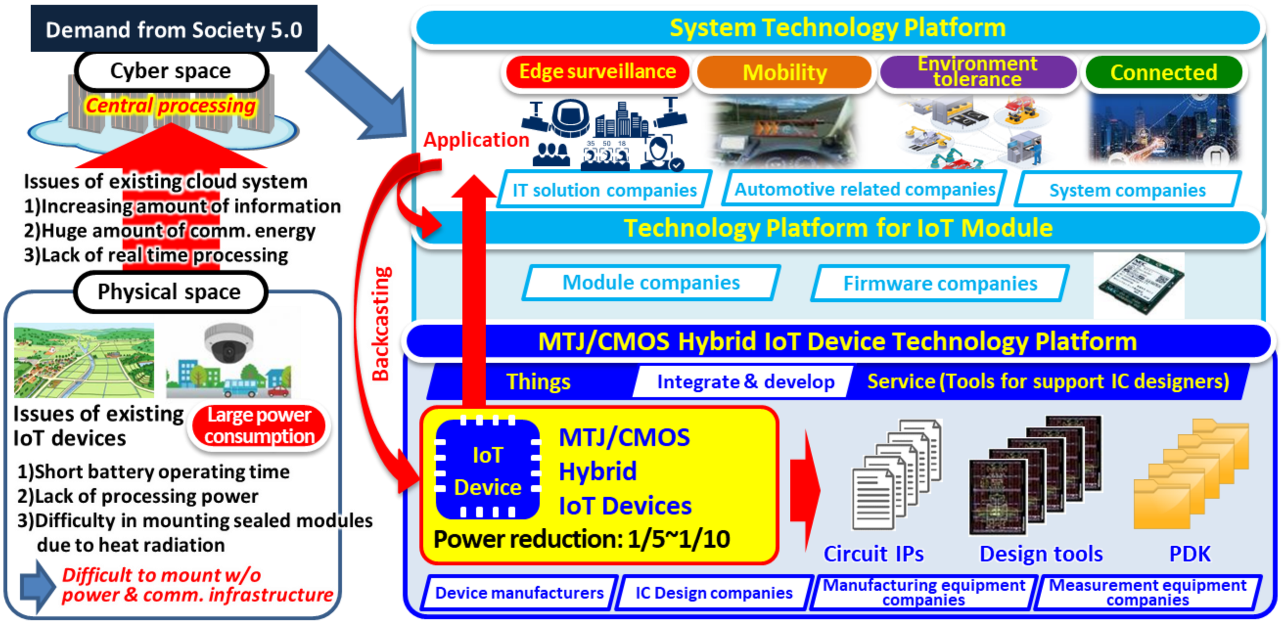


**Figure 2-23. Research and Development Overview**

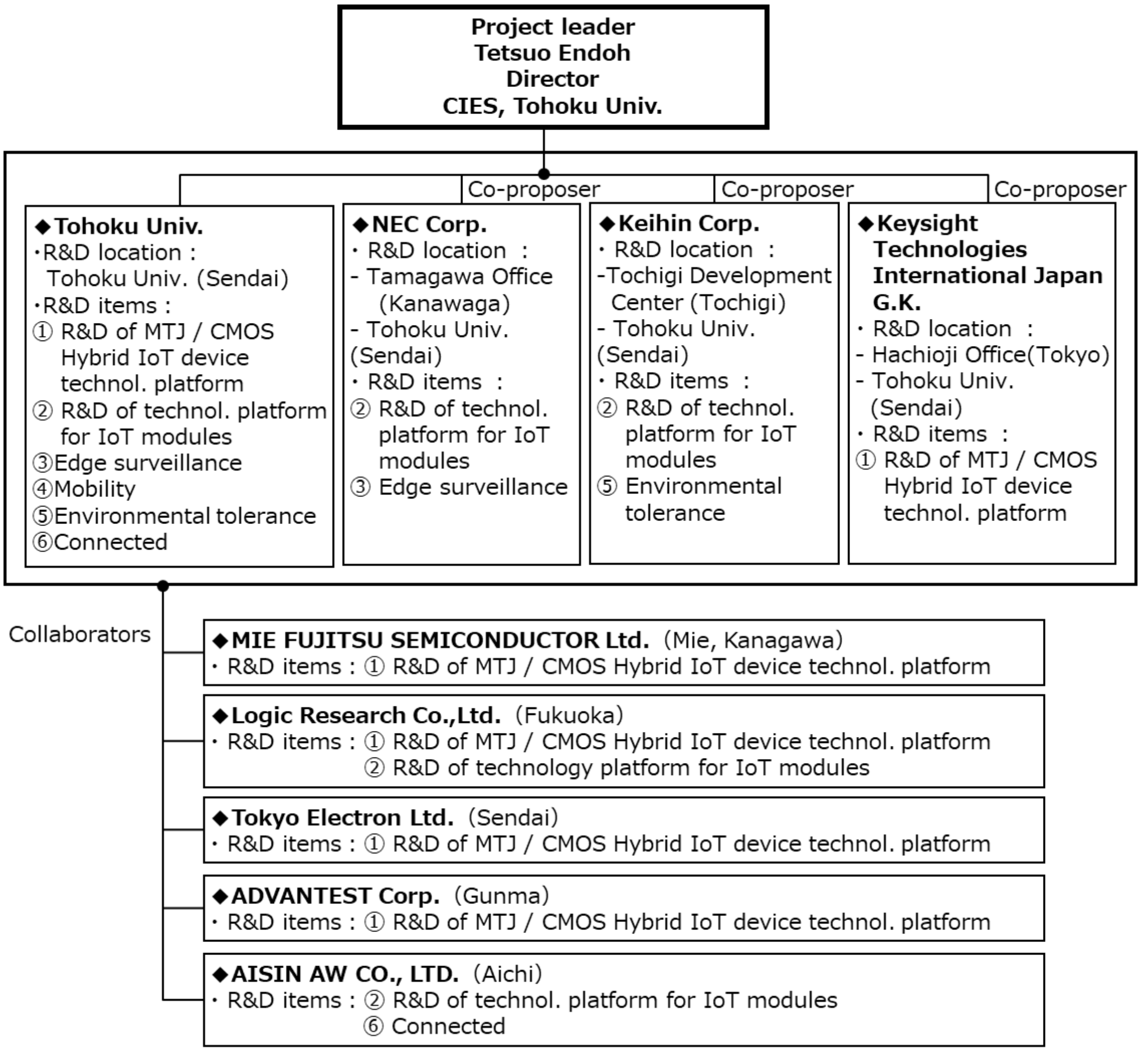


**Figure 2-24. Research Organization Strategy**

| | |
|---|---|
| Issues | Further advanced processing functions are required for IoT devices to reduce the information traffic volume between cyber-physical spaces. However, it is very difficult to realize the enough processing function required in the edge system where the power supplies are limited, through IoT devices based on the existing technologies. This is one of the major technical challenges concerning core technologies for IoT devices in support of Society 5.0. Furthermore, the lack of highly practical IoT devices delays the development of necessary core technologies for systems as well as modules, and as a result major IoT industry that will support society have not started. This is also a major issue for the industry in physical space, for which the integration of core technologies with applications is important. |
| Positioning of Research and Development | In this R&D, we will apply the accomplishments related to spintronics created through the Cabinet Office ImPACT project etc. and develop the MTJ / CMOS hybrid IoT devices and its technical platform that integrate MTJ, which is expected to be put into practical use, with CMOS technologies in order to achieve social implementation at an early stage.<br>Specifically, by providing the IoT device with nonvolatile function (not losing information even when the power is turned off) in addition to the processing function, the standby power is drastically reduced and the dilemma between the conventional power consumption and the processing performance is eliminated. In this way, we aim to establish a platform technology for innovative IoT devices with ultra low power consumption (1/5 - 1/10 compared to conventional) required for physical space. |
| Advantages | No other IoT devices that have the processing function, the non-volatile function, and high practicality have been developed. On the other hand, Tohoku University has been taking the lead in the world in MTJ/CMOS hybrid technologies, as well as pioneering work for MTJ devices, and has technical advantages. Social implementation of "the innovative safety and security technology that will create services directly related to the manufacturing industry and the lives of people, innovative technology for supporting nursing care and the lives of people, innovative automobile traffic systems, innovative manufacturing ("monozukuri") systems, including robots, innovative energy-saving technology, innovative three-dimensional map information utilization technology, and innovative support for remote medical and nursing care, etc." will be created by establishment of core technologies for innovative low-power IoT devices and by module core technologies and systemization core technologies that drive social implementation. The social implementation of the core technologies mentioned above through this research and development will be so great that they will contribute to further enhancements of international competitiveness of the IT industry, automobile-related industries, and semiconductor-related industries, with which Japan (including the companies participating in this program) retains its global presence. |
| Others | Tohoku University will utilize core technologies that have been developed by us in the Cabinet Office ImPACT program, determine application fields for the technologies created through this research and development in Society 5.0, extract requirement specifications and solve technical challenges through back casting, construct a research organization composed of IT companies, automobile companies, twelve device/design/manufacturing equipment/measuring equipment manufacturers, along with three cooperating universities, and promote research and development. Tohoku University will construct systems capable of maintaining the edge platform through standardization and public disclosure of MTJ/CMOS hybrid IoT devices by collaborating with the METI and NEDO. In addition, the university will collaborate with Miyagi Prefecture, as well as with the advanced electronic and machinery industries and the automobile industry, which form the core of the prefecture's manufacturing industries, via the Miyagi Advanced Electronic and Machinery Industry Association (425 companies/groups), and Miyagi Automotive Industry Association (610 companies/groups), from the initial stage of this research and development, with the aim to achieve Society 5.0 in the region. |

**Figure 2-25. Issues, Positioning, Advantages, and Other Aspects of the Research**

[Goals of the Relevant Fiscal Year]
<Development of System Technology Platform>

To improve the evaluation environment, fabricate prototypes of IoT modules by using MTJ-based non-volatile microcomputers created through ImPACT, improve the software development environment such as firmware, and perform early demonstration, thereby extracting development issues of core technologies for systemization. To provide feedback of the extracted issues to the development of core technologies for IoT devices/modules.

<Development of IoT Device Technology Platform>

To obtain device parameters for test chips, and enhance the IP library and PDK by using equipment introduced in the previous and current fiscal years in the research and development of core technologies for MTJ/CMOS Hybrid IoT devices.

To reflect the extracted issues resulting from the early demonstration mentioned above, and design and fabricate prototypes of test chips by using the equipment introduced in the previous and current fiscal years, thereby contributing to the development of the IoT modules to be performed in the next fiscal year.

<Development of Technology Platform for IoT modules>

To promote consideration of 3D packaging of IoT modules, make GaN on Si power controllers higher-frequency operation and more efficient, and further attempt to extract issues towards the achievement of the final goal, the realization of the smallest and most efficient IoT modules in the world.

[Interim Goal] (as of the end of FY2020)
<Development of IoT Device Technology Platform>

To evaluate MTJ/CMOS hybrid IoT devices designed and prototyped in FY2019 on the basis of back casting from the four applications: Mobility, Edge surveillance, Environment tolerance, and Connected. Then, to perform verification examination on the reduction of power consumption to between 1/3 to 1/5 of that of CMOS-based IoT devices, extract issues toward the achievement of the final goal, and hand over the extracted issues to core technologies for IoT modules and systemization. To integrate device parameters for test chips with the integrated process performance to establish the primary PDK, and further integrate the developed circuit IPs. To promote various types of development for solving the extracted issues, make prototypes out of samples that have been made halfway through the previous fiscal year, and promote examination toward demonstration chips. To upgrade the basic MTJ device parameters extraction tool that will be necessary for establishment of PDK and circuit IPs, in parallel with evaluation of chips and additional small-scale prototyping.

<Development of Technology Platform for IoT modules>

To complete primary prototyping and evaluation. Then, to confirm the possibility of size reduction to 1/5 of the conventional technologies, and reduction of energy consumption to 1/10 using simulation.

<Development of System Technology Platform>

To promote consideration and performance evaluation of systems by using the results of the evaluation of test chips made as prototypes in FY2019, provide feedback of the extracted issues to the development of core technologies for devices/modules, and confirm the possibility of achievement of the final goal by using simulation.

[Final Goal] (As of the end of FY2022)
<Development of IoT Device Technology Platform>

To perform verification examination on reduction of power consumption to between 1/5 to 1/10 of that of CMOS-based IoT devices, integrate the integrated process performance with the device parameters used for the verified IoT devices, construct PDK, integrate the developed circuit IPs as well to form a common platform, and reduce the development costs to 1/10. Furthermore, to establish the MTJ device parameters measurement systems for various IoT devices using the MTJ/CMOS Hybrid technologies required for construction of the secondary PDK and circuit IP, and to integrate the modeling technology with the measurement systems.

<Development of Technology Platform for IoT modules>

To realize a size reduction to 1/5 of the conventional technologies, and reduction of energy consumption to 1/10.

In addition, to estimate the development period and cost reduction in collaboration with the subthemes.
<Development of System Technology Platform>
To demonstrate that utilization of core technologies for MTJ/CMOS Hybrid IoT devices will reduce power consumption performance to 1/5 of that of the existing IoT devices in TRL 5 to 7, on the basis of prototyping of demonstration chips.

<u>Research Project No.: PII-2</u>
<u>Research Project Name: Development of Sensor Systems as Human Interaction Device</u>

Principal Investigator: The University of Tokyo
Co-Proposer: National Institute of Advanced Industrial Science and Technology
Dai Nippon Printing Co., Ltd.
Ricoh Co., Ltd.
ConnecTec Japan Corporation

Issue to Be Solved: Research Overview: In this proposal, we will conduct development of innovative sensors, and developments related to the real application of such sensors, that will collect as contact information high-value information that heretofore could not be obtained using various 3-dimensional interfaces that people and things interact with in day-to-day environments.

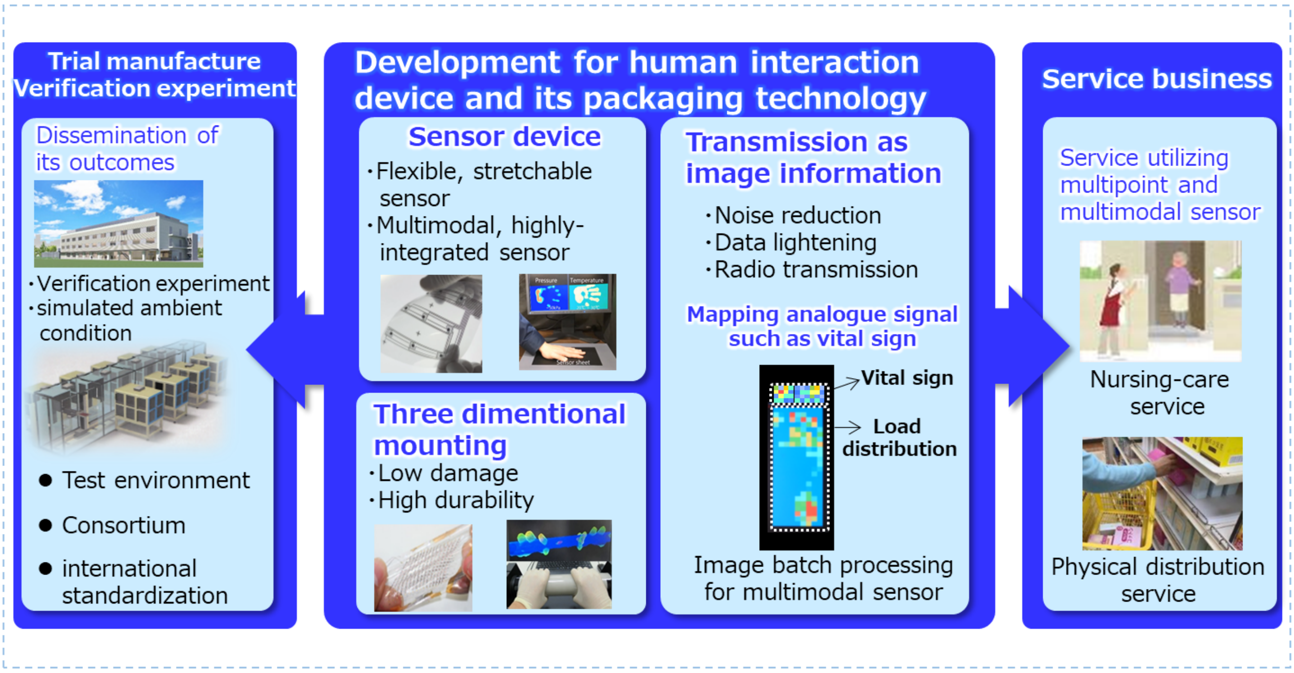


**Figure 2-26. Research and Development Overview**

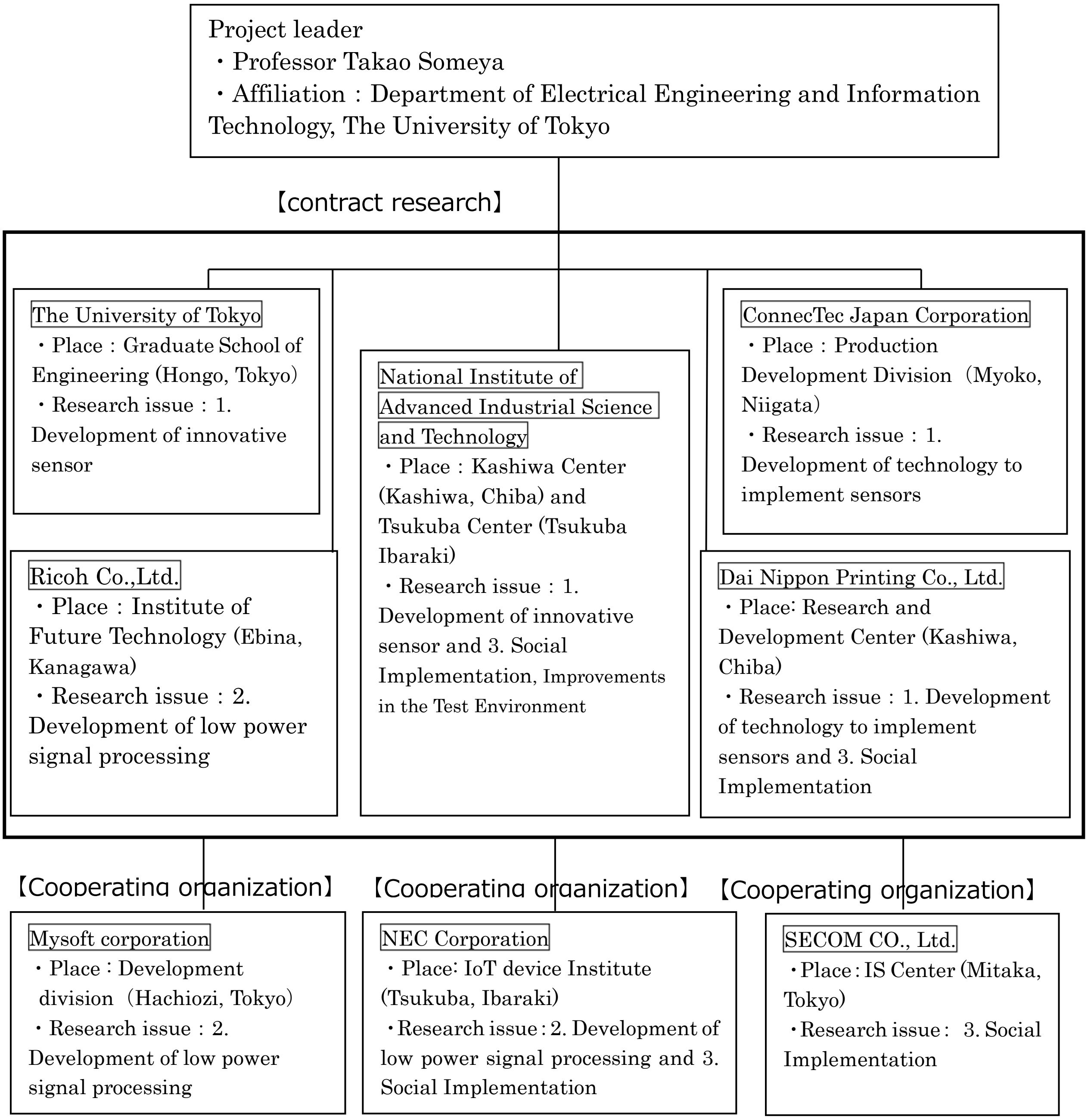


**Figure 2-27. Research Structure Scheme**

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| Issues | The development of a smart society is crucial in responding to labor shortages caused by dwindling birthrates and aging populations, increases in demand for welfare and nursing services, among other social issues, and, as a result, the efficient transfer of information from physical space to cyberspace has become a major technological issue. Although image information is currently being aggressively utilized towards this end, image information is plagued by a number of different issues, such as privacy, blind spot problems, and information overload, so the development of revolutionary sensing technology that supplements existing information collection systems has become necessary. Further, development and application of sensing technology that collects unconscious information from bio-information are sought with respect to people's living environments. |

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| Positioning of Research and Development | This technological development will develop 3-dimensional curved surface sheet sensors, technology to implement such sensors, ad data processing technology, among others, and offer original and revolutionary sensing technology that can simultaneously collect, in real time, individualized identification and recognition as well as status information of particular subjects from contact information obtained through interfacing with people and things. These sheet sensors are characterized by adaptability to large surface areas, multiple points, arbitrary shapes, and multi-modal adaptability, and by having these sensors permeate into various things found around people, the sensors will make it possible to collect multifaced and versatile information regarding people and things that could heretofore not be collected due to limitations on installation environments, etc., and offer equipment control and services, etc. that utilizes this distinctive data. The expected ripple effects this will have on industry include effects such as increased productivity through optimization and automation of distribution and material quality management through application of the present technology, and realization of efficient welfare and nursing services that properly account for privacy. Furthermore, in addition to creating designing and testing environments that can widely apply those technologies, we will also establish a consortium with hub functionality to allow various players in IoT industry areas such as devices and services to come together, thereby disseminating technology and activating the manufacturing industry. |
| Advantages | In order to create information collection systems that efficiently utilize only necessary data in real time, crucial technological issues such as multi-modulization, heavy integration, adaptation to installation environments, and selection of necessary information will need to be addressed. Today, we can see focused, enhanced efforts to advance in each issue both within and without the country, but no organization yet exists that collectively applies these issues in practice to sensing. The present technological development will conduct development by collectively integrating all of the issues described above, and has an advantage in being able to provide a sensing system that allows for utilization of such information. The development will place particular focus on contact information, and is advantageous as an information gathering method by extracting only necessary information, allowing it to supplement areas for which traditional imaging is poorly suited, such as information overload, privacy violations, and information gathering from areas in blind spots. |
| Others | The present technology is based on bio-harmonizing sensor technology and flexible sheet sensor technology developed as part of a project crossing various government ministries, such as the "Bio-Harmonized Electronics" of the JST Strategic Basic Research Programs (ERATO) and the "Development of Basic Technology for Next-Generation Printed Electronics Materials and Process Technology" of NEDO, and has been researched and investigated as part of NEDO's Energy and Environment New Technology Leadership Program for appropriateness, validity, and advantageous positioning as part of the sensor technology necessary for creating a smart society as part of the "multi-modal, high-integration, multi-point distribution information sensor technology development." |

**Figure 2-28. Issues, Positioning, Advantages, and Other Aspects of Research**

[Goals of the Relevant Fiscal Year]

Implement prototype testing of elastic sensor sheets, etc. that have been given multi-point and multi-modal functionality, and, in addition to beginning demonstrative testing with users, acquire new users via deployment at exhibitions, etc.

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

Deliver testing environment and design tools in order to support new participation by businesses into sensor development.

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

Complete analytical technology necessary to utilize data collected through multi-modal sensors in services, and begin investigating commercialization of such services.

Research Project No.: PII-3

Research Project Name: Smart IoT Environment Sensors with a Thermal Harvester at Ordinary Temperatures

Principal Investigator: Tohoku University

Co-Proposer: Mitsui Chemicals, Inc.

Research Overview: The purpose of this research is to develop smart IoT environmental sensors and IoT sensor platforms which can supply a power to the IoT sensors without any battery by harvesting thermal energy even near room temperature. The compact system consists of the smart environment sensor, energy harvester, supercapacitor, and wireless devices. In order to demonstrate the concept of the smart IoT sensor, the sensor system is applied to smart logistics for the security of foods and medicines. We will develop compact IoT environmental sensor systems that can be expanded into safety and security fields.

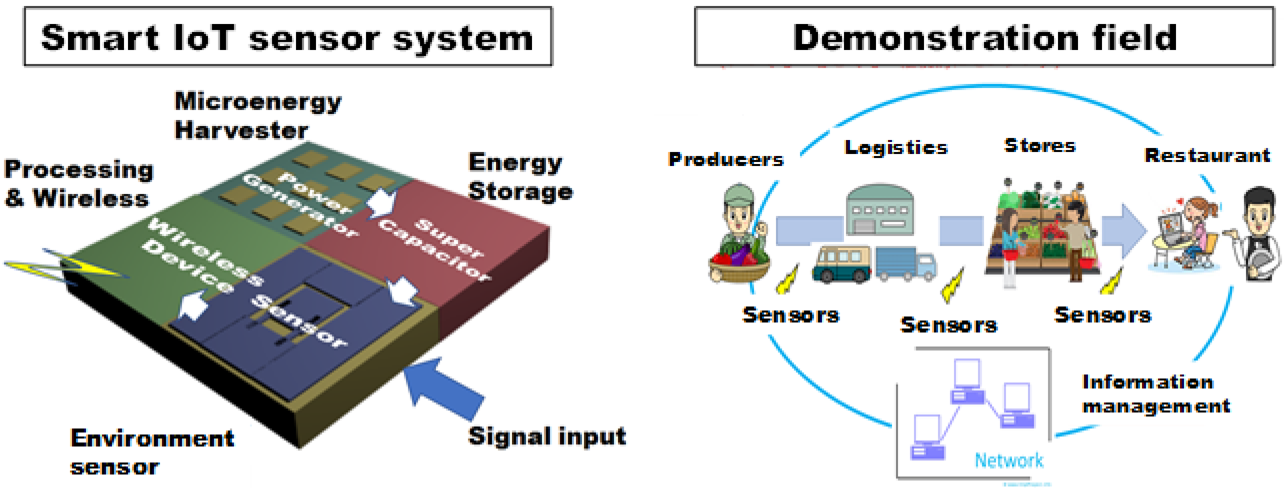


**Figure 2-29. Research and Development Overview**

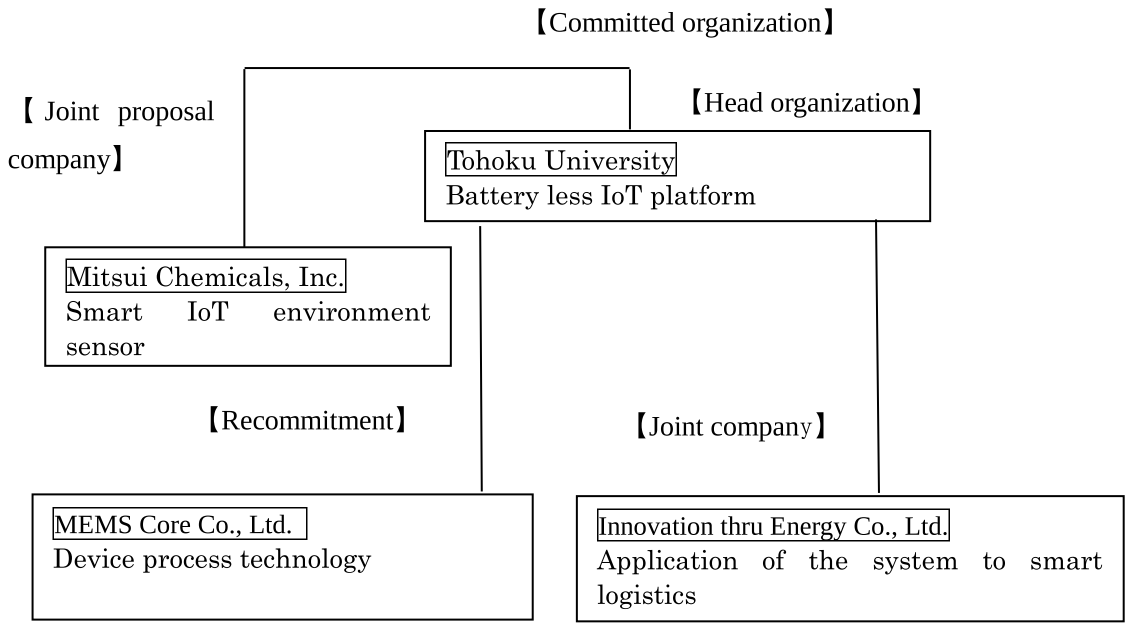


**Figure 2-30. Research Structure Scheme**

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| Issues | IoT sensors, which acquire physical information in order to realize a smart society, are expected to operate in a variety of locations and environments, and require compact and inexpensive systems that ideally operate without a battery. A novel environmental energy harvester will be developed, which generates electrical power from environment as thermal energy including low-quality heat sources. Smart IoT sensors recognizing environment molecules will be developed for applications to safety and security fields. They will be accomplished by common nanofabrication platforms to accelerate the development, and contribute to the realization of Society 5.0 through coordination with the third R&D subtheme. |
| Positioning of Research and Development | ・ Develop systems to generate power from low-quality heat sources and supply energy to IoT sensors (ordinary temperature power generation).<br>・ Develop compact, efficient, and mass-production compatible thermoelectric, power storage elements, and achieve high efficiency ordinary temperature power generation.<br>・ Develop new, low-energy consumption molecule recognition sensors.<br>・ Utilize as smart IoT environment sensor systems.<br>・ Conduct demonstrative testing for potential use in safety monitoring of food and medical supplies for smart logistics.<br>・ Develop systems with the expansibility to be applied in areas such as future environmental monitoring and smart agriculture.<br>・ Contribute to realization of Society 5.0. |
| Advantages | Molecular recognition sensors of each variety are being developed inside and outside of Japan, but no one has yet realized a system that can detect multiple low-concentration molecules at ppm or less. By utilizing a new sensor system using the functional polymer technology possessed by participating members, we can be the first in the world to realize IoT sensors with highly sensitive molecular identification functionality. Furthermore, our group possesses the top technology in thermoelectric material process for mass production, and by expanding this technology to the level of practical application, we can hybridize it with IoT sensors, and realize a battery free IoT sensor platform based on thermal energy. |
| Others | The development environment of the Micro System Integration Center utilizes the results of "Creation of Innovation Centers for Advanced interdisciplinary Research Areas Program" (FY2007 through FY2016). The present research is conducted in coordination with members of industry and academia, such as Tohoku University, Mitsui Chemicals, Inc., MEMS Core Co., Ltd., and Innovation thru Energy Co., Ltd.. |

**Figure 2-31. Issues, Positioning, Advantages, and Other Aspects of Research**

[Goals of the Relevant Fiscal Year]
Create a theoretical model of ordinary temperature power generation elements, and aim for the process development of thermoelectric devices. Acquire knowledge regarding design parameters, etc. through testing of compact heat-storage elements and thin-film micro supercapacitors.

[Interim Goal] (as of the end of FY2020)
A smart IoT sensor platform will be developed. The concept of the smart environment sensors will be demonstrated.

[Final Goal] (as of the end of FY 2022)
IoT environmental sensor system prototype is demonstrated through field testing, a business model for social implementation will be created.

Research Project No.: PII-4

Research Project Name: Research on Ultra-Sensitive Sensor System

Principal Investigator: Toshiba Corp.

Research Overview: In order to realize Society 5.0, we intend to create an edge computing platform that can collect, process, and analyze valuable data from physical spaces in which a diverse array of sensors have been installed, and develop an ultra-sensitive sensor system utilizing revolutionary detection principles that can simultaneously offer real-time capabilities, controllability, and low- energy consumption.

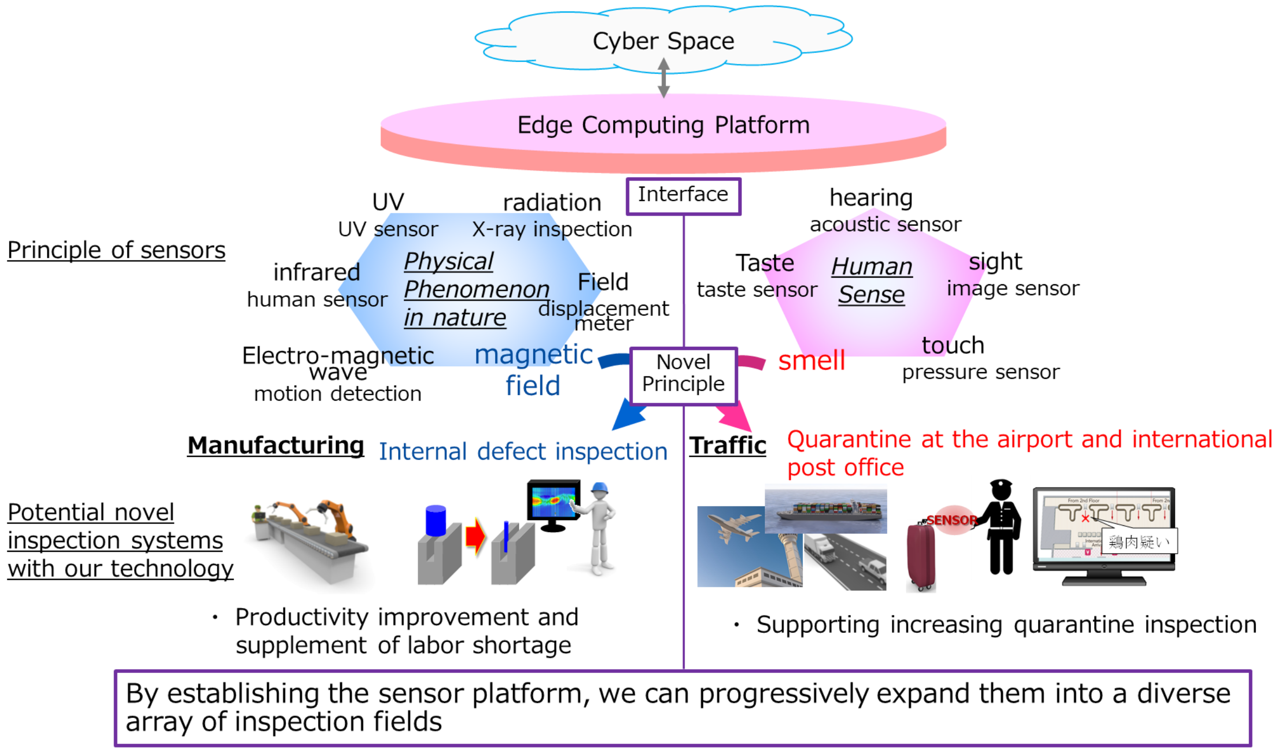


**Figure 2-32. Research and Development Overview**

Toshiba Corporation

- R&D on sensor system based on magnetic field
- R&D on sensor system based on smelling
- R&D on function expansion of smart sensor module

【Re-entrust】

Device & System Platform Development Center Co., Ltd.
- R&D on modularization
- R&D on platform connection

Tohoku University
- R&D on Magnetic flux convergence material

Tokyo Institute of Technology
- R&D on peptide interface

University of Tokyo
- R&D on aptamer interface

Tokyo Medical and Dental University
- R&D on high-sensitive biological reaction

**Figure 2-33. Research Structure Scheme**

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| Issues | Traditionally, various industries have begun utilizing sensors that are based off of what can be detected through the five human sense, and off of physical phenomena in the natural world, but as making these sensors more compact or less energy intensive is difficult due to limitations on their detection principles, at present most processes involve large-scale detection using large equipment, or abandon sensor detection altogether and rely on simple inspections through tacit knowledge of skilled craftspersons. These kinds of sensory processes stand in the way of dissemination and promotion of edge computing platforms during the realization of Society 5.0, the real-time capabilities, controllability, and low-energy consumption of which will progressively become more crucial in the future. |
| Positioning of Research and Development | This will realize sensor element components with revolutionary detection principles that combine nano-materials like magnetic materials and two-dimensional materials, and original circuit designs and structures, as well as materials that maximize the sensitivity of sensors, in order to make the application of crucial inspection processes for which real-time visualization was impossible, possible. Specific points of application are projected to be real-time internal defect inspections of factory (batteries, EV/HEV, power stations, precision electronic devices, etc.) manufacturing lines and infrastructure (bridges, essential components of roads, buildings, etc.) inspections, and quarantine inspections of airports as well as international post offices, etc., and will contribute to the enhancement of quality management of batteries used at EVs/HEVs that are projected to disseminate as a responsive measure against global warming, as well as the prevention of reductions in productivity in the manufacturing industry caused by human resource deficiencies arising from the shrinking of the labor force, and weakening of waterside measures against dangerous materials. By using the sensor platform realized here, we can progressively expand them into a diverse array of inspection fields such as the nursing and healthcare fields, and the agricultural and food products fields. |
| Advantages | Reportedly competitive technologies of elemental components that can be applied to high sensitivity internal defect inspections, which are the targets of magnetic sensors, are: (1) elements with giant magnetoresistance or tunnel magnetoresistance similar to the present proposal, (2) atomic magnetism, and (3) quantum sensors with diamond Nitrogen-Vacancy center. Among these only the present proposal has taken into account specifications necessary for internal defect detection from detection sensitivity, spatial analytical capability, detection depth, element size, all the way to mass production capability. In the same vein, competitive technologies to the elemental components of scent sensors are reported to include (1) metallic oxides, (2) conductive polymers, and (3) bio-sensors that utilize bio-tissue such as olfactory receptors. Among these only the present proposal has taken into account specifications necessary for quarantine detection from high sensitivity and selectivity toward specific scents, portability, mass production capability, and to real-time capability. As both proposed technologies far exceed the limitations of existing technology, they are highly competitive at the international level. |

**Figure 2-34. Issues, Positioning, and Advantages of Research**

[Goals of the Relevant Fiscal Year]

Design and test magnetic flux concentrators (MFCs), which will become the primary technology for enhancing the sensitivity of magnetic sensors, and confirm a 50x MFC gain using original bridge circuit and differential amplifier circuit. Furthermore, we will develop magnetic field sensor modules, begin developing prototype systems that anticipate specific usage cases (short circuits detection of lithium ion batteries, eddy current probes of defects in the interiors of constructs, etc.), and complete investigations into compositions of systems that include magnetic field sensor modules and establishment of operational environments. Furthermore, with respect to scent sensors, in addition to confirming concentration-dependent responses to limonene, which is a citrus odor component, we will test component technologies for taking in odorants from the atmosphere and confirm feasibility as a scent detection module.

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

With respect to magnetic field sensors, we will test a low-noise module that conducts wavelength separation and detection of tested elements and their outputs as well as differential amplification, and confirm high sensitivity that is 50x (pT level) greater than conventional technology. Furthermore, with respect to scent sensors, conduct testing of modules designed to take in and detect scent particles at the ppm level from the actual atmosphere, and conduct operational testing. In addition, confirm specifications of interfaces that connect such sensor devices to edge computing platform.

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

Complete testing of defect inspection functionality of high-sensitivity magnetic field sensor modules. Specifically, continue noise reduction of differential amplification, and realize 1 mm level defect detection at 1/10 of the conventional size elements. For scent sensors, realize technology to detect scent molecules at the detection dog level (ppb level), and demonstrate use in quarantine inspections at actual airports.

[Final Goal]

Realize low-energy IoT chips and innovative sensor technology and establish technology that will make it possible to conduct measurements in environments where installation was heretofore impossible, by reducing the power necessary for neighborhood processing of sensors to 1/5 or less, reducing sizes of sensors to 1/5 or less, and reducing development costs to 1/10 or less, among other improvements. By systematizing standard technological foundations, we can easily conduct social implementation through edge computing PFs described in the first R&D subtheme, eradicate obstacles to participation by small to mid-sized enterprises and ventures and industrialization, and promote the creation of IoT systems.

**III. Technology to Disseminate IoT Devices for Realizing Society 5.0**

**Director in Charge of Subtheme: Sadao Kawamura (Professor, College of Science and Engineering, Ritsumeikan University)**

**Director in Charge of Subtheme: Norio Kodaira (Mitsubishi Electric Corporation)**

The present subtheme is comprised of 2 research and development projects. The following are shared items between, and individualized details for each project.

[Goals of the R&D Subtheme]

In the third R&D subtheme, with the aim of realizing Society 5.0, technologies to disseminate IoT devices in society will be developed. These technologies will promote the introduction and use of robots and other IoT devices in manufacturing processes where such devices have not yet been applied, nursing care, transportation, and service areas (areas like food product factories where shape and hardness are issues, small-scale autonomous mobility services that require group controls (autonomy and synchronization between multiple units) for which communication speed, etc., is an issue).

As such, R&D activities will be carried out with the utilization of the common edge computing platform developed under the first R&D subtheme described above in mind. Technologies to encourage the dissemination of CPS in society include enhancement of real-time processing, which has limitations when used in a cloud application (technology to make materials or parts data intelligent through multi-point sensing), and technology to coordinate controls in physical space with controls in cyberspace (local level optimized controls through sensing modules, etc.) with cyberspace.

The results of the first and second R&D subthemes will be reflected as of this social implementation, and by providing feedback to the first and second R&D subthemes regarding the results of this social implementation, we will achieve high efficiency, high functionality, and high added value of the system as a whole, and demonstrate the establishment of the intelligent knowledge processing infrastructure, which is a research issue of the present program.

In addition, investigating models that conform to regions will be crucial in resolving social issues, and this R&D subtheme will also implement investigations into models that conform to regions.

Research Project No.: PIII-1

Research Project Name: Development and Implementation of Sensor-Rich Soft End-Effector System (SSES) for Cyber Physical System (CPS) Construction

Principal Investigator: Ritsumeikan University

Co-Proposer: Yamagata University
Chitose Robotics Inc.
Man-Machine Synergy Effectors, Inc.

Research Overview: Developing end effectors equipped with flexible and diverse sensors in order to construct cyber physical systems (CPS). The end effectors will be applied into mechanical systems, such as robots, to realize complex tasks in physical space and achieve data conversion in cyberspace. The developed systems will realize fundamental reforms in industries with low work productivity.

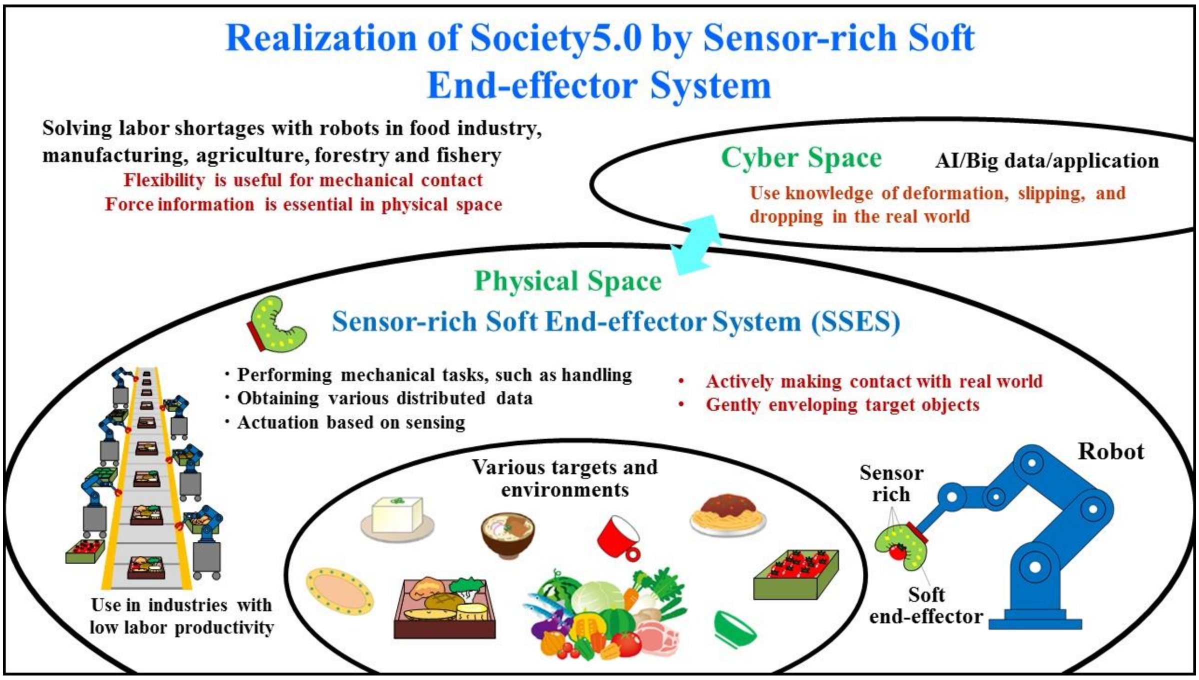


Figure 2-35. Research and Development Overview

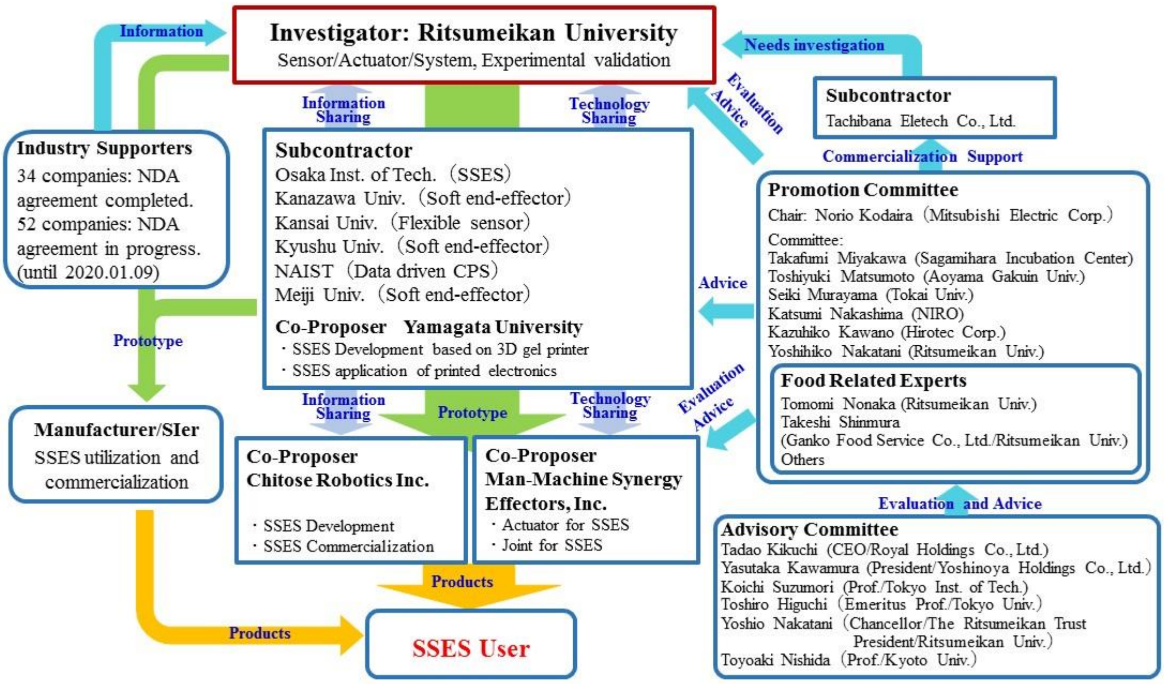


Figure 2-36. Research Structure Scheme

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| Issues | Many industries, such as the food industry and the manufacturing industry, have handling tasks involving various subjects in changing environments. These tasks require deft integration of determination/recognition functions with physical handling. In general, managing these tasks with existing IT and IoT technologies alone is difficult. As a result, industries centered on these tasks continue to experience low work productivity and labor shortage. This research and development will realize, as a CPS, end effector systems that are flexible and equipped with sensors utilizing IoT technology that allows for handling of subjects with various characteristics in changing environments, and will contribute to revolutionizing industries with low work productivity. |
| Positioning of Research and Development | ・ Allows for acquisition of scientific knowledge of various physical operations through integration of visual and tactile information and big data technology.<br>・ Contributes to fundamental research in the soft robotics field driven by needs from society.<br>・ Makes possible of collecting big data using SSES as a foundation.<br>・ Allows for new industrial development such as SSES manufacturing, sales, and services.<br>・ Contributes to resolving labor shortage problem in labor-intensive industries, such as the food industry. |
| Advantages | 3D printers capable of forming elastic materials has been put into practical use, making it possible to easily fabricate soft structures with complex shapes. Under these circumstances, new devices as SSES can be developed using the gel 3D printer and printed electronics technology developed by the members of our research group. Cooperation between Japanese material manufacturers and system integration engineers to realize flexible bending/force sensors using various polymer materials has an international advantage. In addition, the use of big data in the handling field is a new field and gave us an advantage in the future international development competition. |
| Others | We expect to see SSES using in the food industry and the agricultural, forestry, and fishing industry. Furthermore, we will contribute to improving the productivity of small and medium-sized enterprises where the introduction of industrial robots is not progressing. To realize the above, coordination between material manufacturers and Universities, device manufacturers and Universities, user enterprises and Universities, and other fundamental industrial-academic coordination become indispensable. The SSESs proposed in this research will be developed with different characteristics based on industry types, as various types of SSESs will be necessary based on the goals of different tasks. This will create possibilities for many enterprises to develop and sell new SSESs by using the fundamental technologies of this research. |

**Figure 2-37. Issues, Positioning, Advantages, and Other Aspects of Research**

[Goals of the Relevant Fiscal Year]

- Clarifying the fundamental characteristics of each technology by using component prototypes and the like.
- Constructing conceptual plans of implementing the systemization and utilization of data and IoT.
- Conducting SSES tests in demonstration field after SSES prototyping.

[Interim Goals] (by the end of FY2020)

- Completing SSES and IoT systems.
- Conducting on-site tests and achieving demonstration of SSES in the food industry.

[Final Goals] (by the end of FY2022)

- Achieving demonstration in the small and medium-sized enterprises and the agricultural, forestry, and fishing industries.
- Expanding applications of SSES in areas related to the food industry throughout the country.

Research Project No.: PIII-2

Research Project Name: Social Implementation of Self-Traveling Personal Mobility in Which Multiple Units Work Together Safely, Comfortable and Inexpensively by Edge and Cloud Processing of Moving Space Digital Data

Principal Investigator: Panasonic Corporation

Co-Proposer: Suzuki Motor Corporation
National Institute of Advanced Industrial Science and Technology
The University of Tokyo

Research Overview: Achieve inexpensive, safe, and comfortable mobility to intended destinations even for mobility impaired individuals via personal mobility utilizing autonomous mobility systems. Conduct real time processing of environmental recognition and sensor information on the edge side, and on the cloud side, develop technology optimized to synchronize and control multiple units for greater efficiency.

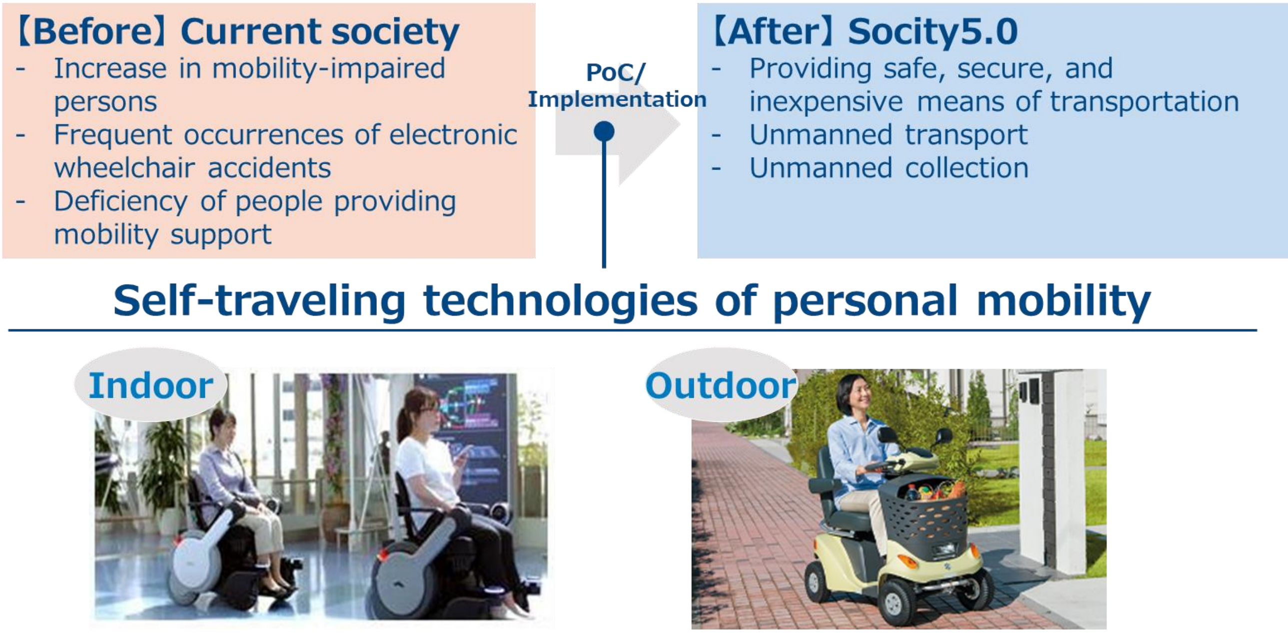


**Figure 2-38. Research and Development Overview**

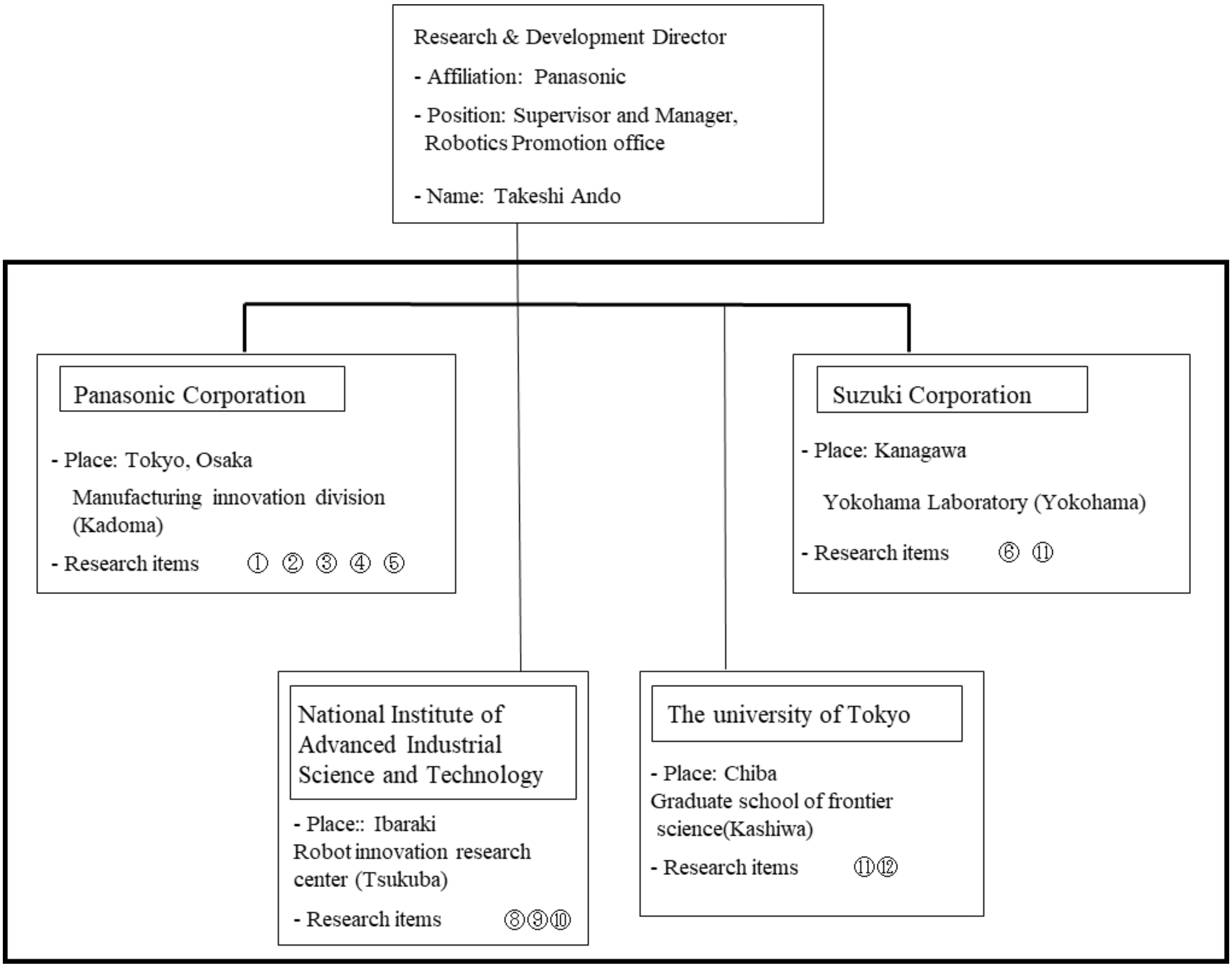


**Figure 2-39. Research Structure Scheme**

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| Issues | The goal is to resolve social issues relating to mobility that will arise with respect to changes in the demographic changes of an aging population and a declining workforce, such as:<br>・ Increase in mobility-impaired persons<br>・ Frequent occurrences of electronic wheelchair accidents<br>・ Deficiency of people providing mobility support among other issues. |
| Positioning of Research and Development | Develop automated traveling technology that supports movement inside facilities such as commercial buildings or movement in exterior areas of living environments, and create a smart society that allows even mobility-impaired persons to go wherever they want to go.<br>Furthermore, the developed technology can be applied, not just to support personal mobility, but also to the automated transport of things, and increase productivity and resolve human resource deficiencies through automation even in the distribution and other industries, which are facing a serious workforce deficiency problem. |
| Advantages | Panasonic has interior mobility robot technology with safety technology at its core, Suzuki has mobility technology as the top manufacturer of electronic wheelchairs, the National Institute of Advanced Industrial Science and Technology has automated mobility technology built up through wide-spread demonstrative |

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| | activities and other activities, and the University of Tokyo has mobility technology that takes into account human characteristics.<br>By combining each party's respective strengths, we can be the first to realize level 4 automated mobility capable of movement in interior and exterior environments. |
| Others | With respect to automated mobility in interior and exterior environments, coordinate with many government agencies (such as the Ministry of Economy, Trade and Industry, the Ministry of Land, Infrastructure, Transport and Tourism, and National Police Agency) to efficiently advance development, demonstration, and introduction. |

**Figure 2-40. Issues, Positioning, Advantages, and Other Aspects of Research**

[Goals of the Relevant Fiscal Year]

In addition to conducting primary development of technology necessary for environment recognition on the edge side, use simulations to test operating systems on the cloud side.

Demonstrate that the developed component technologies satisfy fundamental, demanded specifications.

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

Aim for seamless movement of automated personal mobility while coordinating with operating systems and the like on the cloud side.

**Additional Accelerated Research and Development**

<u>Additional Budget Implementation Item: Coordination to Accelerate Social Implementation of Edge Computing Platforms (PFs)</u>

Principal Investigator: Kyushu University, NEC

Principal Investigator: Mobile Techno Corp.

Principal Investigator: Ritsumeikan University

Overview:

The current primary research issue for the intelligent knowledge processing infrastructure integrating physical and virtual domains is to develop PF technologies that simply and inexpensively construct and utilize IoTs (edge and actuators) that are appropriate to resolving the issues specific to the users themselves. In order to accelerate this technological development, what is important is not to continue development in the traditional waterfall model, but to direct technological demonstrative testing (proof of concept or PoC) and research and development to on-site issues in an agile manner, and provide feedback obtained regarding implementation conditions quickly to the upstream processes in development. As a specific effort to accelerate this process, we plan to prepare actual fields (e.g., kitchen, dishwashing space, healthcare facilities, etc.) and conduct demonstrations with the participation of actual operators and users. We will efficiently collect physical data regarding people, things, and environments through this PoC, and, after extracting and processing necessary information from the edge in real time, accelerate research and development of edge computing that interacts with big data processing at the cyber (cloud) level. We also attempt to interact with on-site actuators (robots and hearable devices) as responses and controls based on sensing results. Furthermore, by cooperating with another SIP program that focuses on security issues, we accelerate the studies on secure wireless communications that are applied to achieve secure real-time data transferrers from sensors, on-site persons, things, and environments to the edge computing platforms. Through the additional accelerated researches, we attempt to make strategic plans regarding industrial promotion, social implementation, policy recommendations, and so on. We start-up a working group (WG) involving third party professionals within the fiscal year. The WG is considered as a predecessor to the acting body (consortium) needed for the utilization and application of physical data involving offerors, creators, and users, which also include stakeholders in the industry.

Implementation Items:

1. By conducting technological demonstrations of the present edge computing construction PFs at the worksites of research operators and users via PoCs, providing rapid feedback regarding the demonstration results to the upstream processes in technological development becomes possible, and will contribute to the early social implementation of edge computing construction PFs. For these demonstrations, the Kyushu University and NEC team will handle the digital healthcare area, and the Ritsumeikan University team will handle the demonstrations of cooking and dishwashing areas. These efforts will involve not just the participation of SIP issue research operators, but also of third party cooperators, and will conduct technological development responsive to on-site issues, as well as the construction of overall systems, and demonstration structures.
2. In addition to technological demonstrations through PoCs, by starting WGs involving industry and consortium members, as well as constructors and users, in Japan and overseas, we can accelerate dissemination strategies and social implementation strategies.
3. In coordination with other SIPs, we will conduct technological cooperations with physical security, and heighten the synergistic effect between physical security and edge computing PF security strengthening technologies, particularly wireless layer technologies.

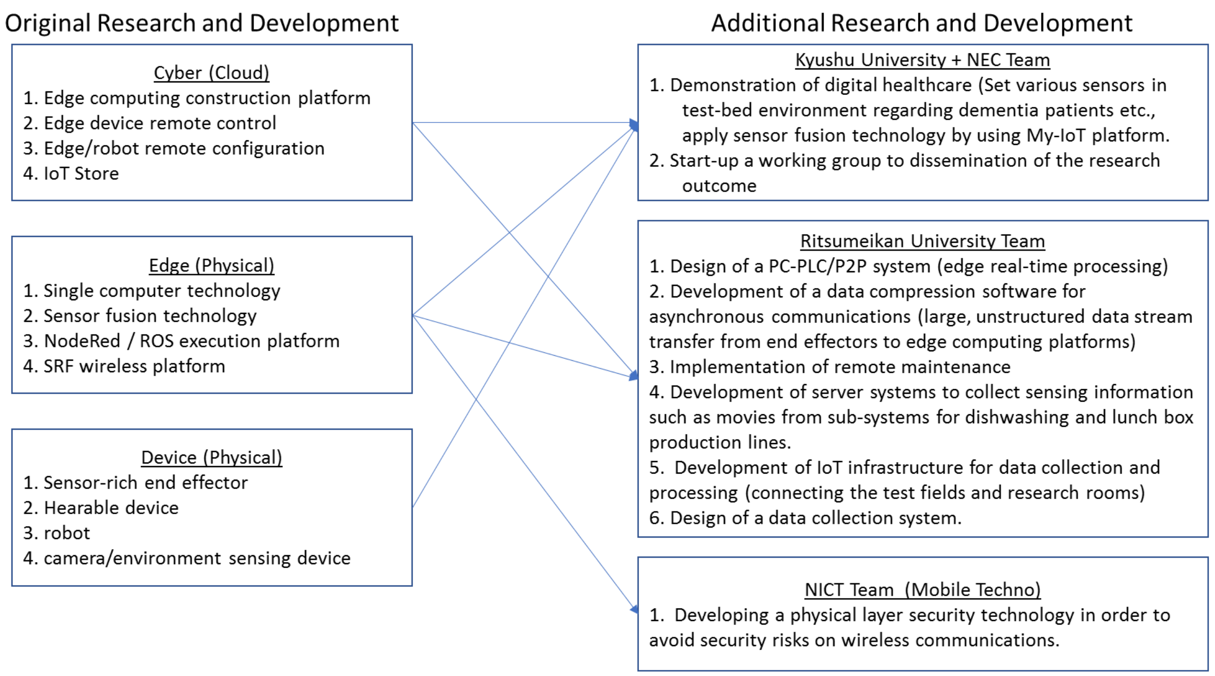


**Figure 2-41. Research and Development Overview**

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| Issues | Internet of Things (IoT) systems tend to involve vertical integrations in system designs, IoT expansion has been limited to specific industries such as the manufacturing industry, and it is therefore difficult to say that IoT is disseminating into other industries where we can expect productivity increases and new business opportunities to solve major social issues. Even robot systems are predominantly developed on a case-by-case basis (PJ base development), and it is difficult to say that generalized development and construction methods have disseminated thoroughly. Furthermore, since edge computing systems that mainly handle sensing data and robotics systems that act as actuators based on sensing information tend to be developed independently, their integration and introduction tend to require large amount of time and effort. In realizing Society 5.0 and CPS, it |

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| | is required not only to bridge the development gap between the data sensing and robot actuations, but also to provide design methodologies, tools, and environments to seamlessly connect the sensing and actuation sub-systems. Additionally, in order to ensure proper activities on the part of IoT and robotics systems, ensuring the security of the physical sensing data is also a pressing issue. Cyberattacks that target the vulnerabilities of IoT equipment have increased rapidly, in particular, and ensuring the safety of edge computing PFs has become a key technology to accelerating the aforementioned social implementation. With respect to edge computing PFs, which include wired and wireless networks, securing technologies to avoid cyberattacks has become a particularly pressing concern. |
| Positioning of Research and Development | 1) Acceleration of Social Implementation of Edge Computing Construction PFs (Kyushu University and NEC team)<br>(1) Makes it possible to verify architectural designs in particular by using human's vital information for the demonstrations of the edge-level sensor fusion technology that handles multiple sensors as a virtual sensor and conducts semantic understanding against the obtained data streams.<br>(2) Contributes to the resolution of actual social issues (in particular, projection of BPSD onset in dementia patients, protection of older individuals, and supporting handicap persons).<br>2) Acceleration of Social Implementation of Sensor-Rich Soft End Effector Systems (Ritsumeikan University team)<br>(1) Allows for acquisition of scientific knowledge of various physical operations through integration of visual and tactile information and big data/IoT technology.<br>(2) Can ascertain status of recovered tableware as preprocessing of tableware washing automation. Furthermore, the tableware classification and recognition results can contribute to effective tableware handling.<br>(3) IoT conversion and ROS conversion of the demonstration field will be good references when introducing sensor-rich soft end-effector systems (SSES) into production sites.<br>3) Collaboration of Physical and Security, and Implementation (Mobile Techno)<br>(1) The technology to be developed is for defense against cyberattacks that cannot be protected in SRF wireless platform using only encryption and authentication, such as radio jamming and radio link destruction that attack radio interfaces.<br>(2) The technology to be developed is a novel physical layer security technology based on the secret sharing that actively utilizes multiple communication routes known as multiple bands (e.g. 2.4GHz / 5GHz) and multiple technologies (e.g. wireless LAN / Bluetooth) recently introduced into general wireless devices.<br>(3) The functions to be developed are realized by software to be easily retro-fitted and effectively applied to IoT devices in manufacturing sites where 40% or more of equipment are commonly utilized for over 15 years.<br>(4) The technology to be developed may contribute to the advancement of wireless IoT, not just in manufacturing sites, but also in areas such as the medical/nursing fields, where ensuring security is one of the crucial issues to be solved. |
| Advantages | 1) Conducting technological developments and demonstrations with actual operators and users to utilize the developed edge computing construction PFs are especially advanced efforts. The PFs cover various sensors that target things, environments, and people, and handles the sensed data streams in conjunction with many cloud platforms to solve social issues (digital healthcare). Furthermore, the work group activities for the edge computing construction PFs, in which not only the main researchers of this SIP project but also other IoT developers and users are included, are valuable.<br>2) Although, on one hand, sharing vocal and visual information via the Internet is quite common, sharing of dynamic information or physical information in the physical space (characteristics of tableware, dropping items, or the visual state of food on a plate, etc.) is not yet widespread. In order to widely share this physical information, this research will construct IoT systems, and, through data collection and analysis, increase the efficacy of the sensor-rich soft end-effector systems (SSESs) to be developed. Usage of IoT technology in the handling field is a new field entirely (connected handling), and may be advantageously |

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| | deployed in future international competition. Further allows for real time efficient usage of information from robotic hands, which are furthest upstream, while also simultaneously acquiring useful information from data analyses conducted in the cloud, which is at the end of the data flow. (Acceleration of social implementation of sensor-rich soft end-effector systems (SSESs).<br>3) Protection of the core technologies of the secret sharing utilizing multiple communication routes by intellectual property rights will ensure a competitive advantage (Collaboration of Physical and Security, and Implementation) |
| Others | 1) Acceleration of the My-IoT development platform (an edge computing construction platform) developed in the present research and development will contribute to the creation of new business models and resolution of social issues that spread across the Ministry of Economy, Trade and Industry, Ministry of Public Management, Home Affairs, Posts and Telecommunications, and Ministry of Health, Labour and Welfare. In particular, the guiding principles of “prevention” and “co-living” set by the Ministry of Health, Labour and Welfare with respect to dementia patients are things that the IoT side will accelerate realization of.<br>2) The connected SSES and IoT platforms that will be developed in the present research and development are expected to be used in fields coordinated with the Ministry of Agriculture, Forestry and Fisheries and the Ministry of Economy, Trade and Industry, such as the agricultural, forestry, and fishing industries.<br>3) Our activities are being done in complete collaboration with the standardization activities of Flexible Factory Partner Alliance (FFPA), a group promoting the standardization in relation to wireless technologies in manufacturing sites and other relevant activities. Thus, in particular, our activities will directly contribute to solving the problems relating to wireless in manufacturing sites and creating new business opportunities from the perspective of wireless technology. |

**Figure 2-42. Issues, Positioning, Advantages, and Other Aspects of Research**

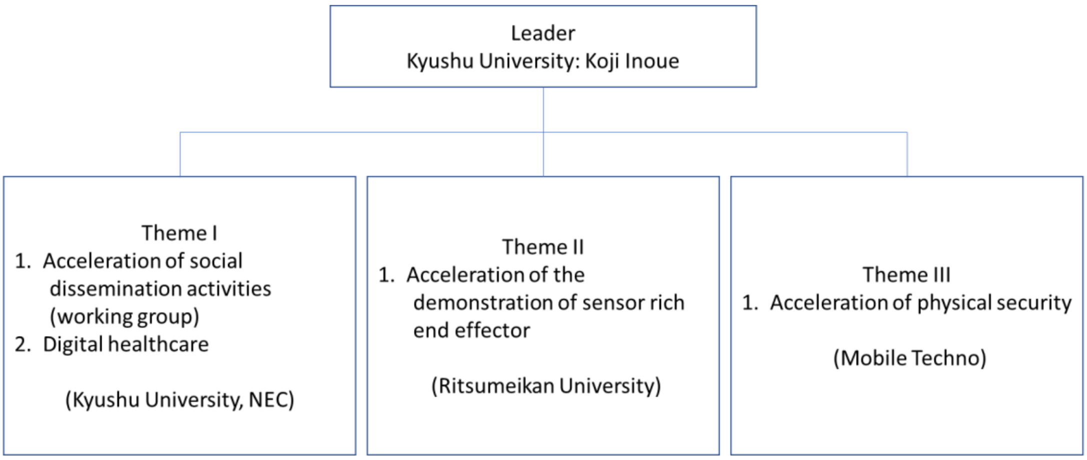


**Figure 2-43. Structure**

[Goals of the Relevant Fiscal Year]

Theme I:

- Acquire digital healthcare facilities and begin advanced demonstrations.
- Establish edge computing WGs.

Theme II:

- Construct systems (P2P, operation approval server, periodic data reception server).
- Collect data from the Ritsumeikan Co-Op and construct environments in demonstrative testing fields.
- Coordinate between robots and cameras using ROS 2.0.

Theme III:

Complete basic design and architecture development for the secret sharing technology actively utilizing multiple communication routes.

[Interim Goal]

Theme I:

Analyze data and confirm results by third parties at digital healthcare facilities.

Move from edge computing WGs to establishment of consortium, and prepare for corporatization.

Theme II:

・ Construct firmware update server.

・ Collect data and construct analysis systems at Ritsumeikan University.

・ In the SIP-SSES demonstration field, collect data regarding sensors attached to hands and robot statuses into the server, and construct big data processing systems for the demonstration field.

・ Construct systems between multiple robots, robot hands, cameras, and sensors using ROS 2.0, confirm actions, collect data, and construct environments in demonstrative testing fields.

[Final Goal (Output)]

Theme I:

Start digital healthcare businesses, establish edge computing consortium, and begin monetization.

Theme II:

Complete development and testing in demonstration fields, begin horizontal deployment into other areas and commercialize.

Theme III:

Complete implementation and evaluation of the secret sharing technology utilizing multiple communication routes, and complete testing of functionality and performance.

<u>Additional Budget Implementation Item: Research and Development of Multi-Sensing Module Platforms</u>

Principal Investigator: Toshiba

Research Overview: In order to construct an IoT system oriented toward the realization of Society 5.0, highly reliable (secure) and precise recognition and determination through sensor fusion utilizing AI is indispensable. However, multi-sensing modules (MSMs) equipped with a diverse array of sensors require large costs and labor for custom development, preventing dissemination. Therefore, we will construct a platform that can readily realize MSMs that integrate multiple sensors with control circuits. This research will introduce devices and sensor technology currently under development by this program (An intelligent knowledge processing infrastructure, integrating physical and virtual domains), as well as sensor technology we have developed in NEDO-Pjs in past. The proposed platform here will reduce development costs to 1/5 and development times to 1/10, and accelerate social implementation by making it easier to utilize IoT systems based on sensor fusion even in small to mid-sized enterprises and ventures.

Implementation Item: This implementation item will involve the development of multi-sensing module platforms (MSM-PFs) equipped with a diverse array of sensors. In FY2019, we will conduct investigations into existing sensor specifications and sensor interfaces, discussions with other research operators regarding the present program (An intelligent knowledge processing infrastructure, integrating physical and virtual domains), and simple device testing evaluations, to implement specifications development of MSM-PFs. In FY2020, we will conduct testing of modules equipped with multiple existing sensors and microcomputers that satisfy specifications to conduct testing of sensor fusion operations that combine data from two or more sensors. In FY2021 onward, we will work on development of multi-parameter sensor fusion that utilizes AI. Additionally, we will examine prototype testing of high-added value MSMs that incorporate innovative sensors, high-speed, nonvolatile microcomputers, and the results of energy harvester technology, and complete testing for the possibility of realizing MSM-PFs that combine objective differentiated sensors and existing sensors through sensor fusion technology.

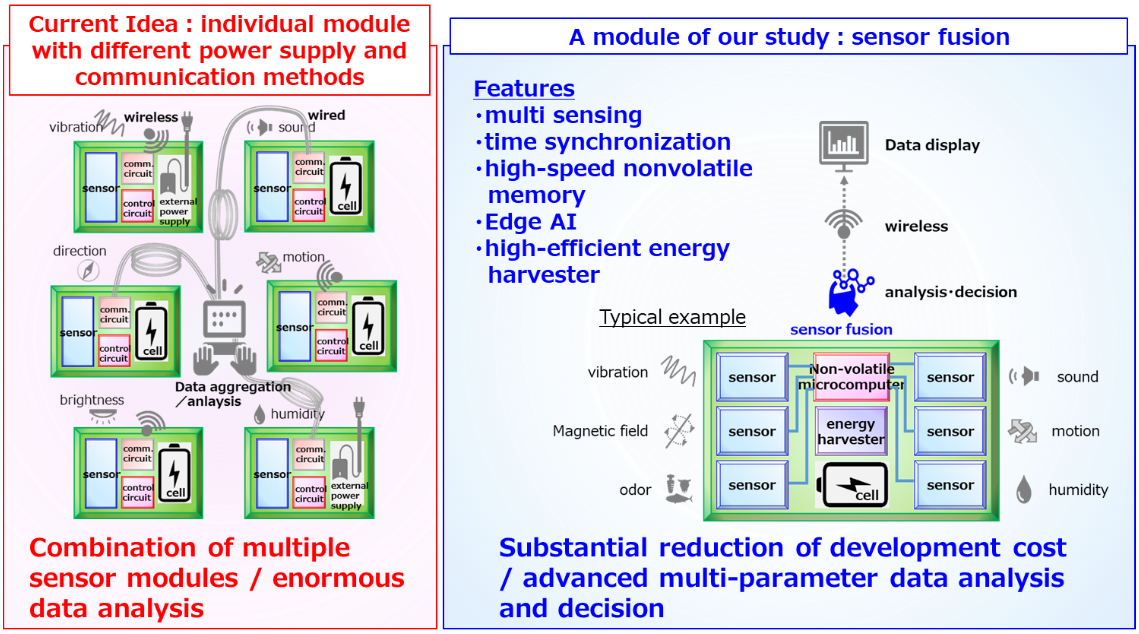


**Figure 2-44. Research and Development Overview**

| | |
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| Issues | In order to construct an IoT system oriented toward the realization of Society 5.0, highly reliable (secure) and precise recognition and determination through sensor fusion utilizing AI is indispensable. However, in order to achieve actual introduction, in addition to the development expenses of the sensor itself, significant expenses, including expenses associated with connections to neighboring circuits, including data transfer, are necessary, thereby standing in the way of dissemination. |
| Positioning of Research and Development | By constructing a platform that can readily realize MSMs that integrate multiple sensors with control circuits, development costs can be reduced and development times can be shortened. This will therefore accelerate social implementation by making it easier to utilize IoT systems based on sensor fusion even in small to mid-sized enterprises and ventures. |
| Advantages | Competing technologies to the MSM-PF of the present theme include (1) the SensorTile of ST Microelectronics, (2) SensorTag of Texas Instruments, and (3) Raspberry Pi of the Raspberry Pi Foundation. When collectively taking into account the conditions necessary for dissemination, such as size, energy consumption, development costs, and interface redundancy, the present proposal is in the most advantageous positions compared to its competitors. |

**Figure 2-45. Issues, Positioning, and Advantages of Research**

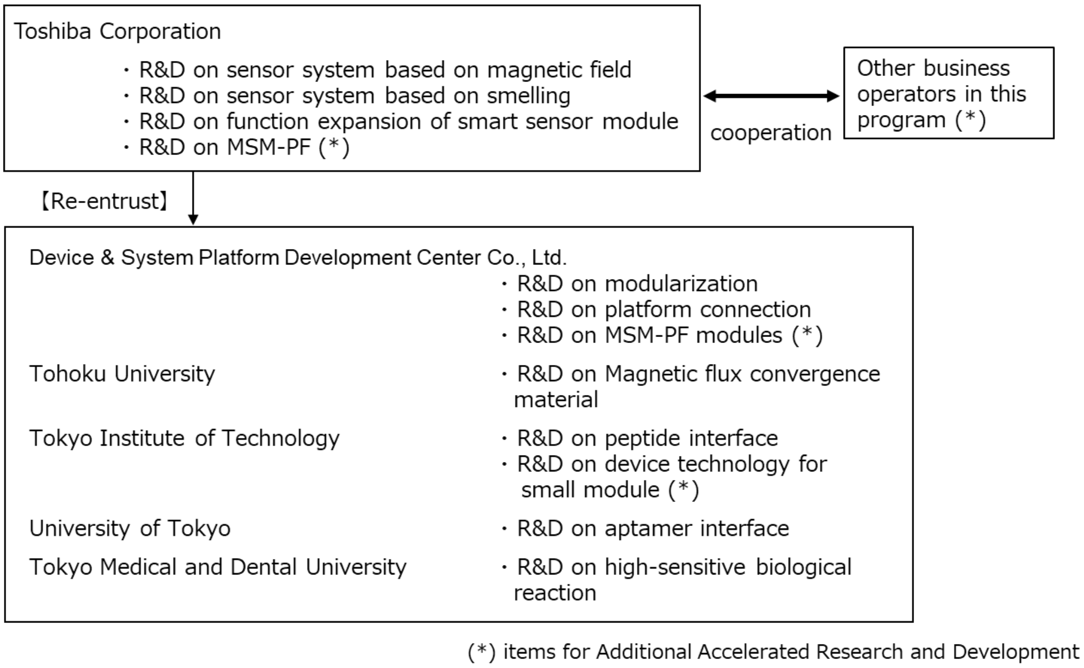



**Figure 2-46. Structure**

[Goals of the Relevant Fiscal Year]
Conduct investigations into existing sensor specifications and sensor interfaces, discussions with other research operators regarding the present program (An intelligent knowledge processing infrastructure, integrating physical and virtual domains), and simple device testing evaluations, to implement specifications development for the MSM-PF to be developed.

[Interim Goal]
Begin testing of modules equipped with multiple existing sensors and microcomputers furnished with the time synchronization function to conduct testing of sensor fusion operations that combine data from two or more sensors.

[Final Goal (Output)]
Work on development of multi-parameter sensor fusion that utilizes AI. Additionally, examine prototype testing of highly value-added MSMs that incorporate innovative sensors, high-speed, nonvolatile microcomputers, and the results of energy harvester technology, and complete testing for the possibility of realizing MSM-PFs that combine objective differentiated sensors and existing sensors through sensor fusion technology. Verify reduction of development costs to 1/5, and development times to 1/10 through the present platform technology.

## 3. Implementation Structure

### (1) Use of the New Energy and Industrial Technology Development Organization (NEDO)

Utilizing grants from NEDO, the present program is implemented via a structure similar to the one in Figure 3-1. NEDO will assist the PD and the Promoting Committee to manage the budget, monitor research and development progress (including monitoring of intellectual property), issue public reports and results on issues (including responses to symposia), support development of research and development plans, announcement materials, and related materials, implement peer reviews related to issues, coordinate communications with external related organizations and academic societies, accompany PD to visits of implementation organizations, conduct relevant studies and analyses, etc.

### (2) Selection of Principal Investigators

Based on this plan, NEDO will select, via open application, principal investigators. The clerical work for the selection screening for the principal investigators shall be conducted by NEDO. Screening standards and the screening methods used by screeners are decided by NEDO in consultation with the PD, Cabinet Office, and government agencies responsible for policy. As a general rule, the PD as well as the case officer from the Cabinet Office shall participate in the screening. No parties with an interest in the principal investigators participating in the application shall participate the screening of that application. Furthermore, there may be situations where the scope of implementation for the research and development themes and the coordination between research and development themes, among other issues, may be considered during the screening process associated with selecting principal investigators.

### (3) Implementation Structure of Research and Development

As a general rule, the research organizations, etc. of enterprises and universities, etc. (hereinafter the "organizations") considered for selection as principal investigators shall be organizations that have research and development bases within Japan, and the participation in research and development by joint business entity structures comprised of participants from industry, academia, and government shall be encouraged. However, if there is an organization that has research and development bases outside of Japan, and there is a need to conduct research and development with such organization in order to utilize the superior research and development capabilities or research facilities, etc. possessed by this organization in a particular field, or from the perspective of meeting international standards, research and development can be implemented in coordination with such organization, but only with respect to that particular type of research and development. Note that a theme leader will be assigned to each R&D subtheme in order to maximize utilization of each implementing party's research and development capabilities, and efficiently and effectively advance research and development, and researchers shall, to the extent possible, group themselves under this theme leader to implement research and development.

### (4) Operational Management of Each Research and Development Theme

PD as well as NEDO shall be responsible for managing and executing each research and development theme, and will implement appropriate operational management in light of the program's aims and goals, as well as the aims and goals of the present research and development, while maintaining a close relationship with related government agencies and the principal investigators. Specifically, in addition to establishing the Promoting Committee and the like and reflecting the opinions of external experts in operational management, they shall manage the progress status of research and development by receiving periodic reports regarding the progress of the research and development themes or by other means. Beyond this, they shall ascertain, at opportune times, trends in technological fields related to the research and development themes as well as changes in the external environment, among other factors, and device any necessary responsive measures.

### (5) Methods of Optimizing Research Structure

In order to advance the present program using the optimal structure, PD will use the "stage gate method" for research issues, and implement active investigations into additions and changes to research issues, and rearrangement, narrowing, additions, etc. to research teams as necessary to respond to the progress status of research issues, investigation results of technological investigations and the like implemented at related organizations or other organizations, and changes in social conditions. PD shall, as necessary, assign a sub-PD to provide support for the advancement of research and development.

In order to reliably execute the management described above, and to implement coordination between research teams working on each of the research issues, PD shall hold business management conferences, and share the goals of the present issues through regular exchanges of information.

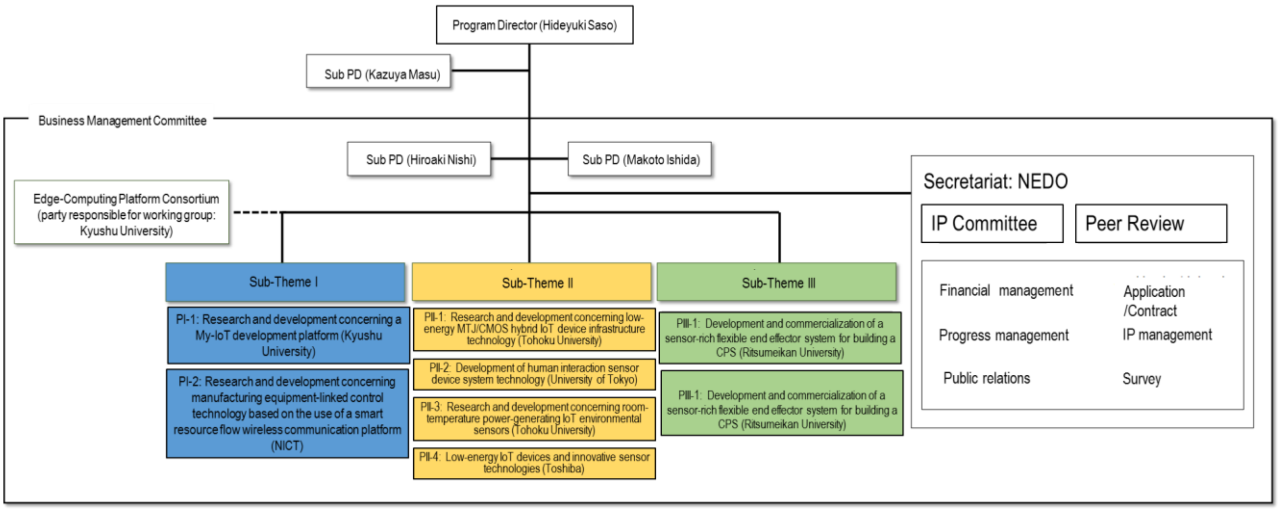



**Figure 3-1. Business Management Meeting**

### (6) Coordination with Government Agencies

The work under this program shall be conducted and advanced in close coordination with relevant government agencies: in general, research and development for sensors, computing, etc. shall be conducted in coordination with the Ministry of Education, Culture, Sports, Science and Technology, communications portions shall be coordinated with the Ministry of Public Management, Home Affairs, Posts and Telecommunications, and devices and practical application will be conducted in coordination with the Ministry of Economy, Trade and Industry. Furthermore, the advancement of practical applications shall be conducted while keeping coordination with the business departments of the Ministry of Health, Labour and Welfare, the Ministry of Land, Infrastructure and Transport, and the National Police Agency, among others.

### (7) Contributions from the Industry

We expect 10 to 20% of the total research and development costs (the total of contributions from the government and the industry) to come from future contributions from the industry (including personnel and material contributions).

## 4. Intellectual Property (IP)

### (1) IP Committee

- An IP Committee shall be placed in NEDO, etc. or the affiliated organization of selected principal investigators (contractors) for each issue or research item that is a part of an issue.
- The IP Committee will be responsible for publishing papers on research and development results achieved by the establishing organization, as well as for determining policies toward the application and maintenance of patents and other IP rights (hereinafter "IP rights") and for coordinating IP rights licensing as necessary.
- As a general rule, the IP Committee shall consist of the PD or a representative of the PD, principal relevant parties, experts, and others.
- The organization that established the IP Committee shall determine the specifics of how the committee will be managed.

### (2) IP Rights-Related Agreements

- In advance of any work, NEDO, etc. will sign contracts or other agreements with contractors to establish the handling of nondisclosure, background IP rights (IP rights already held by the principal investigator or their organization, etc. before participating in the program, as well as IP rights acquired independently of SIP program funds after participating in the program), and foreground IP rights (IP rights created within the program using SIP program funds).

### (3) Licensing of Background IP Rights

- The holder of a background IP rights can license those IP rights to other program participants under conditions established by the IP rights holder (or under terms agreed upon by the program participants).
- If those conditions or other aspects of the IP rights holder's behavior risk becoming a hindrance to SIP (including not only research and development but also the implementation and commercialization of results), mediation will be conducted in the IP Committee to reach a reasonable solution.

### (4) Handling of Foreground IP Rights

- As per Article 19-1 of Industrial Technology Enhancement Act, foreground IP rights shall generally belong to the organization (contractor) to which the principal investigator (as the inventor) belongs.
- If a subcontractor is responsible for an invention and the IP rights will belong to the subcontractor, or in similar such cases, the IP Committee must first give its approval. At this stage, the IP Committee can attach conditions to its approval.
- If an IP rights holder has little interest in commercialization, the IP Committee shall recommend that the IP rights be held by a party that will actively pursue commercialization, or that the IP rights be licensed to a party that will actively pursue commercialization.
- In the event that a party withdraws from the program in the middle of their participation period, NEDO, etc. has the power to transfer without compensation all or part of any patents, or issue licenses for all or part of any patents, for IP rights achieved using SIP program funds during that participation period (if the withdrawing party participated for multiple fiscal years, this applies to all IP rights achieved since the party first began participating).
- In general, the IP rights holder will cover any costs associated with patent application, maintenance, etc. In the case of a joint application, cost distribution and percentage interest in the patent shall be negotiated between the joint applicants.

### (5) Licensing of Foreground IP Rights

- The holder of foreground IP rights can license those IP rights to other program participants under conditions established by the IP rights holder (or under terms agreed upon by the program participants).
- The holder of foreground IP rights can license those IP rights to a third party under conditions set by the IP rights holder, to the extent that those conditions are not more favorable than those set for program participants.
- If those conditions or other aspects of the IP rights holder's behavior risk becoming a hindrance to SIP (including not only research and development but also the implementation and commercialization of results), mediation will be conducted in the IP Committee to reach a reasonable solution.

### (6) Transfer of Foreground IP Rights and the Issuance/Transferal of Exclusive Licenses

- As per Industrial Technology Enhancement Act, Article 19-1(4), the transferal of foreground IP rights and the issuance/transferal of exclusive licenses to such IP rights, require the approval of NEDO, etc., except in cases of transfer resulting from a merger or division (demerger), transfer of IP rights to a subsidiary or parent company, issuance or transfer of an exclusive license, etc. (hereinafter "IP rights transfer or similar resulting from a merger, etc.").
- An IP rights transfer or similar resulting from a merger, etc., shall require the authorization of NEDO, etc., subject to the contract between the IP rights holder and the NEDO, etc.
- Even after the conclusion of an IP rights transfer or similar resulting from a merger, etc., NEDO, etc. can hold a license with the right to sublicense for those IP rights. If the relevant conditions are unacceptable, the transfer shall not be approved.

### (7) Handling of IP Rights after Project Conclusion

- If there are no claimants to IP rights after research and development has been completed, the handling (abandonment or inheritance by NEDO, etc.) of those IP rights will be negotiated through the IP Committee.

### (8) Participation by Foreign Organizations (Companies, Universities, Researchers, etc.)

- The participation of a foreign organization is permitted if necessary to proceed with program tasks.
- In the interest of proper operational management, a representative or point of contact handling administrative issues pertaining to research and development contracts and similar must be located within Japan.
- IP pertaining to foreign organizations shall be shared between NEDO, etc. and the foreign organization.

## 5. Evaluations

### (1) Evaluating Body

The Governing Board shall conduct evaluations, inviting external experts and others to participate. These evaluations shall be conducted with reference to results reports of self-inspections conducted by the PD, NEDO, etc. The Governing Board can host such evaluations for each field or task.

### (2) Evaluation Period

- There shall be preliminary evaluations, year-end evaluations at the end of each fiscal year, and final evaluations.

・ After project conclusion, follow-up evaluations will be conducted as necessary after a certain amount of time has passed (generally three years).
・ In addition to the above, evaluations can also be conducted mid-fiscal year as necessary.

### (3) Evaluation Parameters and Standards

Based on the General Guidelines for the Evaluation of Government Research and Development (R&D) Activities (Issued by the Prime Minister on December 21, 2016), and aiming to evaluate necessity, efficiency, effectiveness, and other such factors, evaluation parameters and standards shall be as follows below. Evaluations shall not simply judge accomplishment or failure of goals, but shall further include analysis of causes, proposals for ways to make improvements, etc.

1) Importance of the purpose; consistency with the objectives of the SIP system.
2) Adequacy of targets (especially outcome targets); degree of achievement of the progress schedule for achieving those targets.
3) Whether proper management is being conducted. In particular, whether there have been benefits due to collaboration between government agencies.
4) Quality of practical implementation and commercialization strategies; degree of achievement of those strategies.
(5) For final evaluations: anticipated effects or ripple effects. Whether post-project follow-up plans are appropriate and clearly established.

### (4) Application of Evaluation Results

・ Preliminary evaluations shall be conducted concerning plans for the next and subsequent fiscal years, and applied to plans for the next and subsequent fiscal years.
・ Year-end evaluations shall be conducted concerning results up through the present fiscal year and plans for the next and subsequent fiscal years. These evaluations shall be applied to plans for the next and subsequent fiscal years.
・ Final evaluations shall be conducted concerning results up through the final fiscal year, and applied to post-project follow-up, etc.
・ Follow-up evaluations shall be conducted concerning the progress of the practical implementation and commercialization of tasks' results, and shall feature proposals for improvements, etc.

### (5) Publishing Results

・ Evaluation results shall generally be made public.
・ Governing Boards that conduct evaluations shall not be made open to the public, due to the involvement of non-public research and development information, etc.

### (6) Self-Inspections

#### 1) Self-Inspection by Principal Investigator

The PD shall select the principal investigator who will perform a self-inspection. (In general, the principal researcher/research organization will be selected for each research item.)

The selected principal investigator shall apply "5.(3) Evaluation Parameters and Standards," inspect both achievements since the last evaluation and future plans, and not simply judge accomplishment or failure of goals, but shall further include analysis of causes, ways to make improvements, etc.

### 2) Self-Inspection by the PD

With reference to the self-inspection results of principal investigators as well as the opinions of third-parties and experts as necessary, the PD shall apply "5.(3) Evaluation Parameters and Standards"; inspect both the achievements and future plans of the PD, NEDO, and the principal investigators; and not simply judge accomplishment or failure of goals, but shall further include analysis of causes, ways to make improvements, etc. Drawing on the results of this self-inspection, the PD shall determine whether each principal investigator should continue their research and offer necessary advice to the principal investigators and others. In this way, this system should enable autonomous, self-directed improvements.

The PD, with the help of NEDO, shall create materials based on these results for the Governing Board.

### 3) Self-Inspection by the Management Agency

Self-inspections by NEDO shall consider topics such as whether administrative procedures are being properly conducted in terms of budget implementation.

## 6. Strategy for Commercialization

### (1) Research and Development Promotion Toward Commercialization

After a common edge computing platform and low-energy IoT chips have been developed, they will undergo demonstration testing in manufacturing and other sectors experiencing workforce shortages. Successful results will demonstrate the effectiveness of the platform's solution for promoting economic development and addressing social issues as well as help encourage the use of CPS. To this end, the R&D activities described under the three R&D subthemes will be promoted with a view toward commercializing project results. After selecting enterprises that will actually handle commercialization as partners for each subtheme, we will seek to receive between 10 to 20% of the total funds necessary for personnel, locations, equipment, etc. from the private sector. In particular, once the research stages have progressed and we have reached the social implementation and commercialization stage, we will advance while expanding investments from the private sector. This will allow us to swiftly advance commercialization in the industry.

- In the first R&D subtheme, cyberspace and the physical space will be unified with minimal labor by developing common platform technologies in order to resolve the various problems caused by deficiencies in IT professionals.
- In the second R&D subtheme, we have set as a goal social implementation via development and systemization of low-energy IoT devices and devices neighboring sensors, in which Japan has a competitive advantage.
- In the third R&D subtheme, we have set specific goals including increases in productivity through development of robots, etc. through advanced fusion of cyberspace and the physical space, when faced with representational social issues for which real-time capabilities and precision are crucial.

Additionally, with respect to the intelligent knowledge processing infrastructure integrating physical and virtual domains, by combining the results of existing PRISM and ImPACT, results concerning each government agency (three research organizations for artificial intelligence, etc.), and the results of the paired themes of "Big-Data and AI-Enabled Cyberspace Technologies," and "Cyber Physical Security for IoT Society" among SIP issues in order to develop a more appealing platform, and by constructing systems to maintain and renew through consortia and the like, we can continuously promote new business opportunities and participation by the industry after the completion of the program, thereby maintaining and expanding the international competitive capability and financial growth of Japan.

### (2) Measures for Dissemination

The project is designed to establish a common edge computing platform as a solution for integrating cyber and physical spaces with lower labor workload. It is expected that the IoT market will be revitalized by the entry of various industries that have missed business opportunities due to IT professional shortages.

As specific policies for technology dissemination,

- The first R&D subtheme will realize edge computing platform technology. Furthermore, in accordance with Japan's open and closed strategies, the common edge computing platform will be open to the public and maintained so that a variety of organizations, including small and medium-sized companies and venture businesses, will be able to develop IoT solutions. This will lower the barriers to entry into services that utilize advanced CPSs, and we can expect the provision of a diverse array of services that will resolve various social issues.
- The second R&D subtheme will resolve the issue of practical application found in low-energy IoT devices and innovative sensors, in which Japan has a strength, and by definitively connecting this to the first R&D subtheme, make social implementation through the third R&D subtheme possible, and promote new participation. Furthermore, this subtheme will support continuous deployment of Japan's scientific and technological capabilities, thereby making a large contribution to the acquisition of competitive ability at the international level.
- In the third R&D subtheme, by submitting examples of actual social implementation regarding specific and representational issues where real-time capabilities and precision are sought, we can broadly deploy the specific value of research details throughout society. By demonstrating the usage of results of digital data analyzed in a versatile and compounded manner with minimal labor, we can expect creation of new markets or promotion of participation.
- The physical space technology developed in this program will be disseminated by standardizing and opening the interface standards, thereby allowing many players in the industry to use them.
- The first and second R&D subthemes will be maintained and promoted through the establishment of consortia and the like that involve the industry through coordination with each government department, thereby contribute to the creation of new industries.

## 7. Other Important Items

### (1) Basis Law, etc.

This program is implemented based on the following: Act for Establishment of the Cabinet Office (Act No. 89 of 1999) Art. 4-3(7)3; Basic Policy on the Cost of Promoting Innovation in Science and Technology (May 23, 2014; Council for Science, Technology and Innovation); Implementation Policy for the Cross-Ministerial Strategic Innovation Promotion Program (SIP) Second Phase (FY2017 Revised Budgetary Provision) (March 29, 2018; Council for Science, Technology and Innovation); Guidelines for the Cross-Ministerial Strategic Innovation Promotion Program (May 23, 2014; Council for Science, Technology and Innovation, Governing Board); and National Research and Development Agency Act on the New Energy and Industrial Technology Development Organization, Art. 15-1(2).

### (2) Plan Flexibility

This plan shall be revised as required in the interest of maximizing and accelerating achievement of results.

## (3) PD and Assigned Personnel

### 1. Program Director

Hideyuki Saso (since Apr.2018)

### 2. Sub Program Director

Kazuya Masu (since Apr.2018)

Hiroaki Nishi (Since July 2019)

Makoto Ishida (Since July 2019)

### 3. Director General for Science, Technology, and Innovation

Toshio Tonouchi (Since Oct. 2018)

### 4. Assigned Personnel

Susumu Sugano
(Since Apr.2018)

AkioTamagawa
(Since Apr.2019)

Attachment Material: Financial Plan and Estimates

**FY2019 Total: 1,950,000,000 yen**

**(Funding Breakdown)**

1. Confirmed distribution amount for the current fiscal year (including general management expenses and indirect expenses)
   1,750,000,000 yen
2. Amount of last fiscal year's adjustment expenses (*) to be distributed 200,000,000 yen
   (*The expenses set for adjustment in FY2019 while confirming the distribution for the previous fiscal year)
3. Amount carried over from last fiscal year 942,000,000 yen

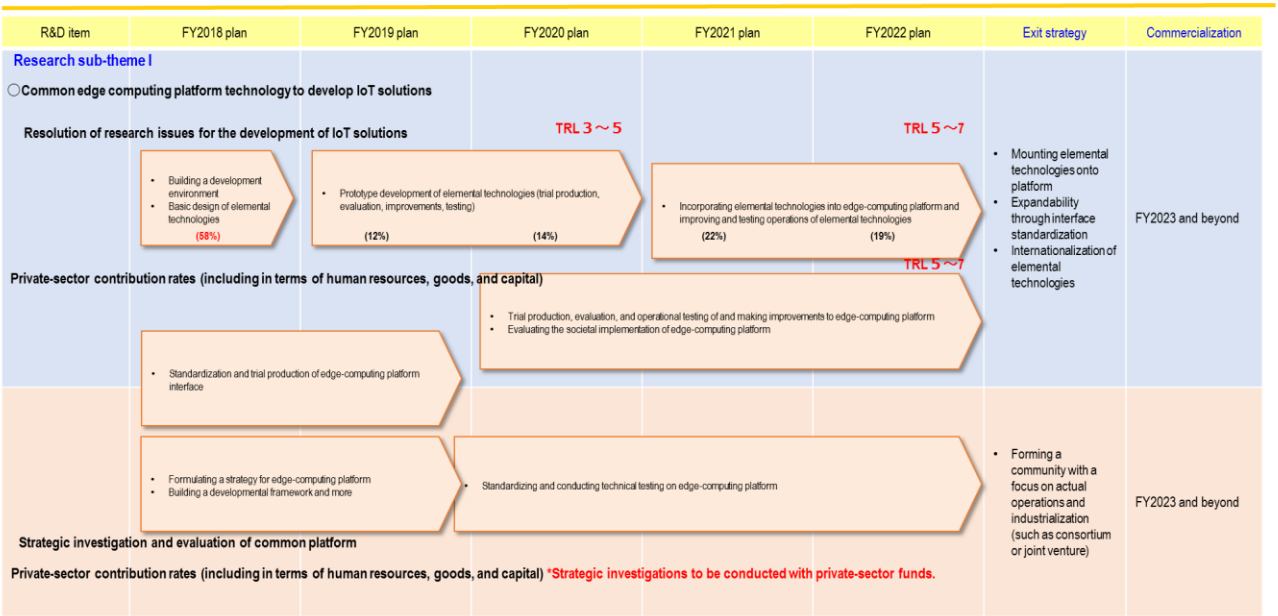
**Total 1,950,000,000 yen (confirmed distribution + adjustment expenses)**

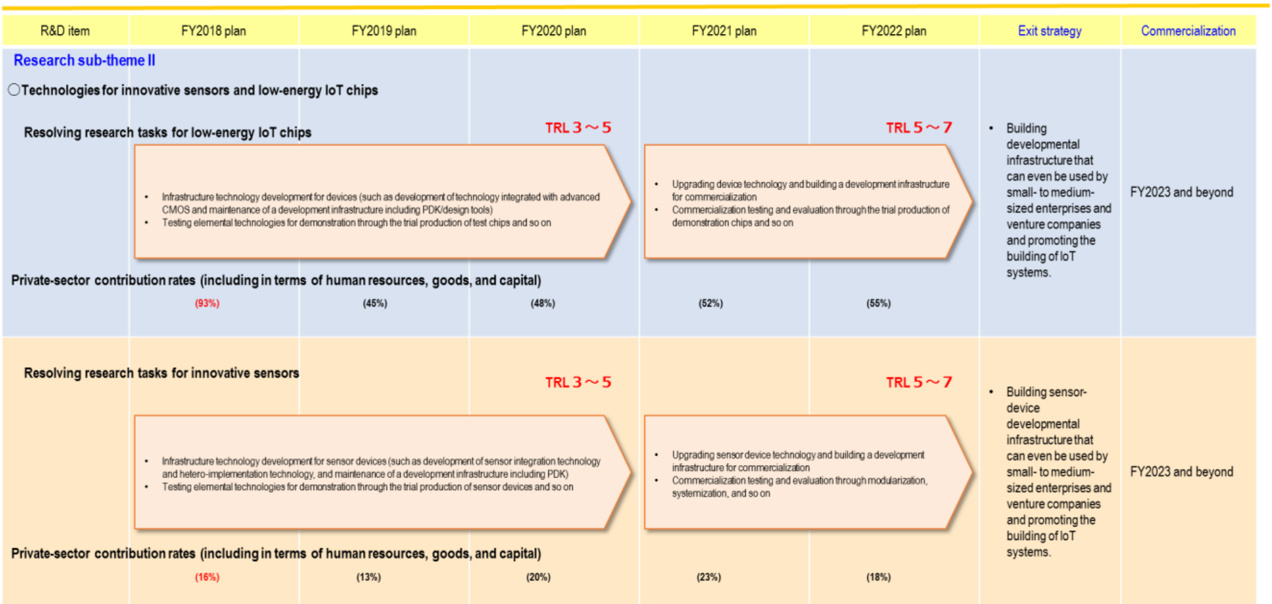
**(Expenditures)**

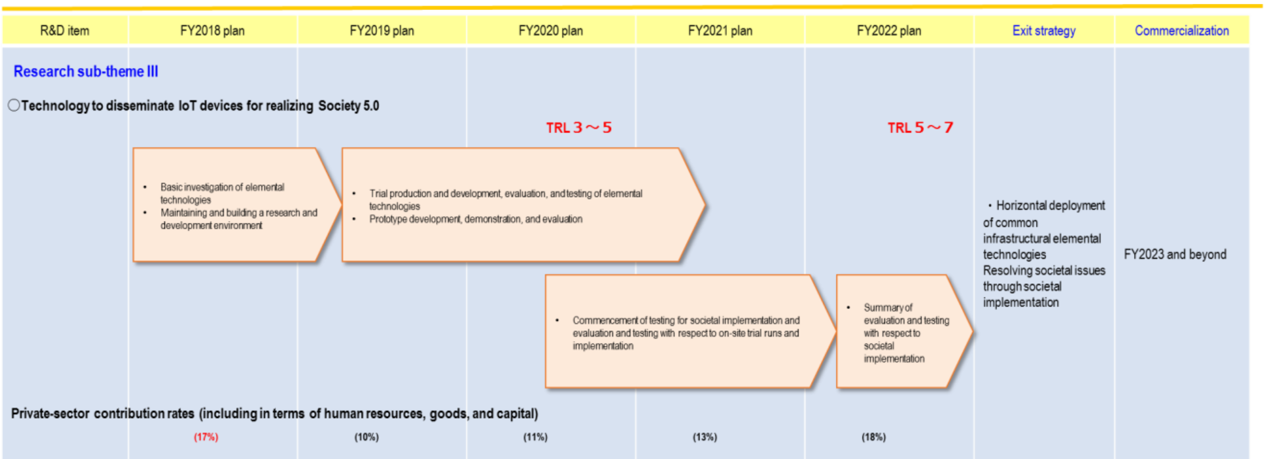
1. Research fees, etc. (includes general management expenses and indirect expenses) 2,523,000,000 yen
2. Business advancement expenses (personnel expenses, evaluation expenses, conference expenses, etc.)
   100,000,000 yen

**Total 2,623,000,000 yen (confirmed distribution)**

Schedule


R&D item
FY2018 plan
FY2019 plan
FY2020 plan
FY2021 plan
FY2022 plan
Exit strategy
Commercialization
Research sub-theme I
○Common edge computing platform technology to develop IoT solutions
Resolution of research issues for the development of IoT solutions
TRL 3～5
TRL 5～7
• Building a development environment
• Basic design of elemental technologies
(58%)
• Prototype development of elemental technologies (trial production, evaluation, improvements, testing)
(12%)
(14%)
• Incorporating elemental technologies into edge-computing platform and improving and testing operations of elemental technologies
(22%)
(19%)
TRL 5～7
Private-sector contribution rates (including in terms of human resources, goods, and capital)
• Trial production, evaluation, and operational testing of and making improvements to edge-computing platform
• Evaluating the societal implementation of edge-computing platform
• Standardization and trial production of edge-computing platform interface
• Mounting elemental technologies onto platform
• Expandability through interface standardization
• Internationalization of elemental technologies
FY2023 and beyond
• Formulating a strategy for edge-computing platform
• Building a developmental framework and more
• Standardizing and conducting technical testing on edge-computing platform
Strategic investigation and evaluation of common platform
Private-sector contribution rates (including in terms of human resources, goods, and capital) *Strategic investigations to be conducted with private-sector funds.
• Forming a community with a focus on actual operations and industrialization (such as consortium or joint venture)
FY2023 and beyond


R&D item
FY2018 plan
FY2019 plan
FY2020 plan
FY2021 plan
FY2022 plan
Exit strategy
Commercialization
Research sub-theme II
○Technologies for innovative sensors and low-energy IoT chips
Resolving research tasks for low-energy IoT chips
TRL 3～5
TRL 5～7
• Infrastructure technology development for devices (such as development of technology integrated with advanced CMOS and maintenance of a development infrastructure including PDK/design tools)
• Testing elemental technologies for demonstration through the trial production of test chips and so on
• Upgrading device technology and building a development infrastructure for commercialization
• Commercialization testing and evaluation through the trial production of demonstration chips and so on
Private-sector contribution rates (including in terms of human resources, goods, and capital)
(93%)
(45%)
(48%)
(52%)
(55%)
• Building developmental infrastructure that can even be used by small- to medium-sized enterprises and venture companies and promoting the building of IoT systems.
FY2023 and beyond
Resolving research tasks for innovative sensors
TRL 3～5
TRL 5～7
• Infrastructure technology development for sensor devices (such as development of sensor integration technology and hetero-implementation technology, and maintenance of a development infrastructure including PDK)
• Testing elemental technologies for demonstration through the trial production of sensor devices and so on
• Upgrading sensor device technology and building a development infrastructure for commercialization
• Commercialization testing and evaluation through modularization, systemization, and so on
Private-sector contribution rates (including in terms of human resources, goods, and capital)
(16%)
(13%)
(20%)
(23%)
(18%)
• Building sensor-device developmental infrastructure that can even be used by small- to medium-sized enterprises and venture companies and promoting the building of IoT systems.
FY2023 and beyond


R&D item
FY2018 plan
FY2019 plan
FY2020 plan
FY2021 plan
FY2022 plan
Exit strategy
Commercialization
Research sub-theme III
○Technology to disseminate IoT devices for realizing Society 5.0
TRL 3～5
TRL 5～7
• Basic investigation of elemental technologies
• Maintaining and building a research and development environment
• Trial production and development, evaluation, and testing of elemental technologies
• Prototype development, demonstration, and evaluation
• Commencement of testing for societal implementation and evaluation and testing with respect to on-site trial runs and implementation
• Summary of evaluation and testing with respect to societal implementation
• Horizontal deployment of common infrastructural elemental technologies
Resolving societal issues through societal implementation
FY2023 and beyond
Private-sector contribution rates (including in terms of human resources, goods, and capital)
(17%)
(10%)
(11%)
(13%)
(18%)