Application Guideline-Annex

Chapter 6 Prioritized Theme and Technology Theme for Research Proposals

R&D Type	Mission Areas for which Proposals will be Solicited	R&D period	R&D costs	page
Small-start Type (Feasibility study)	**“Advanced Intelligent Information Society” <new>** (R&D Supervisor (Program Officer): MAEDA Eisaku) Human centric digital twins services	up to two and a half years	up to JPY 35 mil.	4
	“New Social Challenges” <new> (R&D Supervisor (Program Officer): TAKAHASHI Keiko) Sustainable and resilient social system for healthy nature	up to two and a half years	up to JPY 35 mil.	8
	“Society Optimized for Diversity” <new> (R&D Supervisor (Program Officer): WAGA Iwao) Reproducible evaluation on our sequential states for social improvement	up to two and a half years	up to JPY 35 mil.	12
	“Sustainable Society” (R&D Supervisor (Program Officer): KUNIEDA Hideyo) Breakthrough technologies to accelerate breeding and strain improvement in biological production for a sustainable society	up to one and a half years	up to JPY 12 mil.	17
	“Most Safe and Secure Society in the World” (R&D Supervisor (Program Officer): TANAKA Ken-ichi) Realization of wellbeing by feedback based on psychological states evaluated by objective methods	up to one and a half years	up to JPY 18 mil.	22
	“Low Carbon Society” (R&D Supervisor (Program Officer): HASHIMOTO Kazuhito) Realization of a low carbon society through game changing technologies	up to four and a half years	up to JPY 123 mil.	29
	“Common Platform Technology, Facilities and Equipment” (R&D Supervisor (Program Officer): OSAKABE Nobuyuki) Realization of common platform technologies, facilities and equipment that create innovative knowledge and products	up to two and a half years	up to JPY 35 mil. (Component technology type: up to 23 mil.)	52
Large-scale Type	(R&D Supervisor (Program Officer): OISHI Yoshihiro) Innovative microwave measurement techniques for a safe, secure, and smart society <new>	up to nine and a half years	up to JPY 2.7 bil.	69

*R&D periods of “Small-start Type” represents terms of feasibility study. R&D costs of “Small-start Type” represents direct cost for feasibility study.
R&D costs of “Large-scale Type” represents direct cost.

6.1 Small-start Type

For small-start type, JST sets prioritized themes for proposals based on mission areas selected by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), as shown below:

① Advanced Intelligent Information Society

In recent years, the rapidly evolving digitalization, data coordination and its utilization has created a new reality in which people, organizations, logistics—in reality, almost everything—are constantly connected on a global level and mutually influence one another. In this mission area, we aim to realize a next-generation information society that enables creation of new values and immediate response to uncertain and discontinuous changes through collection of diverse and reliable data in the real world and connection with various things to them.

② New Social Challenges

Japan faces a number of issues, including public health crises such as the new COVID-19 infection, unforeseen disasters, declining birthrate and aging population, climate change, rural-urban issues, food and resource problems, aging infrastructure, and the risk of natural disasters. Besides, there is demand for appropriate responses to the changes in Japan’s security environment, and the need to increase the resilience of our land and social functions. In this mission area, we aim to solve such emerging social problems.

③ Society Optimized for Diversity

In the future, people's life is expected to be changed intrinsically. The modes of behavior and action such as transportation, business practices, and lifestyle habits will be specifically released from the constraints of physical space and time, and thus transformed. In addition, human resources that have not been able to play active parts in the past will be released from restrictions, and the social diversity will be improved. In this mission area, we aim to realize a society in which merchandises and services are optimized for various users.

④ Sustainable Society

This mission area focuses on technologically challenging targets to secure resources and food (securing stability and circulation of resources and food supplies), to realize a sustainable society as responding to a super ageing and declining population (forming healthy and longevity society using the advanced technologies, developing social infrastructure for sustainable urban and local communities, and effectively and efficiently extending life-cycles of infrastructure), to improve the manufacturing and kotozukuri (story creation) competitiveness, to reserve the biodiversity and so on. It also includes marine technologies that contribute to the sustainable development and utilization of the ocean.

⑤ Most safe and secure society in the world

This mission area responds to natural disasters; securing food safety, the living environment, industrial safety and health, and cyber security; and responding to national security problems.

⑥ Low Carbon Society

In order to achieve a significant reduction in greenhouse gas emissions by 2050, we focus on technologies for energy creation, energy storage, energy conservation, stabilization of energy use, and carbon recycling, with the cooperation of related ministries and agencies to carry out seamless research and provide development support from basic research to practical application.

⑦ Common platform technology, facilities and equipment

We will promote common infrastructure technologies and advanced research equipment that will support a wide range of diverse R&D activities.

By means of this effort, we aim to：

・ Open up new interdisciplinary areas, support Japan's basic scientific capabilities as a foundation for the world's most advanced research achievements and contribute to the creation of sustainable science and technology innovation.
・ Contribute to the improvement of the competitiveness in Japan's measurement and analytical instrumentation industry by developing creative and original technologies and instruments that will drastically replace conventional technologies and instruments.

Meanwhile, while pursuing the above aims and objectives, we will specifically prioritize R&D activities in relation to the following subjects:

(i) High-risk, high-impact, advanced measurement and analytical technologies and equipment, etc.
(ii) Development of application and systemization concerning data analysis and processing technologies
(iii) Development of technology that will contribute to increased productivity in R&D sites

6.1.1 Advanced Intelligent Information Society

New

R&D Supervisor (Program Officer: PO):
MAEDA Eisaku
(Dean/ Professor, Tokyo Denki University)

I. Goal of the Mission Area

Society 5.0[1] has been set as the society that Japan aims to become, and the Sixth Science, Technology, and Innovation Basic Plan state that the key to achieving this goal is to build every element of society as a digital twin. As the convergence of the cyber and the real is rapidly progressing, placing "Human" at the center of the system design (Human-in-the-Loop) is one of the essential requirements for Society 5.0[2]. Also, digital twins have taken the lead in the manufacturing industry, but in recent years, the scope of digital twins has been expanding, and there are growing expectations for the use of digital twins not only in cities but also in people and society[3][4].

On the other hand, the society around us is facing uncertain and discontinuous changes, such as instability of the world order caused by geopolitical changes, worsening climate change, loss of biodiversity, intensification of natural disasters, and unexpected global epidemics of infectious diseases[5]. Also, two advanced technologies, machine learning and genome editing, which have made rapid progress in recent years, will not only transform our lifestyles and industrial structures but may also determine the future of the human race. In this transitional period of great change, for individuals and society to respond appropriately to the uncertain and discontinuous changes that may occur in society, there are high expectations for the use of various data to predict the future and to support decision-making by individuals as well as a society based on such predictions.

Based on this background, this mission area aims to establish information technology that will transform all elements of society into digital twins and bring about a new way of life and behavior for humans and society, as well as to create new services based on this technology.

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1 A human-centered society that achieves both economic development and solutions to social problems through a system that highly integrates cyberspace and physical space.

2 "Principles for a Human-Centered AI Society" Cabinet Office Integrated Innovation Strategy Promotion Council (2019)

3 "Innovative Digital Twin ~Complex Phenomena Modeling for the Future of Manufacturing and Establishment of Its Advanced Design and Manufacturing Base Technology~" JST CRDS-FY2017-SP-01 (2017)

4 "DX Report - Overcoming the ~IT System "Cliff of 2025" and Full-Scale Development of DX~", Study Group for Digital Transformation, Ministry of Economy, Trade, and Industry (2018)

5 "FY 2020 Environmental White Paper, White Paper on a Sound Material-Cycle Society and White Paper on Biodiversity" Ministry of the Environment (2020)

II. Prioritized theme

Human centric digital twins services

(1) About the theme

In this prioritized theme, targeting individuals and organizations as a component of society, based on the premise of a digital twin (AI digital twin) with AI technology at its core, the project aims to: (1) create new value for emerging needs and issues, and (2) propose and realize new concepts and services on the AI digital twin.

The prioritized theme is based on the following two perspectives. First, while it is true that modern AI technology, with machine learning as its mainstay, is sweeping many industrial fields, the use of digitalization and AI technology is just at the beginning and is only being implemented on a trial basis for each field and issue, given its enormous potential. The future that we can envision and foresee today is only a small part of the possible future, and there must still be many new and unexpected ideas buried in it.

Second, the Earth has now entered the “Anthropocene” epoch, in which all regions of the planet are being affected by various human activities. Environmental changes over the past 100 years caused by human activities, such as carbon dioxide emissions and population growth, have been so explosive that the “Point of No Return” may have already been crossed. This problem will become even more apparent in the next 10 years. With this background in mind, this prioritized theme will promote research and development to solve specific problems and present a new vision of the future society by carefully picking up the social needs that lie beneath our feet and prioritizing them appropriately.

Specifically, it requires an optimal combination of technologies related to data collection, processing, conversion, and integration, which are the prerequisites for digital twinning, as well as data conversion technologies suitable for modern AI technology, intelligent integration of output results, etc., with an eye toward the future of services, in addition to the advancement of individual elemental technologies. Also, a bird's-eye view across industrial and academic fields is necessary, but such efforts are currently insufficient.

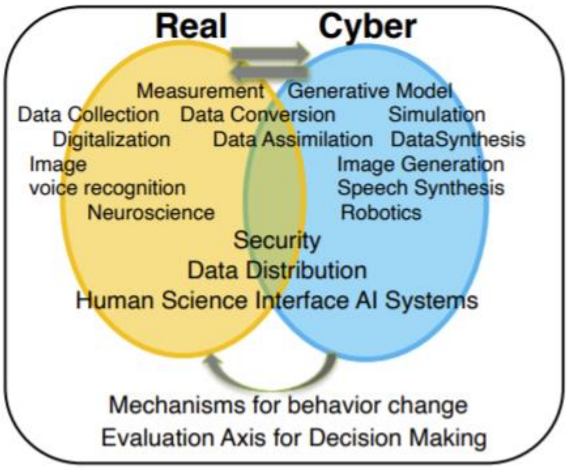

Fig. Examples of technologies to be covered by this prioritized theme

Therefore, this prioritized theme aims to create new services by combining individual technologies in the Real World (e.g., measurement, data collection), Cyber (e.g., generative model, simulation), technologies that connect the Real World and Cyber (e.g., data assimilation, security), and feedback from Cyber to the Real World (e.g., mechanisms for a behavioral change), in addition to the advancement of these technologies.

This prioritized theme covers a wide range of R&D fields based on the above perspectives. The following is a list of possible examples, but there is no need to limit the scope. R&D proposals based on original ideas that meet the objectives of this prioritized theme are welcome.

a. Disaster prevention x Digital Twin

- Large-scale simulations that incorporate geophysical data and human behavior
- Implementation of a disaster generation model that incorporates probability models
- Conduct disaster drills using the above, collect human behavior data, and provide new services to respond to disaster events.

b. Learning and Education x Digital Twin

- Propose and implement a new learning and education environment that envisions an online environment.
- Propose, implement and demonstrate evaluation indicators to induce behavioral changes in learning and education.
- Collection, analysis, and feedback of non-verbal and verbal information related to learning and education

c. Food x Digital Twin

- Visualization and control of the circulation system from production to consumption
- Propose and implement a mechanism to bring about behavioral change that leads to food loss reduction
- Element cycle, genome information, traceability

d. Healthcare x Digital Twin

- Visualization and prediction of health status based on lifestyle and history of physical and intellectual activities
- Proposal and implementation of an on-demand online medical service using a digital twin

(2) R&D Supervisor’s policies for proposal selection, and R&D management

① Policies for proposal selection

Information technology is rapidly developing, and it is an era in which original ideas and concepts can bring about great innovation. While the "Ideal Future" that governments and politicians think of is a necessary condition with as little risk as possible, and the "Desired Future" that consumers and companies think of is a scenario with hopes and expectations, it is important to think of another " Possible Future" from the perspective of researchers and engineers. The "Possible Future" can be said to be the future that is envisioned based on technological possibilities and future potential. While taking into consideration of the "Ideal Future" and "Desired Future", participants are expected to submit challenging R&D proposals based on original ideas and concepts for a "Possible Future" looking about 10 years into the future.

Please keep the following points in consideration when making a R&D proposal.

(About the scenario of the R&D proposal)

- Based on the purpose of the prioritized theme, the proposer should set the target field (e.g., industrial field as an outlet), POC (stage at which it can be determined whether a practical application is possible), indicate the requirements (e.g., peripheral technologies) for social implementation and the path for resolution.
- In the above, specify the "possible future" looking about 10 years into the future, and demonstrate the superiority and uniqueness of the R&D proposal based on science and technology that is not an extension of conventional technology, based on the proposer's strengths and domestic and international R&D trends.

- After the POC is achieved, specify how society and people's lives will change when technology is implemented in society.
- R&D proposals can be submitted even if the path to social implementation is not yet clear, as long as the original ideas and concepts are clear. Even in this case, the applicant should show objectively and concretely what is lacking at the time of the proposal and how it will be addressed during the feasibility study period.

(Presentation of goals for a feasibility study (FS) and full R&D project)

- Indicate the concept of the full R&D project, the content of the POC to be achieved in the full R&D project, as well as its social and economic impact. Also, clearly state the milestones in quantitative terms.
- A feasibility study (FS) is to confirm the feasibility of conducting the full R&D project and achieving the POC, and the participants will be required to concentrate on solving technical bottlenecks, testing hypotheses, and team building necessary for the full R&D project concept.

(About the team structure)

- It is not necessary to organize the team to cover the entire R&D concept from the beginning. Nevertheless, if there are additional requirements that need to be met during the feasibility study period to realize the concept of full R&D project, clearly indicate which researchers will need to be collaborated with and the planned activities for collaboration.
- Based on the content of the R&D proposal, applicants may be asked to plan and participate in workshops for collaboration among proposals and team-building.

② Policies for R&D management

At the R&D management committee, we will establish a management system that can provide appropriate advice and guidance through the reviews of research plans and site visits, study groups, and so on. The R&D management committee, including the R&D Supervisor, the R&D management committee members and the R&D practitioners work together to promote R&D, aiming to achieve the theme goal.

A feasibility study is to confirm the feasibility of achieving POC, conducting R&D with an emphasis on solving technological bottlenecks and testing hypotheses, consider the composition of the R&D team consisting of companies and academia that is necessary and optimal for achieving POC, and brush up the full R&D project concept in preparation for full R&D project. Also, even during the feasibility study period, the project will proactively disseminate the results of the research when high-impact research results are obtained.

③ R&D period and costs

For FY2021, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2023) and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period. Every researcher is required to undergo a stage-gate evaluation for transition to a full R&D project at the time designated by the R&D Supervisor before the end of FY2023.

A full R&D project should be planned with a period of up to five years and with a total cost of up to JPY 570 million (direct costs) for the whole period.

After adoption, we will flexibly allocate the budget according to the R&D content.

6.1.2 New Social Challenges

New

R&D Supervisor (Program Officer: PO):
TAKAHASHI Keiko
(Senior Researcher/ Professor, Waseda University)

I. Goal of the Mission Area

The global pandemic caused by the novel coronavirus disease (COVID-19) has transformed our consciousness and our way of life. We are now required to reconsider what will be the essential and what will be the challenges in shaping the world in the future, and to attempt how to make the world better. On the other hand, the explosive development of information science and technology in recent years gives us a sense of a future and will bring us new benefits.

In retrospect, it has been pointed out that the global social and economic development to date has threatened the sustainability of the global environment, and the negative effects of science and technology have also been highlighted, such as the uneven distribution of technology and wealth. Since the World Science Forum announced the Budapest Declaration (1999), which states that " The role of science in the 21st century is not only the creation of knowledge, but also the role of science for peace, development, and society," countries around the world have been promoting R&D to solve social issues, but it is noted that the results of R&D alone do not necessarily lead to solutions.

Even under these circumstances, the social issues that have been pointed out for a long time still firmly exist, and the nature of these issues is changing along with climate change, changes in global and social conditions, as well as changes in our consciousness itself. Today, social issues caused by the spread of COVID-19, such as the public health crisis and the increasing severity of natural disasters, have become more serious and more complex as multiple issues are interrelated with each other. For example, localized heavy rains cause not only direct damage to people due to flooding, but also damage to crops, houses and local industries caused by inundation, which is becoming more and more uneven and serious as a result of the shortage of workers due to the declining birthrate and aging population. The destruction and damage of renewable energy facilities and infrastructures including roads and railroads has also affected electricity and distribution, while qualitative changes in the damage to rivers and forests have also been noted. Such damage is becoming larger in scale and the time required for recovery is becoming longer. Also, the nature of the damage caused by torrential rains and its impact differs between cities and rural areas, which means that countermeasures must be different based on the characteristics of each region. We are in the midst of a turning point where we need to rethink conventional social issues from a new perspective and find new ways to solve them, with an eye to the future.

In such a turning point, social issues cannot be solved by a single technology or solution but require one to look beyond the vertical divisions/ silos of academic fields and organizations, to see the future from multiple perspectives, and to find ways to solve them. In addition to the complexity of social issues that are expected to emerge in the future, it is necessary to take into account the uncertainty of future society, economy, and environment, as well as the balance between efficiency and redundancy in constant and emergencies.

Thus, this mission area aims to analyze, integrate, and develop the required knowledge and technological development based on the relationships among multiple social issues, while designing a social system that can inclusively solve them. To achieve this, it is necessary to gather wisdom not only in science and technology, but also in collaboration with social and mathematical sciences, and to work in cooperation with companies, governments, NPOs, etc. to incorporate new values into society. Challenging initiatives are expected from young researchers and engineers who have the ambition to change society beyond the conventional academic fields.

II. Prioritized theme

Sustainable and resilient social system for healthy nature
(1) About the theme

This prioritized theme aims to build a new circulating society system that finds solutions based on scientific knowledge and technological development and feeds back the evaluation of the impact of implementing the solutions, to make human and natural environment more sustainable and resilient.

The interrelationships among social issues change not only with changes in the natural environment, but also with political, economic, and technological developments. Therefore, it is important to constantly evolve the social system rather than finding unique solutions. To achieve this, it is important to quantitatively measure, observe, analyze the interrelationships among the environment, water, biological resources, the flow of people and goods, and to design and construct a social system based on the evaluation of discontinuities and uncertainties. For example, it is required to construct and circulate a social system that can adapt to climate change based on impact assessment technology and risk management technology through the development of a multifaceted analysis system that includes trade-off elements such as human activities and ecosystem conservation, as well as extreme phenomena and outbreaks, rather than just the conventional prediction of climate change.

Furthermore, various issues such as climate change, natural disasters, food production, declining birthrate and aging population, public health, urban and rural areas, or infrastructure are interconnected, and even if one issue is solved, new issues may be triggered in the process. Therefore, it is necessary to take multiple approaches to establish social systems with multiple angles in mind.

In this prioritized theme, the emerging social issues are organized into seven categories, and the elements of digital technology, data, mathematical science, and ELSI are considered to be the foundations that support these issues (Fig.).

In FY2021, R&D proposals will be solicited with a focus on "building a social system that is prepared for a drastically changing environment and increasingly severe natural disasters," taking into account the relationship between urban and rural areas and public health, with a focus on "climate change" and "disasters," which have been pointed out as urgent global issues (Fig. ①).

Specifically, with the primary goal of solving social issues, the project will promote R&D on the development of low-cost and environment-friendly observation and measurement technologies, multi-component simultaneous analysis technologies, prediction methods for extreme phenomena, technology for evaluating the reliability of predictions, and risk management technologies, as well as on the design of social systems to prepare for changing environments and disasters by combining these technologies.

From FY2022 onward, the call-for-proposals will take a multifaceted view of various social issues and show ways to solve them, while changing its focus to "consumption and production," "food, water, and the environment," "decarbonization and energy," along with "low birthrates, aging society, and demographic changes" (Figure ②③).

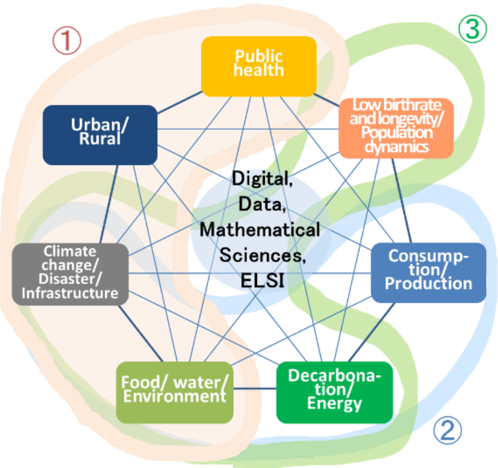

Fig. Three multiple perspectives envisioned for the seven categories and four foundations for solving emerging social issues

(2) R&D Supervisor’s policies for proposal selection, and R&D management

① Policies for proposal selection

Rather than proposals that connect conventional science and technology to the solution of social issues, <u>a proposal to design a sustainable and resilient social system that aligns the science and technology necessary to solve social issues</u> is preferred. In particular, proposals based on original ideas that would have a significant impact if realized are welcome.

In FY2021, proposals that focus on social systems to prepare for drastically changing environments and increasingly severe natural disasters will be solicited, however, those that go beyond this focus to solve multifaceted problems are also welcome.

Please indicate the following points in your proposal. Even at the stage of an idea or hypothesis, a proposal is acceptable if it logically shows what is lacking at the time of the proposal for feasibility study and what will be addressed during the feasibility study period.

- Analysis of social issues that emerge from multiple perspectives with an awareness of their interrelationships, how the results are perceived, what issues need to be resolved, how they will be resolved, and the future society (vision) after resolution
- R&D elements (scientific knowledge, data, mathematical science, technology, etc.) and social system design methods required to solve the above issues
- Recipients of the constructed social system and the POC to be achieved (the stage where it is possible to determine whether a practical application is possible)
- Ethical, Legal, and Social Issues (ELSI) to consider in building new social systems
- Analysis methods for trade-offs and synergies in implementing the proposed social system
- Superiority and uniqueness of R&D proposals based on domestic and international R&D trends, rather than an extension of conventional technologies
- Structure necessary to build a new social system (It is not necessary to have all the teams needed to achieve the POC at the time of proposal. In this case, provide an activity plan for establishing the system during the feasibility study period.)

Furthermore, since the interrelationships among social issues vary depending on the environment, society, and economic infrastructure, even if the proposal aims to build a social system for a specific area, demonstrates the possibility of cross-sectional development in an objective and logical manner.

② Policies for R&D management

At the R&D management committee, we will establish a management system that can provide appropriate advice and guidance through the reviews of R&D plans and site visits, study groups, and so on. The R&D management committee, including the R&D Supervisor, the R&D management committee members and the R&D practitioners work together to promote R&D, aiming to achieve the goal of the prioritized theme.

This mission area is not limited to technology development research that is an extension of the current seeds but challenges the solution of social issues through the construction of a new circulating society system. Since the main objective is to "Solve Social Issues", R&D elements and approaches that should be added to the construction of the social system should be considered during the feasibility study (FS) period. During the FS period, proceed with the study of R&D elements and initiatives that should be added to build the social system.

Moreover, during the FS period, it is important to collaborate not only with R&D but also with social implementation leaders such as companies, governments, NPOs, NGOs, etc., to realize the concept and POC for full R&D project. Support for finding and matching new collaborators that become necessary during the feasibility study period will be provided by the R&D Supervisor and members of the R&D Management Committee.

In the stage-gate evaluation for the transition from FS to full R&D project, it is assumed that the prospects for realization and the magnitude of the impact will be confirmed based on the R&D plan that was thoroughly examined and revised to increase feasibility during the FS period.

Since the social issues targeted by this prioritized theme offering are important not only in Japan but also internationally, the project will actively promote network building by disseminating the activities and results of the R&D projects both in Japan and internationally.

③ R&D period and costs

For FY2021, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2023) and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period. Every researcher is required to undergo a stage-gate evaluation for transition to a full R&D project at the time designated by the R&D Supervisor before the end of FY2023.

A full R&D project should be planned with a period of up to five years and with a total cost of up to JPY 570 million (direct costs) for the whole period.

After adoption, we will flexibly allocate the budget according to the R&D content.

6.1.3 Society Optimized for Diversity

New

R&D Supervisor (Program Officer: PO):
WAGA Iwao
(Professional Fellow, NEC Solution Innovators, Ltd.)

I. Goal of the Mission Area

This mission area was established based on the 6th Science and Technology Innovation Basic Plan to realize a society in which novel products and services are developed to adapt diverse individuals. To achieve the human-centered society of Society 5.0, we need to reinforce the perspective of understanding and harmonizing individuals in the society, with the development of science and technology.

The first time to read the title of this mission area, you could feel something uncomfortable as a scientific target. But, this sentence indicates the unexpected convergences of various technologies at the time of global big-change, and the requirements of novel methodology that purports to "Liberate" humanity from the constraints of the past.

To start our operation on this mission area, the first preparations have been made by interviewing about 50 experts, mainly prominent researchers in Japan. Since the Japanese name for this mission title includes “individual” which represents the basic component of our community or society, and “optimization” to imply the state of harmonized society, from these interviews we defined the term "individual" as "a complex and separate entity that can be transformed in a variety of ways depending on attributes, situations, values, etc." and "Optimization" as "a state of well-being in which the individual is freed from constraints and can fulfill his/her physical and mental needs as an individual, while at the same time fulfilling the needs of others.”

Based on these definitions, we set the long-term vision of this mission area in the following 4 steps. In 2021 we focus on the measurement of changes in the factors that constitute the state of individuals: then it is followed by the elucidation and utilization of actions that enhance the wellbeing of individuals, the measurement of the factors that constitute the state of groups and the analysis of their interrelationships, and the development of actions that lead individuals to the optimum in society, such as altruism (Fig. 1).

Fig. 1 Roadmap to the goals of this mission area

To challenge this new task, the R&D team in this mission consists of diverse membership, including gender-balanced researchers, young people, and talented people who had multi-national back grounds. In addition to engineering and medical fields, a wide range of talents such as psychology, humanities, evolutionary biology, art, and design specialists are encouraged to participate. In 2021, this project would need to compose with the number of comrades not only from universities and national research institutes, but also from small and medium-sized enterprises, large corporations, and NPOs. It is necessary to build a foundation of human network for 2022 and beyond, to promote the formation of a community ecosystem that brings in people who can empathize with and co-create with our philosophy.

In this challenge of R&D, it is also necessary to consider the diversity, such as gender, age, region, and so on. While targeting a variety of individuals, it is important to design research methods and research plans with biological, socio-economic, or psychological differences in mind.

In this era we live and the digital technologies have a great power on our life for the first time, this challenge is designed to use them not only for efficiency or automation, but the benefit of humanity. The tasks you are aiming for are not for yourself, should be the R&D for someone else. To obtain a desirable future and society by back-casting methods, R&D proposals are welcome from people who are expected to be active in academia and industry.

II. Prioritized theme

Reproducible evaluation on our sequential states for social improvement

(1) About the theme

The recent society had been optimized for "Expansion and Growth" of the human population or the economy, as represented by the growth rate of the Gross Domestic Product (GDP). The social emphasis was always based on the improving productivity or efficiency, not only on organizations but also on even each individual. In such an expansion and growth-oriented society, citizen’s life is not prioritized, and as a result, "Fragmentation", "Disparity" and "Mental Problems" are becoming more serious and popular in our society. We need to break away from the traditional old thinking ways and these problems. It is necessary to make a major shift in our consciousness and principles from the conventional expansion towards a novel society that is optimized for diversity with this research aims,

As a precedent case of the indicator to evaluate a society optimized for diversity, a well-being index is considered as a better alternative than GDP in the "Great Reset," the main theme of the World Economic Forum Annual Meeting at Davos in 2021. The OECD (Organization for Economic Cooperation and Development) also has been attempting to create an overall picture of well-being through the activities to find indicators and has developed an index (Better Life Index) to measure a well-being states of the Better Life Initiative from 2011. The World Health Organization (WHO) also defines well-being as "a state of good physical, mental, and social well-being.

In Japan, the Cabinet Office's Study Group on Well-being (established in 2010) has been studying various indicators to visualize well-being, and the Japanese Well-being Initiative, established in March 2021, is working to develop a new scale to measure well-being.

The 6th Science, Technology and Innovation Basic Plan states that "Bringing diverse happiness (well-being) to each citizen of the nation" and also "A society in which each person can realize diverse happiness (well-being)" would be a concrete image of our society (known as Society 5.0) that Japan should aim to create.

Most of the prior measurement methods of individual conditions systematized by subjective well-being in Japan and abroad are based on questionnaire-based evaluation methods. It has been proven to be useful and reliable methods for policymaking and other purposes. However, in the case of questionnaire surveys, it is difficult to grasp the changes in well-being due to external and internal factors in detail, and there is a bottleneck of ambiguity due to the lack of a quantitative method based on simple measurements. Therefore, it has not yet been applied to various industrial applications.

On the other hand, many recent technologies in engineering, information science, biology, and other fields have developed measuring methods for the state of individuals and their surrounding environment with high temporal resolution and high sensitivity from sensing data. For example, it is now possible to detect the tension of an individual in real-time by measuring multimodal biometric data such as facial expressions and heartbeats. Using these latest sensing technologies and biomarkers, it has become possible to measure the state of an individual. There are high expectations for the development of methods to quantitatively understand the optimization of individuals by combining various sensing data.

In this prioritized theme, research methods and knowledge from the humanities and social sciences, as well as analytical technologies such as sensing, machine learning, and artificial intelligence (AI), will be layered to develop technologies to measure the various well-being factors that constitute individuals and to visualize their sequential changing states. In the future, these technologies will be applied to the real world, and efforts will be made to realize the evaluation and visualization of the dynamic well-being of individuals.

(2) R&D Supervisor’s policies for proposal selection, and R&D management

① Policies for proposal selection

In preparing a R&D proposal, set up a specific scene in society, such as home, school, nursing care, business, and select major measurement targets related to the state of individuals as factors of well-being, assuming a wide variety of people in each scene. For example, a variety of factors such as emotion, motivation, self-affirmation, initiative, independence, sense of originality, gratitude, empathy, connection, and altruism can be assumed. Indicate how the target factors are related to the measurement and visualization of wellbeing (Fig. 2).

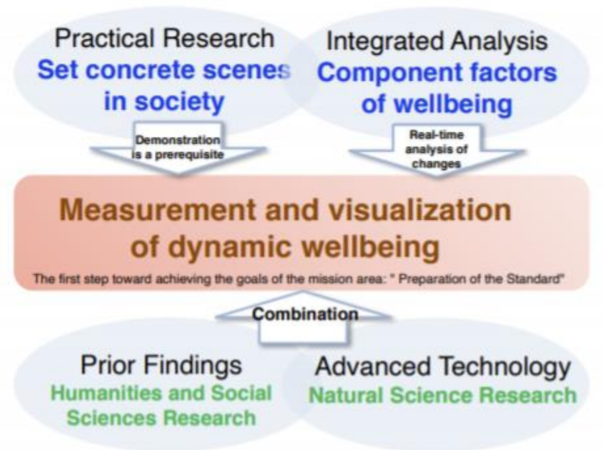

Fig. 2 Outline of this Prioritized Theme

For the selected factors of well-being (single or multiple), technology will be developed to convert them into real-time data by measuring human behavioral information (movements, patterns, etc.) and biometric information (eye contact, facial expressions, biochemistry, brain activity, etc.), while verifying the correlation with questionnaire surveys and statistical data analysis. Any measurement method is acceptable, as long as it can be adaptive for simple and useful social implementation in the end.

Furthermore, through integrated analysis of the measured factors and analysis using machine learning, artificial intelligence (AI), etc., researchers are encouraged to develop technology to accurately and reproducibly evaluate the sequential states of individuals. Methods for measuring and analyzing factors, as well as methods for dynamic evaluation from integrated analysis of factors, should be described in detail, and R&D proposals that integrate the fields of humanities, social sciences, and natural sciences, incorporating each analytical method, are actively sought. Also, the results of the factor measurement and analysis must be validated by evidence.

Social implementation within the R&D period is not required. However, R&D proposals that that lead a concrete path toward the creation of new non-profit support and commercial services that optimize the state of well-being based on the assessed and visualized individuals are actively sought.

The following points should be kept in consideration when making R&D proposals.

(Diversity)
In this mission area, the perspective of diversity in terms of gender, age, and region is emphasized. Applicants should be sure to indicate in their R&D proposals which aspects of diversity they have included. In particular, it is necessary to consider the balance of gender, age, region, in the content of R&D. Include a description of how the research methods and research plan take into account biological, socio-economic, or psychological differences among the diverse individuals involved.

(Inter-disciplinary Collaboration)
Although the R&D proposals that involve collaboration among different fields of the humanities, social sciences, and natural sciences are encouraged, it is acceptable to submit proposals in only one of these fields at the time of proposal. In such a case, provide a specific description of what is expected of the different fields from the viewpoint of strengthening the R&D proposal.

(Response to Ethical Issues)
In this prioritized theme, not only the living conditions of individuals, but also the measurement and utilization of human biometric data will be the subject of R&D, consideration of privacy, respect for the individual's will (freedom of choice, free will to consent or withdraw), physical and psychological effects, ethical issues, and institutional issues in the management or utilization of the acquired data will be assumed. To achieve the thematic goal and realize social implementation, it is possible to include how to solve these ethical issues as an additional research subject. research subject. In such a case, provide the R&D cost (including a breakdown) for the research in question, along with the specific research content and research system, in the R&D proposal. For details of the R&D costs, refer to “③ Period and R&D Costs."

② Policies for R&D management

At the R&D management committee, we will establish a management system that can provide appropriate advice and guidance through the reviews of R&D plans and site visits, study groups, and so on. The R&D management committee, including the R&D Supervisor, the R&D management committee members and the R&D practitioners work together to promote R&D, aiming to achieve the goal of the prioritized theme.

As a research management system, the research promotion (companionship) and research evaluation tasks will be separated. In the research promotion (companionship), research progress will be fully supported by experts from the same standpoint of researchers. While creating an environment where researchers can concentrate on their own project, a support team will be established to provide researchers what they need promptly, especially in the areas of cross-disciplinary collaboration and the promotion of social implementation. Also, research evaluation team will be conducted from the perspective of social impact, science, and technology based on the evaluation criteria outlined in this program.

Furthermore, regarding ethical issues, it is envisioned that efforts such as collaboration with other JST projects will be promoted in the research management to provide the necessary support.

Furthermore, after the adoption of the proposal, it is assumed that the collaboration among the adopted research and development projects will be strengthened and the system will be expanded to achieve the thematic goals. To achieve the goals of this mission area, the R&D Supervisor, the members of the R&D Management Committee, and the researchers of the R&D themes will closely share information and constructively exchange opinions on the points to be strengthened in each R&D theme, and will also promote activities to incorporate outside opinions through public events.

③ R&D period and costs

For FY2021, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2023) and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period. If the R&D proposal also covers research to solve ethical issues, a separate evaluation will be conducted after the proposal is selected, and the R&D cost will potentially be increased. Every researcher is required to undergo a stage-gate evaluation for transition to a full R&D project at the time designated by the R&D Supervisor before the end of FY2023.

A full R&D project should be planned with a period of up to five years and with a total cost of up to JPY 570 million (direct costs) for the whole period.

After adoption, we will flexibly allocate the budget according to the R&D content.

6.1.4 Sustainable Society

R&D Supervisor (Program Officer: PO):
KUNIEDA Hideyo
(Director, Aichi Synchrotron Radiation Center)

I. Goal of the Mission Area

The "Realization of a Sustainable Society" is an ultimate goal not only for Japan, but also for the whole humankind. The world has turned its goals of development towards a sustainable society rather than economic development only. It is also expressed in the Sustainable Development Goals (SDGs) of the United Nations. We now face the necessity to improve the quality of life and realize sustainable development of society at the same time.

Japan’s slow economy has been undergone over the last 20 years or longer in a changing global environment such as climate change and globalization. Many industries, especially manufacturing, in which Japan has enjoyed advantages, are found to show signs of declining international competitiveness. In addition, Japan’s population aging faster than that of other countries has begun to decrease the population of productive laborers and to increase the number of seniors who need social support. It is a fact that the sustainability of people’s lives is at risk. This mission area takes maximum advantage of science and technology to flexibly adjust changes in “environment” “society” and “economy,” and aims for realization of a higher-quality and more mature society.

The prioritized themes of this mission area take into account ideas proposed from the public and discussions with experts in various fields. These themes are considered for the goal of improving the natural environment (ecosystem services) to realize a sustainable society and the human well-being and of maximizing benefits for future generations.

In FY2017, the following two prioritized themes have been chosen: “Innovation in manufacturing for new process of sustainable resource circulation” and “Improving intellectual capability to enhance 'a Socially Active Life' for overcoming the reducing labor force.” In FY2018, “Creation of innovative food production technologies responding to future changes in climate and social demands” has been added. In FY2019, a new theme “Enhancement of product durability and usability for resource efficient society” has been added to the above themes.

In this fiscal year, we make the second call for proposals on “Breakthrough technologies to accelerate breeding and strain improvement in biological production for a sustainable society” set in FY2020.

To realize a sustainable society, the expansion of layers for future-oriented researchers and practitioners is believed to be crucial. Various research fields and stakeholders need to tackle the future as a single, united team. For that reason, this mission area actively takes on the appointment of young researchers and the construction of multidisciplinary research systems.

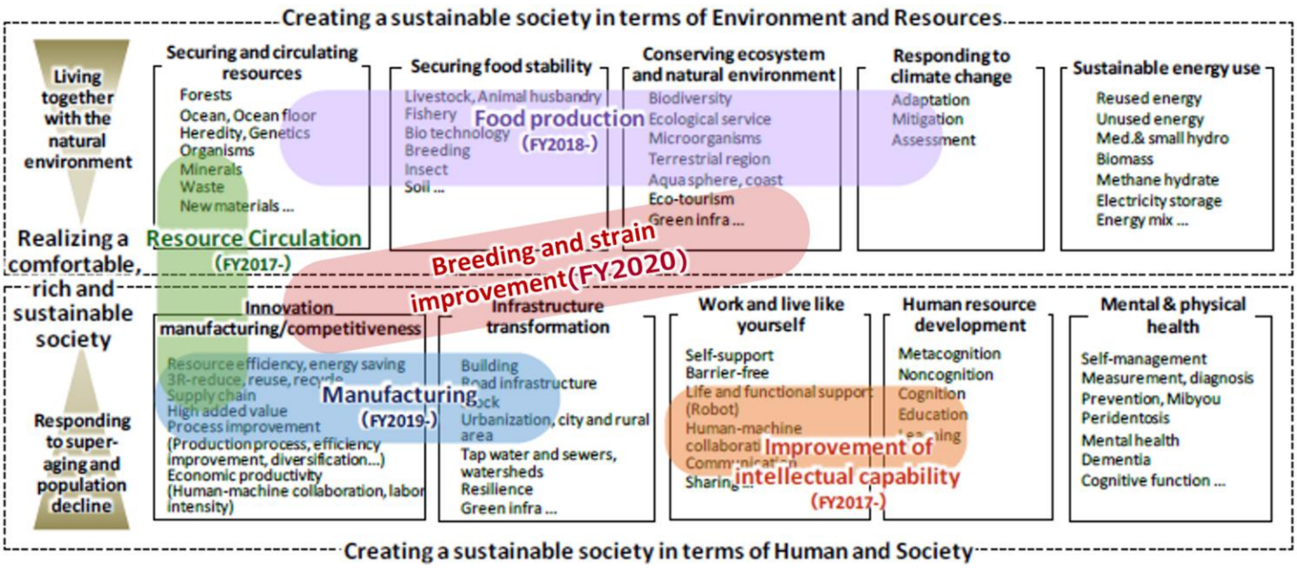

Fig.1 Designing process of the prioritized themes for the “Sustainable Society” mission area

II. Prioritized Themes

Breakthrough technologies to accelerate breeding and strain improvement in biological production for a sustainable society

(1) About the theme

This prioritized theme aims to establish technologies to accelerate breeding and strain improvement for efficient and environmentally-friendly biological production of industrial materials and foods to realize a sustainable society.

Demand for industrial materials and food is expected to increase as the rise in global population, and economic growth continues in emerging and developing countries, and more people look for better living. However, to meet the increasing demand, we need to introduce mechanisms and technologies to reduce environmental load to a meaningful level since sustainability is jeopardized due to the generation of wastes including wastewater and a high dependence on diminishing resources.

As one of these solutions, efficient and environmental load-reducing production of these industrial materials and foods is expected by making the best of the function of organisms that have been evolved and optimized over the years. In fact, many varieties have been derived so far with a wide range of technologies from mating to genetic manipulation. Especially in recent years, the emergence of technologies such as genome editing has accelerated the development speed, and attempts have been made to derive new varieties of various species. Regarding the handling of organisms subject to genome editing in Japan, modification of a gene with no exogenous genes and indistinguishable from mutations in the nature is distinguished from conventional “genetic modification” prescribed in the Cartagena Act, and excluded from regulations on labeling and safety reviews. In this manner, the environment for handling genes and resulting products is being put into place. However, gene sequences directly linked to high-efficiency production of target materials and foods have not yet been identified in many species. Even if they are identified, genome editing is not easy: there are cases where the current tissue culture method cannot be applied to plants with the same crop species but different varieties, and editing is difficult depending on the gene sequence. For these reasons, there are many cases where it is not possible to derive a new variety, or it takes time to derive with the current technology.

This prioritized theme targets establishing various technologies mainly related to the derivation of new breeds and strains of species, mainly plants, microorganisms and insects, to derive new varieties that produce highly functional industrial materials and foods with efficiency and low environmental load. Through this objective the theme aims to realize a society ensuring fulfilling life and friendly to the earth.

(2) R&D Supervisor's policies for proposal selection, and R&D management

① Policies for proposal selection

In the fiscal year 2021, the call for the theme focuses on plants, and in anticipation of the transition to full R&D project, we invite R&D proposals that can be expected to have a synergistic effect through collaboration and cooperation with the project adopted in the fiscal year 2020. The specific targets of this year's call are the expansion of genetic variation, selection of genetic variation, and fixation of genetic variation among the six steps of breeding (Figure 2).

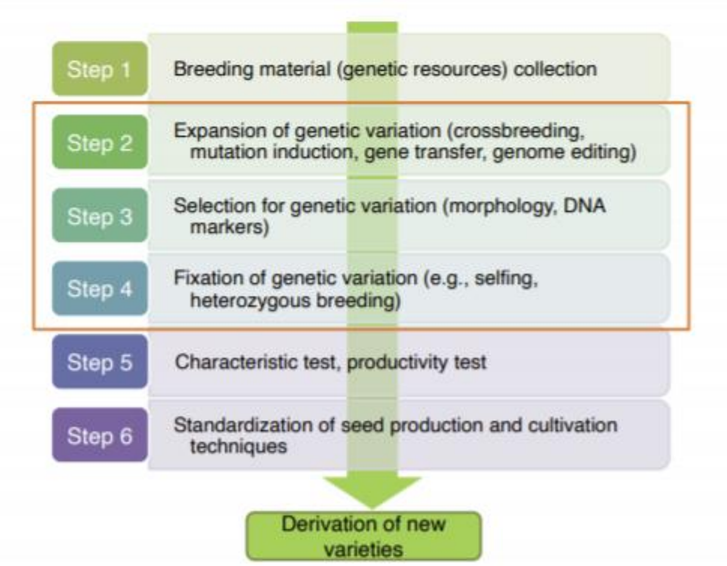

Fig. 2 The six steps of breeding improvement and the targets for FY2021

The proposal should focus on innovative science and technology to solve bottlenecks related to the derivation of new breeds and strains. It should also set the trial derivation of breeds and strains, which have high social and industrial needs and exert strong impact, but have never been realized, as objectives in full R&D project to prove the effectiveness of such science and technology. In feasibility study, R&D should focus on the solution of the largest technical bottleneck and confirmation of its feasibility, which are key points to achieve POC. In preparation for the full R&D project, the project will collaborate and cooperate with the already adopted research projects, examine the composition of the R&D team by companies and academia that is necessary and optimal to achieve POC, in addition to refinement of the full R&D project concept.

Some examples of innovative technologies focused in the proposal are listed below. However, R&D is not limited to these examples, and proposals based on a wide range of ideas and possibly exerting a strong impact once realized are welcome.

- Technology to generate beneficial mutations at target sites with high efficiency using new methods.
- Technology that dramatically improves the efficiency of genetic mutation selection by utilizing technologies from other fields.
- Innovative technology that dramatically increases the efficiency of mutation fixation.

Please be sure to include the following in the proposal documents. We strongly expect them to be as concrete and quantitative as possible.

- The concrete image of the social implementation of proposed R&D and the magnitude of realistically assumed social and industrial impact
  - If you aim to create a versatile technology, present examples of envisioned applicable breeds and/or strains and resulting industrial materials and foods with high social and industrial needs and strong impact.
- The bottleneck which is difficult to solve at present and deters the realization of the “image of social implementation” in the previous item
  - The technological bottleneck does not have to be limited to one. If there is more than one, add the difficulty and the priority of resolution to their description.
  - In addition, to the technological bottlenecks mentioned above, explain, if any, ethical, legal, and social issues (ELSI) toward social implementation of R&D results (e.g. genome manipulating technologies or industrial materials and foods produced by such technologies).
- POC (proof of concept; a stage for the society and industries to be able to judge practicability) aimed to be achieved at completion of full R&D project
  - It is necessary to clearly indicate the innovative science and technology that solve the “bottleneck” in the previous item.
  - In addition to solving bottlenecks, it is necessary to set a goal of trial derivation of breeds and/or strains for the production of industrial materials and foods.
- Goals and contents of feasibility study for full R&D project
  - The feasibility study intends to confirm feasibility for achieving POCs and should focus on solving the largest scientific and technological bottlenecks.
  - Regarding R&D that requires consideration of ELSI, it is necessary to sort out issues for social implementation and clarify the path to solving them on the basis of the consideration in the proposal.

R&D proposal to be excluded:

- Proposals that are not expected to be linked to the proposals adopted in 2020
- Proposals that target an organism other than plants
- Proposals with mere expansion of existing technology (e.g. application of existing genome editing technology to breeds and/or strains known to be applicable) as the main tool
- Proposal to spend most of R&D resources not for establishing innovative science and technology, but in topics such as large-scale database construction
- Proposals to set only the establishment of breed and strain improvement technologies (e.g. genome editing technologies) as a POC

Items for special consideration:

It welcomes challenging research proposals and newcomers from other research fields that have not yet being involved in this field. Even a research plan at the idea stage or a lower TRL study could be proposed, if the proposal objectively and specifically shows a plan in the proposal concerning what is lacking and how to overcome it during the feasibility study

② Policies for R&D management

At the R&D management committee, we will establish a management system that can provide appropriate advice and guidance through the reviews of research plans and site visits, study groups, and so on. The R&D management committee, including the R&D Supervisor, the R&D management committee members and the R&D practitioners work together to promote R&D, aiming to achieve the theme goal.

This prioritized theme considers active mergers of different fields beyond conventional scientific fields effective, because it aims for marked sustainability and stabilization of the production and supply of industrial materials and foods on the premise of creating innovative science and technology. Moreover, collaboration among business firms, society, and academia is keenly expected as it needs to lead strong social demands in the future. And for those reasons, collaboration with related domestic programs is included in promotion of R&D maximizing the outcomes.

In addition, this prioritized theme is assumed to be quickly applied to society and industry once the bottlenecks are eliminated and significant impacts on society and economy are revealed. Therefore, transition to full R&D project is positively considered even during a feasibility study period. If deemed necessary by the R&D Supervisor to maximize the social and economic impact, we may combine and integrate multiple R&D projects and improve R&D plans (including team formation, budget reallocation, or project cancellation/termination), regardless of the stage of the project (at the time of adoption or during research).

③ R&D period and costs

For FY2021, a feasibility study should be planned with a period of up to one and a half years (up to end of FY2022) and a total cost of up to JPY 12 million (direct costs) for the whole feasibility study period. Every researcher is required to undergo a stage-gate evaluation for transition to a full R&D project at the time designated by the R&D Supervisor before the end of FY2022.

A full R&D project should be planned with a period of up to five years and with a total cost of up to JPY 570 million (direct costs) for the whole period.

After adoption, we will flexibly allocate the budget according to the R&D content.

6.1.5 Most Safe and Secure Society in the World

R&D Supervisor (Program Officer: PO):
TANAKA Ken-ichi
(Senior Engineer, Mitsubishi Electric Corporation)

I. Goal of the Mission Area

Our society is changing every day. We always need to explore how to improve “Safety and Security” with the social changes.

This mission area is expected to deliver POC which provides “safety and security” to the society by various kinds of services and researches necessary for services. Above all, the most important thing is the continuity of the activities utilizing research results. To provide such continuous services, it is necessary to design a clear business model and realize a good economic cycle. For this purpose, we would like to positively seek proposals concerning services to search for comfort and pleasure in addition to positive factors without adhering to the image of reducing/eliminating factors that have been found negative in association with such a keyword as “safety and security.”

For the prioritized theme, "Realization of wellbeing by feedback based on psychological states evaluated by objective methods" launched in FY2020, we aim for the development of techniques to objectively estimate psychological states and to provide appropriate feedback according to psychological states to realize the wellbeing of individuals. In FY2021, proposals that aim to move to full R&D project by integrating with the projects adopted in FY2020 will be solicited with emphasis.

For details of the theme under which proposals are called for in FY2021 and the relationship with the prioritized themes to date, please refer to the schematic below.

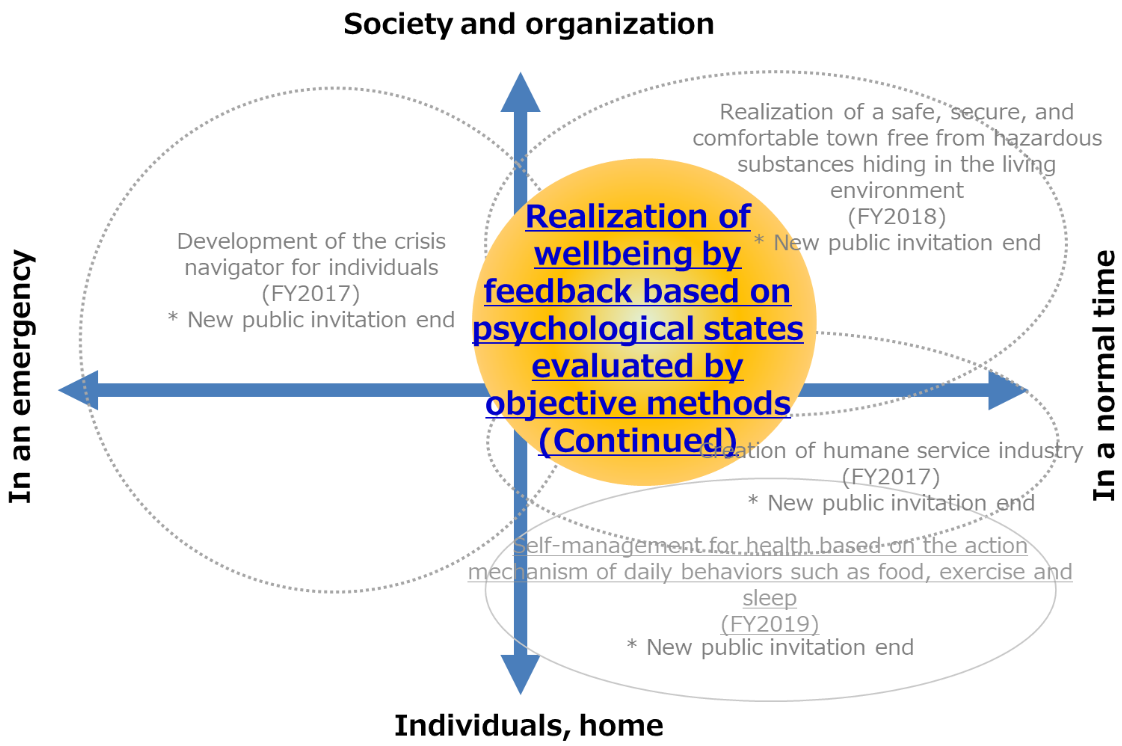

Fig. 1 Positioning prioritized themes for this mission area (outline)

II. Prioritized themes

Realization of wellbeing by feedback based on psychological states evaluated by objective methods

(1) About the theme

With the declining birthrate and aging population, it is essential in Japan to realize the wellbeing of individuals with the adequate demonstration of their abilities. For that purpose, it is important for us to meticulously understand the psychological state of individuals and groups in daily life, detect early signs of deterioration of mental health resulting from the continuation of a certain psychological state such as anxiety and depression and promote improvement, or increase motivation and concentration in learning and working by promoting positive psychological states such as delight. Accordingly, knowing various psychological states in daily life and providing an appropriate feedback will lead to the realization of the active life of individuals.

Triggered by internal factors (imagination, memories, etc.) or external factors (environmental stimuli, etc.), our psychological state changes in various ways in daily life at school or workplace, and so on. Human psychological state is represented not only by verbal expressions (linguistic information), movements and facial expressions (dynamic information), but also by biological reactions such as heartbeat, blood pressure, and body temperature that act on the autonomic nervous system. In addition, the psychological state is said to have a profound effect on certain behaviors such as buying too much and found to be closely related to the social behaviors of people.

Up to now, human psychological state has been studied mainly through behavior observation in an experimental environment and questionnaires. However, it is necessary to keep in mind that these methods include the subjective elements of the observer and the respondent, and it is difficult to know psychological states in daily life because of difficulties to follow continuously changing state of mind. Recently, technologies for detecting delight and sorrow from facial image data and visualizing delight, anger, sorrow and pleasure from heartbeat or psychological models have been developed, and technologies for objectively estimating the temporary psychological state from facial expression and heartbeat are on the way to completion. Furthermore, if long-term changes in psychological state in daily life can be followed, a sign of mental disorders or state of exaltation may be detected, but it is not yet achieved. R&D for detecting these sign and state by measuring brain activity is also in progress, but this approach is not available without changing daily life by measuring brain activity because a large-scale device such as fMRI is required.

For estimating an accurate psychological state in daily life and its changes, new objective methods are required to use data that can be measured continuously at school or workplace, etc.

It is also important to establish feedback methods for improving psychological states in daily life to realize the active life of individuals. For example, there is a need to clarify the relationship between various stimuli and people's senses, perceptions, and psychological states, such as the improvement of motivation through the interaction between the sense of touch and the sense of hearing when drawing pictures or letters with one's hands, and to promote psychological states in which each person can demonstrate his or her abilities by developing feedback methods using this mechanism.

In consideration of the above, this prioritized theme aims to develop new technologies for objectively estimating psychological states based on data that can be continuously measured in daily life and to develop appropriate feedback methods according to psychological states, to promote psychological states in which each individual can demonstrate his or her abilities, and to realize a society in which life and work are worthwhile.

(2) R&D Supervisor’s policies for proposal selection, and R&D management

① Policies for proposal selection

In this prioritized theme, technology for objectively estimating people's psychological states based on multiple data continuously measured, and appropriate feedback methods according to psychological states based on scientific evidence will be developed for implementation in daily life such as schools and workplaces.

In FY2021, a prioritized theme will be placed on soliciting R&D proposals that aim to move to full R&D project by integrating with the R&D proposals adopted in FY2020 (hereinafter referred to as "Existing Projects"). Specifically, while referring to the technology for estimating the psychological state of existing projects (Table 1), proposals are sought that set up new applications and develop effective feedback methods for appropriate improvement and promotion of the psychological state.

Table 1 Technologies for estimating the psychological state of existing projects (adopted in 2020)

Subject Name	Psychological State Estimation Techniques	
	Data Measurement	Psychological State to be Estimated.
① Mobile health technologies for the management of warning signs for depression toward reducing presenteeism	Questionnaire, lifestyle behavioral indices (amount of activity, rhythm, content, conversation, sun exposure, etc.), neurophysiological indices (heart rate, voice), neurocognitive indices, brain activity (fMRI)	Subthreshold depression (≒Presenteeism)
② Wellbeing augmentation via emotion sensing from facial expressions	Questionnaire, facial expression (electromyogram), skin electricity, saliva (cortisol), brain activity (fMRI)	Types of emotions (joy, anger, sorrow, pleasure), quality, strength quality and intensity
③ Mental optimization by interoception decoding and modulation	Questionnaire, heart rate, facial expression (gaze, pupil diameter), respiration, voice, behavior (posture, gait, sleep), brain activity (fMRI)	Perception on internal bodily conditions (Mental Condition)
④ Augmenting shared dining experiences with heartfulness practice and QOL measurements	Questions (self-monitoring), facial expression, speech, activity (volume), heart rate, biomarkers, sweating and skin conduction, electromyography	Human QOL (physiological and psychological) status and social interaction activity status
⑤ Maximization of interventional ways for promoting health by improving fatigue debt dynamics	Questionnaire, facial expression, heart rate, behavior (volume, sleep), cognitive function, blood	The dynamics of the depth and gradient of fatigue, the degree of accumulation

Reference: Summary of Existing Projects (Prioritized Theme Website)
https://www.jst.go.jp/mirai/en/program/safe-secure/theme05.html

Figure 2 shows the portfolio of applications for this prioritized theme for R&D proposals that should not overlap with existing projects. The following are examples of applications for this call: learning and education for children, mental care for adolescents and perinatal care, and human relations (including telework, etc.) for working people. The following are examples of applications for which we are seeking proposals: learning and education for children, mental care for adolescents and perinatal care, and human relations for working people (including telework, etc.), however, proposals can be made for any application for which the development and application of feedback methods can be considered.

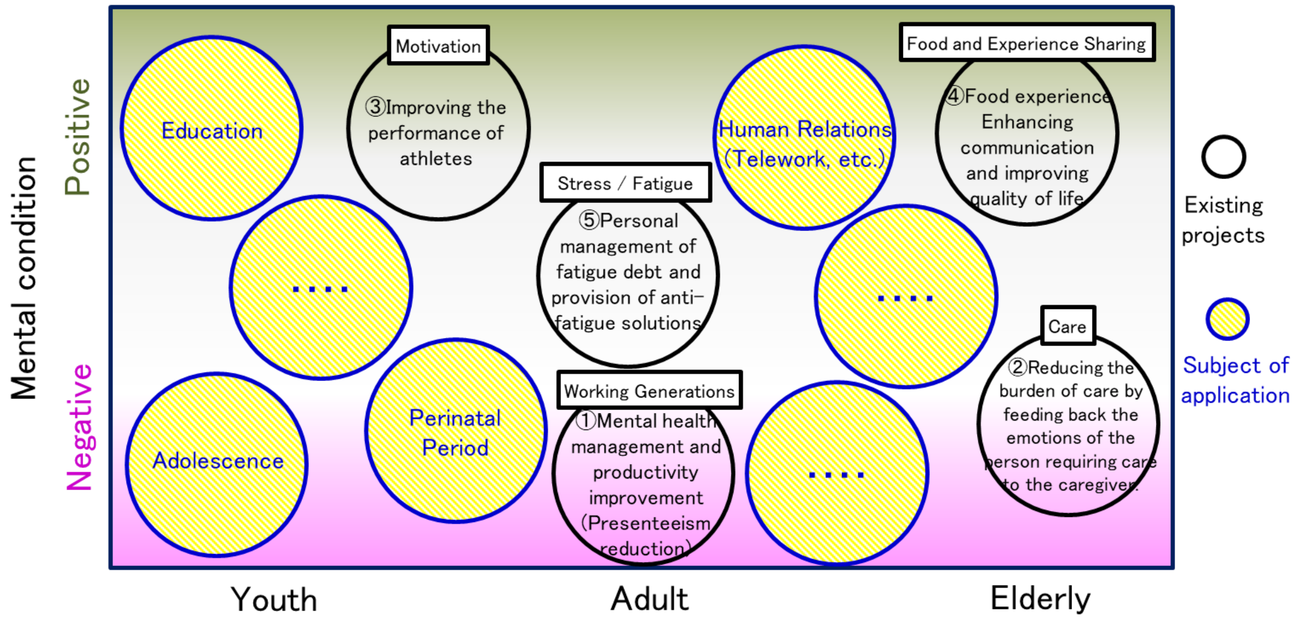

Fig. 2 Portfolio of applications for this priority application theme

In case the technology for objectively estimating the psychological state and the development of appropriate feedback methods according to the psychological state, which constitutes the R&D proposal, is similar to existing issues, the research content may be adjusted for adoption.

As in the previous year, priority is given to proposals that have a high possibility of outcome being applied to the areas other than those proposed and have a high impact. The potential areas of application and feasibility must be presented if the application is likely to be propagated to a wide range of industry.

This prioritized theme handles not only individual living conditions but also R&D including measuring and utilizing biometric information of people as well as feedback to intervene in psychological state, etc. Therefore, consideration should be given to privacy, esteem of individual willingness (freedom of choice, free will of consent and withdrawal, etc.), physical and psychological effects, and ethical and institutional issues in management and application of data obtained in the research period. Please make a concrete plan that is feasible for data acquisition in the actual environment such as daily life in sufficient consideration of these aspects. When making a proposal that involves invasion of data sensing, it is essential to sort out ethical issues and explain the necessity and the policy of countermeasures.

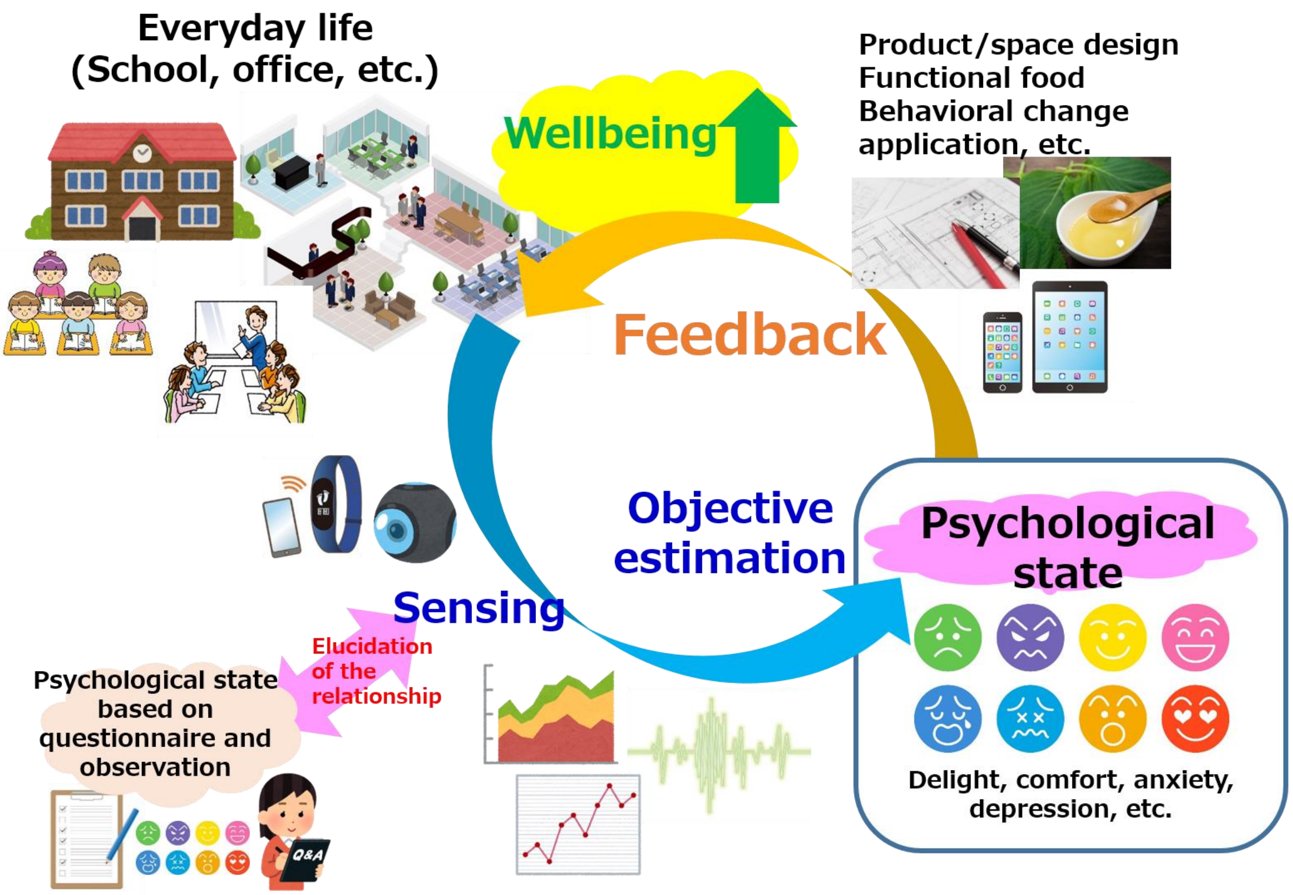

Fig. 3 The whole image that this prioritized theme aims

② **Policies for R&D management**

At the R&D management committee, we will establish a management system that can provide appropriate advice and guidance through the reviews of research plans and site visits, study groups, and so on. The R&D management committee, including the R&D Supervisor, the R&D management committee members and the R&D practitioners work together to promote R&D, aiming to realize a "society in which everyone feels protected"

R&D proposals are expected to include data processing and feedback methods in light of psychological theories and to be jointly conducted by researchers in the humanities, such as psychology and economics, the natural sciences, biochemistry, engineering, and medicine. In the transition from exploratory research to full R&D project, integration and restructuring of the team participating in the research project and the research project are also expected.

For transition from feasibility studies to full R&D projects, we may integrate or restructure the research teams participating in.

③ **R&D period and costs**

For FY2021, a feasibility study should be planned with a period of up to one and a half years (up to end of FY2022) and a total cost of up to JPY 18 million (direct costs) for the whole feasibility study period.

Every researcher is required to undergo a stage-gate evaluation for transition to a full R&D project at the time designated by the R&D Supervisor before the end of FY2022.

A full R&D project should be planned with a period of up to five years and with a total cost of up to JPY 570 million (direct costs) for the whole period.

After adoption, we will flexibly allocate the budget according to the R&D content.

6.1.6 Low Carbon Society

R&D Supervisor (Program Officer: PO):
HASHIMOTO Kazuhito
(President, National Institute for Materials Science)

I. Goal of the Mission Area

It is a global issue to build a "low carbon society," in which the emission of greenhouse gases, especially carbon dioxide (CO_2), which is a cause of the global warming problem, should be suppressed. The "Paris Agreement," adopted in the 21st session of the Conference of the Parties of the United Nations Framework Convention on Climate Change (COP21) held in December 2015, called for the parties to limit the temperature increase to less than 2°C compared to pre-industrial levels and to pursue efforts to limit it to 1.5°C. In correspondence with this agreement, the government of Japan set forth a target, "to reduce greenhouse gas emission in fiscal year 2030 by 26 % compared to fiscal year 2013," in December 2015; to attain this target, the Global Warming Prevention Headquarters has determined to make steady efforts.

In addition, the "Long-term Strategy under the Paris Agreement" (Long-term Strategy), a cabinet decision in June 2019, proclaimed a "decarbonized society" as the ultimate goal, and, with the aim of accomplishing it ambitiously as early as possible in the second half of this century, announced the government's audacious efforts toward the realization of 80% reduction of greenhouse gas emissions by 2050. Furthermore, the "Progressive Environment Innovation Strategy," compiled at the Council for Integrated Innovation Strategy in January 2020, presented roadmaps for establishing innovative technologies to accomplish the target of cutting greenhouse gas emissions in its long-term strategy, and social implementation of these technologies.

To attain this target, we need an innovative technology based on a completely new concept and science, in other words, the creation of "game changing technology."

For the creation of a game changing technology, completely new proposals made by researchers in different fields are also important, in addition to the challenging proposals that may result from the integration, utilization, and/or development of the forefront research methods by researchers in this field.

To promote the creation of a game changing technology based on the proposals for prioritized themes we called for from the general public as well as on the interviews with experts in relevant specific fields and other fields, we, in our R&D management committee, examined the prioritized theme for FY2021.

As a result, we came to a decision that it was extremely important to make continuous efforts to develop innovative technology; thus, the prioritized theme was set as a continuation from FY2020, "realization of a low carbon society through game changing technologies." Furthermore, we classified the fields of the technologies in relation to low carbon emission into four Sub-Themes; then, based on the analysis of the contents in the prioritized themes called for from the general public as well as on the "bottleneck issues" (the technological issues in implementing achievements in the society) presented FY2020, we reset our bottleneck issues to call for more R&D proposals for solving those issues.

It should be noted that “the management method by harmonized various technological seeds” has been introduced from fiscal year 2019 in Sub-Theme “④ Creation of recycling-oriented polymer materials to realize a low carbon society.” This is a new approach for creating new social values by combining technological seeds in different fields and systems for early accomplishment and social implementation of the results. For details, refer to Sub-Theme ④ in “● Description on R&D” and “● R&D period and costs.”

II. Prioritized theme

Realization of a low carbon society through game changing technologies

Sub-Theme	Classification	Bottleneck Issue
①Energy creation technology	R3-B1	Highly durable / highly efficient Pb-free perovskite solar cell
	R3-B2	Organic solar cells with conversion efficiency of 20% or more
	R3-B3	Low-cost tandem solar cells exceeding theoretical limit of single-junction solar cells
	R3-B4	New concept solar cells using nanostructures and unused energy
	R3-B5	Lightweight, flexible, high-efficiency solar cells
	R3-B6	Artificial photosynthesis aiming for dramatic improvement in efficiency
	R3-B7	Water electrolysis technology that enables sustainable hydrogen production from renewable energy sources
②Energy-saving technology based on physical/chemical processes	R3-B8	Innovative energy saving and high efficiency related technologies for electric power/power conversion systems
	R3-B9	Fundamental technologies of green electronics for energy saving data communication and data center
	R3-B10	Development of innovative thermal energy utilization technologies
	R3-B11	Process intensification using high-efficiency, high-performance separation technologies
	R3-B12	Innovation of bulk chemicals production technologies based on a new reaction field to save energy required for causing chemically difficult reactions
③Carbon neutral technology using chemical process and bio-	R3-B13	Technologies for large-scale and efficient conversion of CO_2 into methanol, olefins, and other chemicals
	R3-B14	Development of highly efficient greenhouse gas separation membrane and sorbent

technologies	**R3-B15**	Development of highly efficient biomass gasification processes for chemicals production
	R3-B16	Efficient exploration and application technology of new biological resources for a low-carbon society
	R3-B17	Technologies for improving biomass productivity with minimum resource input
	R3-B18	Synthetic biological technology and innovative bioprocess technologies for designing cells with high productivity for useful substances
④**Creation of recycling-oriented polymer materials to realize a low carbon society**	**R3-B19**	[Management method by harmonized various technological seeds] Creation of recycling-oriented polymer materials to realize a low carbon society
⑤**Other**	**R3-B20**	New approaches for a low carbon society

* “Sub-Theme” here refers to those in sub-classification of the bottleneck issues.

* Describe the names of the prioritized themes, Sub-Theme numbers (① – ⑤), Classification of Proposals (R3-B1 – R3-B20), and the names of the bottleneck issues in the “application to prioritized themes” on the cover sheet of the R&D Proposal Document (Form 1).

【Example of the description】

Prioritized theme	Realization of a low carbon society through game changing technologies ① R3-B1: Highly durable / highly efficient Pb-free perovskite solar cell

* Individual bottleneck issues are not necessarily independent and maybe interrelated, thus it is expected that an R&D proposal may relate to multiple bottleneck issues. In that case, select the bottleneck issue to which the technology is most strongly related or " ⑤ R3-20: New approaches for a low-carbon society" to be submitted.

(1) About the theme

We aim to create a game changing, innovative technology based on a completely new concept and science, and cooperate with other JST projects, endeavors by governmental bodies and others to implement our achievements in the society, satisfying the demands for services that are expected to be present in 2050 and contributing to the realization of a low carbon society where CO_2 emissions are drastically reduced. Fig. 1 shows an overview of this mission area.

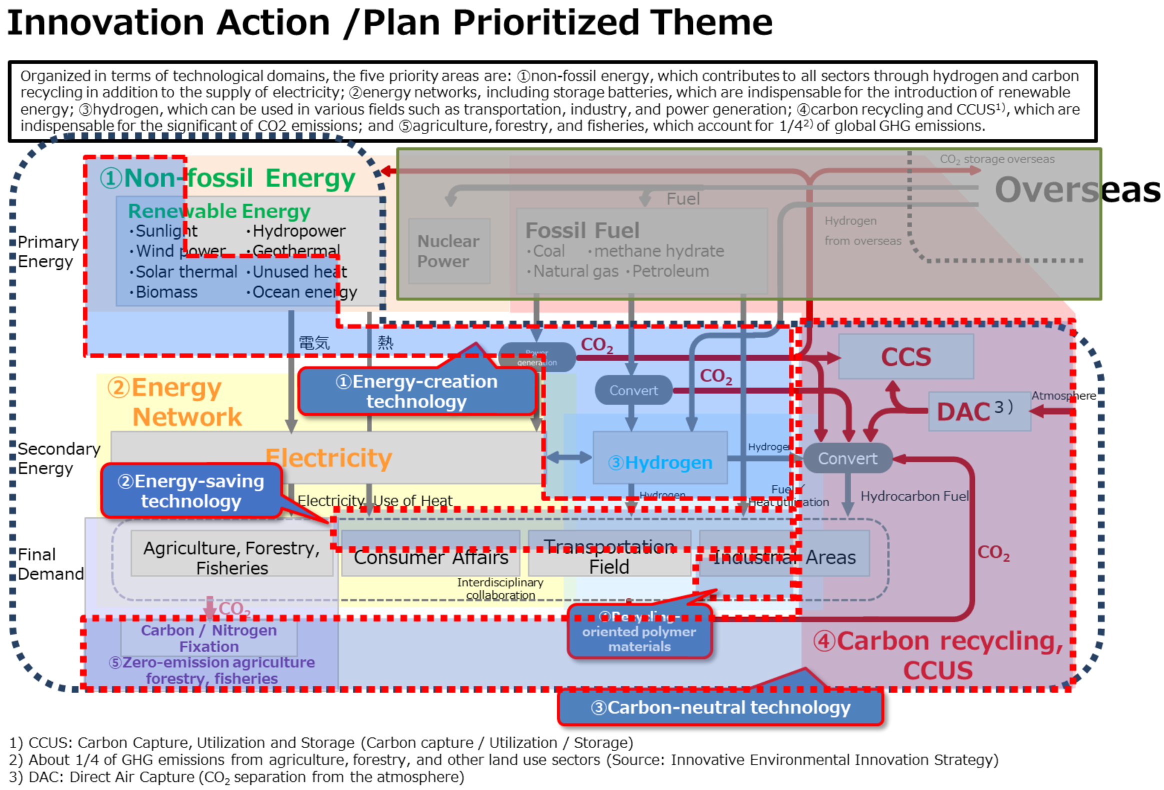

Fig. 1 An overview of the "Low Carbon Society" mission area
(Correspondence between the targets of the low-carbon society mission area and the sub-themes set in the Innovative Environmental Innovation Strategy)
Source: "Innovative Environmental Innovation Strategy" (January 21, 2020) by the Integrated Innovation Strategy Promotion Council

As mentioned above, the "Plan for Global Warming Countermeasures," a cabinet decision in the year 2016, set up a target as the strategic objective with a long-term target in view; that is, "to pursue efforts to reduce the emission of greenhouse gas by 80 % by the year 2050." To attain this target, it is "essential to create the innovation that realizes a drastic reduction in the amount of emissions in the whole world, including those technologies that are not a continuation of any conventional reduction technology;" therefore, it is one of the roles our country should play to strongly promote the mid- and long-term R&D in the field of energy and environment for realizing innovation in the reduction of CO_2 emission with wisdom gathered from the industries, academes, and governmental bodies and spreading the outcome to the world. This is also the concept included in the long-term strategy and "Progressive Environment Innovation Strategy" determined in January 2020. The concept of the creation of a game changing technology addressed in this mission area agrees with these strategies and we will promote the R&D that are closely connected to the public interest.

Furthermore, we, considering the R&D funds from the government and also the impact on the society, expect that the point of view of "the cost engineering of a low carbon technology" should be included in the proposals in this mission area. This is for the rational forecast of the technology development at the time of a low carbon technology and system being introduced in the society in the future and also for the assessment of the effect on reducing the amount of CO_2 emission; this is also an important viewpoint for attainment of the target by the year 2050, namely, the 80% reduction of greenhouse gas emissions. We hope that, with respect to the low carbon technology and system within the scope of the issues in the proposals, examinations should be made from the perspective of the cost, on the timing of the establishment of a technology as well as the timing of its industrialization, on the outlook for the market size, and on other aspects; in addition, we also hope that certain measures (scenarios) for the solution of these issues should be presented.

As for the point of view of the contribution to the international society, we can also assume, for instance, that we should use excellent technology to advance the endeavors or any other effort in cooperation with willing developing countries or any other country, such that our country may use its technological ability to play a core role in reducing the amount of CO_2 emissions around the globe. In the world of industries, the Japan Business Federation (Keidanren) has compiled the "Commitment to a Low Carbon Society" (formulated in January 2013, revised in April 2019) and established the "Development of Innovative Technology" as one of the mainstays in their plans, stating that "we also make use of the cooperation among industries, academes, and governmental bodies to proactively cope with the development and practical implementation of the innovative technology in a mid- to long-term period." We can expect that we, apart from contributing to corporations in reducing their CO_2 emissions to attain the target of reduction, may be on the direct path to the enhancement of the industrial competitiveness of Japan only if an innovative technology is created to contribute to the solution of any bottleneck issues that hinder the low carbon application aimed at in this mission area, and the technology is transferred to corporations.

(2) R&D Supervisor's policies for proposal selection, and R&D management

● Policies for proposal selection

We select proposals by following the requirements listed below to adopt the issues that meet the concept of this program (the verification of the concepts based on innovative R&D).

・To be able to make a great contribution to the reduction of CO_2 emission (beyond the point of view of science)
・To propose a technology required by corporations that will undertake the burden of its implementation in the society
・To propose innovative research that ought to be managed by universities, colleges, and/or other academic institutes

Moreover, for the sake of the implementation in the society, we, if necessary, will cooperate with other governmental bodies in other programs to transfer our achievements.

Through our endeavors stated above, we aim to create a game changing technology that will, while satisfying the expected demands for services in the year 2050, drastically reduce CO_2 emissions and, thus, we lead it to implementation in the society, contributing to the realization of the low carbon society.

● Evaluated items and norms

The selection will be based on the criteria described in "Chapter 2, 2.1.2 (5) Selection viewpoints," but in this mission area, we put an emphasis on the quantitative representation of contribution of the technology to be evaluated, including the potential amount of CO_2 reduction throughout the process in which this technology is used, to the realization of a low carbon society around 2050.

● Description on R&D

There are, roughly classified, two types of approaches to solve the global warming problem; that is, "measures for applicability" and "measures for mitigation." The former indicates the adjustment of the state of nature and/or the society to reduce the influence of the warming, whereas the latter indicates the suppression of the emission of greenhouse gas per se. For the measures for mitigation, the expectation is high with respect to the contribution by scientific technology; we, in this mission area, aim to create a game changing technology that contributes to the realization of a low carbon society based on measures for mitigation.

To this day, various trials have been performed in the course of the development of technologies that contribute to the reduction of CO_2, a large number of which have not been applied in the real world. The causes of this, i.e., "bottleneck issues," will be compiled and presented by the parties relevant to this mission area.

In this mission area, we think that completely new proposals made by researchers in different fields are also important in addition to the challenging proposals that may result from the integration, utilization, and/or development of the forefront research methods made by the researchers in this field. Therefore, based on the analysis of the contents in the prioritized themes called for from the general public, as well as on the bottleneck issues presented in the FY2020, we reset our bottleneck issues to specifically describe the contents. The four Sub-Themes (① to ④) that classify this field are shown below.

① Energy creation technology

R3-B1 Highly durable / highly efficient Pb-free perovskite solar cell

Lead-containing solar cells require specific management for their production and disposal, which increases their costs. Apart from mega-solar systems, the application for home-appliance use is also increasing; to prevent the environmental load from growing, lead-free applications are essential. Many studies have been already conducted to cope with the lead-free application to perovskite solar cells; however, currently, they have not yet achieved sufficient characteristics compared to other solar cells. In addition, it is necessary to replace solar cells in a short period if they do not have sufficient durability; therefore, what we want here is solar cells that have high durability about the same as solar cells currently in use (for 20 to 25 years). Perovskite solar cells have improved durability, owing to the optimization of materials and processes; however, this is not yet sufficient.

With these circumstances considered, we call for challenging proposals aiming to realize a perovskite solar cell that is lead-free and composed of low-environmental load materials, and has both high durability and high efficiency (more than 20% efficiency/cm^2), for example, like the following:

- Enhancement of Pb-free perovskite materials based on Sn and Bi board and development of solar cells
- Development of new structures such as Pb-free double perovskite crystals and application to solar cells
- Development and improvement of encapsulation materials and technologies that achieve high durability and realization of high-efficiency Pb-free perovskite solar cells using them

R3-B2 Organic solar cells with conversion efficiency of 20% or more

Organic solar cells have excellent characteristics such as the high film forming characteristic, light, flexible and low cost. Therefore, they are among the prospective candidates for solar cells in the future.

With similar characteristics as the solar cells, the development of perovskite solar cells is advancing; however, the organic lead, which is included in them, requires specific management for its production and disposal. This is one of the significant obstacles for the home-appliance use, beyond the application to mega-solar systems. Lead-containing perovskite solar cells can have both high short-circuit current density (Jsc) and open-circuit voltage (Voc); therefore, conversion efficiencies exceeding 20 % have been attained. On the contrary, improving the conversion efficiency of organic solar cells is said to be difficult, particularly because of the process of losing Voc. We need to solve the mechanism of such voltage loss and to construct a scenario to connect to the enhancement in efficiency; moreover, we need to develop materials that suppress the route of voltage loss based on such construction. Recently, with the development of a new non-fullerene type bulky acceptor, the conversion efficiency has rapidly improved, such as the efficiency exceeds 15% and area over 1 cm^2, and development of organic-solar cells has reached a new phase.

With these circumstances considered, it is necessary to elucidate the mechanism of the voltage loss process, construct a scenario that leads to the improvement of efficiency, and develop materials that can suppress the voltage loss process. We call for challenging proposals to realize organic solar cells that can have both greatly improved Jsc and Voc. We expect to achieve a high efficiency organic solar cells by elucidating the molecular mechanism of electron and hole-transport, developing materials and battery structures. Challenging proposals aiming for a breakthrough efficiency improvement and durability are welcome, for example, such as the following:

- Search and development of non-fullerene type acceptor materials, and production high efficiency and high durability organic solar cells
- Development and improvement of voltage loss control method for organic solar cells
- Establishment of new structure organic solar cell design method, and achievement of high efficiency and high durability

R3-B3 Low-cost tandem solar cells exceeding theoretical limit of single-junction solar cells

Tandem solar cells, in which the absorption wavelength range is expanded by stacking semiconductor materials with different bandgaps, are expected to be used as solar cells that can achieve conversion efficiencies exceeding the theoretical limit of about 30% for single-junction solar cells. However, high efficiency has been achieved only with a limited combination of materials, and sufficient conversion efficiency has not been obtained with a combination of versatile materials. It is important to develop tandem solar cells that combine low cost with high efficiency and high durability. For example, Si and CIGS solar cells (Bandgap ~1.1 eV) with high conversion efficiency and excellent durability are candidates for the bottom layer solar cells. For the top layer solar cells, semiconductor layers with a bandgap of about 1.5 to 1.7 eV are being considered as the light-absorbing layer. Also, perovskite semiconductors and organic semiconductors are promising candidates for the bottom and top layers of tandem solar cells due to their high bandgap manipulability, although R&D proposals for tandem solar cells using Pb-perovskite are possible, it is necessary to clearly show the path to Pb-free. For challenging R&D proposals aimed at achieving significant efficiency improvement and high durability of solar cells at low cost by using tandem type solar cells, taking into account the electrical and optical performance of the entire module and system for practical use, are invited. For example, the following R&D proposals are expected.

- Proposal and practice of new system structure design and optimization method considering bandgap alignment, current and voltage characteristics of junction interface and photon management, etc.

- Development and improvement of tandem solar cells such as perovskite/Si and perovskite/CIGS that do not contain elements with large environmental impact such as Pb and Cd
- Perovskite / perovskite tandem solar cells aimed at Pb-free
- Design and practice of all-organic tandem solar cells

R3-R4 New concept solar cells using nanostructures and unused energy

The theoretical maximum conversion efficiency of a single junction solar cell is about 30%. This is because ordinary solar cells cannot absorb light with energy lower than the bandgap, and excess energy is lost as heat in the case of light with higher energy. On the other hand, quantum dot solar cells can form an intermediate band within the band gap, and it has been pointed out that the majority of light energy can be converted into electricity. Therefore, intermediate band solar cells are expected to theoretically achieve efficiencies of 60% or more in a concentrating mode. However, the conversion efficiency obtained is low, and it is necessary to optimize the intermediate band materials such as quantum dots, the formation method, and the solar cell structure, in addition to fundamental studies including the validity and feasibility of theoretical models. In this category, we are inviting for challenging R&D proposals aimed at realizing solar cells with unprecedentedly high conversion efficiency through the design of solar cells using new concepts such as quantum effects and photon management, the development of materials, and cell structures based on these concepts. There are no restrictions on the materials, but the R&D proposals must demonstrate the advantages over conventional solar cells, as well as specific fabrication methods and efficiency targets. Combinations of conventional technologies, such as the combination of photovoltaic and thermal power generation, are not eligible for application. For example, R&D proposals such as the following are expected.

- High-density quantum dot system fabrication technology that achieves long carrier life and high efficiency solar cells
- Development of ultra-high efficiency solar cells utilizing new phenomena such as multi-exciton generation and hot carriers
- Development of ultra-high efficiency solar cells by photon management using photonic crystals and plasmons
- New theoretical proposal for ultra-high efficiency and its experimental practice
- Development of an unprecedented new solar cell that dramatically increases efficiency by using light and heat simultaneously

R3-R5 Lightweight, flexible, high-efficiency solar cells

With the advent of the IoT society, it is important to develop compact and lightweight power supplies that support the operation of various types of sensors and small electronic devices. Another important issue is the development of solar cells that are compatible with flexible and stretchable electronics, which are expected to develop in the future. The development of solar cells that can be installed in places where they have not been used in the past due to weight limitations and elasticity, and solar cells that can be mounted on mobile devices are also attracting attention, but the design is also required. To achieve these goals, the development of ultra-lightweight solar cells using bendable, thin, and flexible materials and substrates with high energy conversion efficiency and long-term stability is a challenge. Therefore, proposals are invited for challenging R&D aimed at the development of new thin-film solar cells that are flexible, ultra-lightweight, highly efficient, and highly durable at the same time. For example, R&D proposals for the development research and technology development of the following solar cells using ultra-thin inorganic and organic materials are expected.

- Proposal of a new structure that can suppress the decrease in solar cell efficiency due to thinning and weight reduction
- Development of Curvable, Ultra-Thin, High-Efficiency Crystalline Si Solar Cells
- Fabrication of Ultra-thin Film Semiconductors on Lightweight Film Substrates and Realization of Excellent Solar Cell Properties
- Development of ultra-thin film solar cells using new technologies such as epitaxial lift-off method
- Development of lightweight and stretchable transparent conductive films and solar cells using these films

R3-B6 Artificial photosynthesis aiming for dramatic improvement in efficiency

Artificial photosynthesis is an ultimate goal for realizing a low carbon society. The methods to activate stable small molecules such as water or carbon dioxide to convert to the useful substances such as hydrogen or methanol using sunlight, and development of catalysts that promote such converting process are the very important bottleneck issues. Another important issue is the development of fundamental technologies to convert only solar energy into energy carriers with high energy density. Projects concerning hydrogen generation by aqueous photodegradation or photochemical synthesis to produce useful substances such as methanol from carbon dioxide are called for as artificial photosynthesis projects, which are not simply for model study but 100% socially useful. In this case, it is a key to use water as an electron source, but not to use a sacrificial electron donor. In addition, these issues include the synthesis of organic chemical compounds socially useful for the society, with utilizing the electrons extracted from water, or development of the energy conserving process to significantly reduce the existing synthesis steps. We are expecting comprehensive proposals involving the isolation processes of products at such artificial photosynthesis, for example, such as the following:

- Development of new catalytic materials aiming at efficiency more than double that of conventional
- Design and development high-efficiency oxidative-reductive with suppression of charge recombination and backward electron transfer
- Development of electrodes for electrochemical reaction using photovoltaic power generation
- Development of solar utilization technology to convert ammonia and alcohol into fuel and resources

R3-R7 Water electrolysis technology that enables sustainable hydrogen production from renewable energy sources

To realize a low-carbon society, Japan is required to drastically reduce its carbon dioxide emissions (80% reduction in greenhouse gas emissions by 2050). Traditionally, hydrogen has been attracting attention as a clean energy medium (carrier) that contains no carbon and emits no carbon dioxide (CO_2) when used.

Currently, hydrogen is produced from fossil fuels such as oil and coal, but it is not a clean energy source as it is because it produces CO_2 as a byproduct during production. By applying CCS (carbon dioxide capture and storage) technology to the CO_2 byproduct, it is treated as a CO_2-free energy medium (blue hydrogen). On the other hand, CO_2-free hydrogen (green hydrogen) obtained by water electrolysis using electricity produced by renewable energies such as solar and wind power has high expectations, but there is a wide range of issues such as cost, efficiency improvement, load fluctuation response, and lifetime.

Moreover, strategic R&D are required because these technologies contain conflicting elements. For example, alkaline water electrolysis technology with low equipment cost has been commercialized for large-scale water electrolysis, but adaptation technology to fluctuating renewable energy and improvement of hydrogen production efficiency issues have been left unsolved. On the other hand, polymer electrolyte membrane water electrolysis technology is suitable for fluctuating renewable energies because of its ability to cope with frequent start-ups and shutdowns, but it requires the use of expensive precious metal electrocatalysts. To produce hydrogen on a large scale and in a sustainable manner, it is especially important to produce hydrogen from seawater that is not being used effectively by electrolysis. However, this process has not been put to practical use because of concerns about the deterioration of the equipment and the impact on the environment due to the generation of chlorine gas as it is.

In light of the above, the following technologies that can solve these problems are solicited in this bottleneck.

- Water electrolysis technology in the neutral region without using precious metal electrocatalysts
- Hydrogen production technology from seawater that does not produce chlorine

② Energy-saving technology based on physical/chemical processes

R3-B8 Innovative energy saving and high efficiency related technologies for electric power/power conversion systems

To realize a low-carbon society, energy-saving and high-efficiency power/power conversion systems are required in various fields such as mobility (automobiles, etc.), home appliances, and industrial machinery. To achieve energy saving and high efficiency in power/power conversion systems, it is necessary to develop manufacturing technologies for highly reliable and ultra-low-cost substrates of next-generation power semiconductor materials such as gallium nitride, gallium oxide, and diamond, soft magnetic materials with low iron loss and high saturation flux density for high-frequency passive elements such as inductors, and soft magnetic materials with high resistance to voltage, on-resistance, and operating speed for inverters and converters. Also, digital control, multilayer integration, and packaging technologies for circuit systems for high-efficiency drive of power/power systems are important.

In the proposals for structure, system, circuit or device development, the superiority to the existing systems should be indicated by prior theoretical prediction or estimation by simulation. In the proposals for material development, a perspective based on theoretical prediction or the results of preliminary experiments that suggest characteristics superior to the existing materials should be submitted. In both cases, the R&D plan should include a performance demonstration using prototypes.

Practical examples are shown below, but we are looking for innovative technological proposals without limited to these examples.

- Storage battery and inverter system with high efficiency and energy regeneration
- High-efficiency motor control with the low-speed operation and high responsiveness
- Soft magnetic material with characteristics exceeding Ni-Zn ferrite at a frequency of 50MHz or more
- Wide bandgap switching device that realizes high breakdown voltage, low on-resistance, and high-speed operation

R3-B9 Fundamental technologies of green electronics for energy saving data communication and data center

Toward the realization of the future society (Society 5.0) that Japan is aiming for, the volume of data communication in communication networks that collect huge amounts of sensor information (big data) attached to objects and people, such as home appliances, buildings, transportation equipment, and agriculture, is rapidly increasing. Also, the need for high-definition images is dramatically increasing in areas such as 4K/8K video content services, security, education, medical care, and the volume of data communication is continuing to increase. Furthermore, in the data centers where this data is processed in the cloud, the rapid increase in the number of high-performance chips and terminals has led to an explosive increase in the volume of communications within the data centers. If the current status quo is maintained, the power required for these data communication processes will increase exponentially, and it is predicted that it will reach 1/3 of the total power consumption in the 2030s. The development of innovative hardware that can reduce the power consumption per communication bit by several orders of magnitude is urgently needed to meet the ever-increasing communication demand and to realize a low-carbon society.

The bottleneck issues to be overcome in this technological field exist in all communication paths from the edge side to the cloud side. For example, on the edge side, it is necessary to develop power amplifiers for ultra-low power wireless communication and edge information processing devices and chips. On the cloud side, it is necessary to solve bottlenecks in information processing and communication paths using various technologies, including power-saving high-speed router devices, ultra-low power photoelectric interfaces, and power-saving communication between information processing boards and chips.

Specific examples of the proposals are shown below, but we are looking for innovative power saving technologies without limiting to these examples.

- Information processing devices for the edge based on new principles and architectures such as quantum technology and spintronics technology
- Information compression chips (edge side) that dramatically reduce the amount of data transferred to the cloud side for real-time image recognition data using AI, etc.
- Low-power LSI chip-to-chip optical interconnection and LSI interface technology with low data transfer delay
- Communication system hardware technology that significantly reduces the amount of communication power per bit

R3-B10 Development of innovative thermal energy utilization technologies

High power conversion efficiency based on the Carnot cycle can be obtained in turbines and engines that operate at high temperatures, but in the middle and low temperature region that accounts for the majority of energy consumption, the technology for using thermal energy meeting the costs for manufacturing/maintenance of the system is still not matured. So, much heat is discarded to the environment. For this reason, there is a strong demand for development of thermal power conversion technology and heat management technology such as heat transfer, heat storage, heat shielding, heat insulation, heat regeneration and heat recovery that contribute to the reduction of greenhouse gas emissions in the middle and low temperature region. Furthermore, with the acceleration of electrification and the shift to hydrogen, there is a growing social need for integrated thermal control of batteries, inverters, and motors; higher efficiency of air conditioning, oil cooling, and air cooling systems; and measures to prevent heat damage.

We call for proposals of the innovative thermal energy utilization technologies which can meet this demand. For example, they include innovative and highly efficient heat exchangers, heat transfer media with high heat transfer efficiency and excellent durability, low cost thermal storage medium and technology, highly thermally insulated/highly functional heat insulating materials, highly efficient thermoelectric conversion materials/systems, low friction interface formation/mechanism/control, and heat utilization systems including high-efficiency binary power generation using new refrigerants, optimal design and upgraded use of thermos acoustic engines, low-temperature driven heat pumps, etc. In addition to lowering the cost of each system, issues are the optimization of the shape and structure, size reduction of devices by increasing the density of the heat medium, prevention of corrosion and assurance of reaction durability. In addition, we also expect ideas for innovative thermal energy utilization technologies in a broad sense that go beyond conventional technologies. Principles of thermal energy utilization technologies to be developed, concreteness of structures, and possibility of social implementation of system maintenance and manufacturing costs are important points of evaluation.

Specific examples of the proposals are shown below, but we are looking for innovative power saving technologies without limiting to these examples.

- Chemical heat storage material with high-speed heat storage and high heat storage capacity, promotion of heat transfer in reaction layer in chemical heat storage device
- High durability super insulation that contributes to thermal management of living space, heat-shielding low-E glass, long-life vacuum insulation, and cool roof and cool load that maintains long-term performance.
- Medium structure and characteristics control that enable both low pressure loss and heat transfer enhancement in heat medium transportation
- New thermal energy storage and CO_2 recycling that contribute to P2H2P in renewable energy

R3-B11 Process intensification using high-efficiency, high-performance separation technologies

The energy consumption of production processes in the chemical industry is greatly affected not only by the manufacturing process but also by the post-process processes such as separation, recovery, and recycling of unreacted raw materials, products, and solvents.

For example, the distillation method is used for concentrating hydrous alcohol, and the cryogenic separation method is used for separating olefin / paraffin mixtures having close molecular weights, but both of them involve large energy consumption. To reduce costs, the separation, recovery, and recycling of non-reactional raw materials and solvents may be omitted in some cases because of large energy consumption. Therefore, to achieve a low-carbon society in the chemical industry, a major challenge is to review such energy-intensive processes and improve the energy efficiency of production processes.

To solve this problem, highly efficient and energy-saving separation technologies are needed to replace conventional separation methods. So far, various separation technologies such as membrane separation, phase separation, adsorption, extraction, crystallization, as well as high-performance separation processes that hybridize these technologies, and reactive separation technologies (membrane reactor, reactive absorption, reactive crystallization, reactive distillation, etc.) have been investigated. Among these, membrane separation technology is expected to replace distillation as a highly efficient and energy-saving separation technology. As the material for the separating membranes, we have a variety of options to select, including organic polymer materials, inorganic materials, organic–inorganic compound materials, and etc., however, it is necessary to establish the innovative technology beyond the conventional technologies with respect to permeability, selectivity, and durability for the practical application.

This time, in addition to the R&D of these new separation membranes, our scope includes the development of support layer for separation membranes as well as a new membrane module structure and module materials that enable energy saving and cost reduction.

At the proposal, it is given as a requirement, in addition to the clear indication of difference from theoretical values, to show superiority (prospect) over conventional process in the energy saving rate when the target technology is realized.

R3-B12 Innovation of bulk chemicals production technologies based on a new reaction field to save energy required for causing chemically difficult reactions

Reducing energy consumption in the production of bulk chemicals has become an important measure for low-carbonization in the chemical industry. C1 chemistry is a system of reactions in the production of the chemical products that come from the conversion of each type of carbon source into CO or H2, or come directly from methane material, which involve many problems. For instance, the current methanol synthesis process is a process consisting of methane steam reforming (endothermic reaction) under a high temperature exceeding 750°C and methanol synthesis reaction (exothermic reaction) at about 250°C, and has become an energy-intensive process that emits a large amount of CO_2. Research on direct methanol synthesis by oxidation of methane has been conducted, but it is not easy to oxidize low-reactive methane and stop it with highly reactive methanol, and it has become one of the highly difficult reactions. Ammonia is in great demand for a wide range of applications, including fertilizers, fibers, and chemicals These basic chemicals are expected to become energy carriers in the future, however, it is manufactured on a large scale using the energy-consuming Barber-Bosch process (400-500°C, 100-300 atm), which leads to large CO_2 emissions. To reduce the energy consumption of such energy-intensive processes and to improve the selectivity of target materials in high-level reactions, a dramatic improvement in catalyst performance is a bottleneck issue.

To reduce the energy consumption of such energy-intensive processes and to improve the selectivity of target materials in high-level reactions, a dramatic improvement in catalyst performance is a bottleneck issue.

Although development of catalysts for reducing the energy consumption of such energy-intensive processes and improving selectivity for highly difficult reactions is active, breakthroughs for dramatic improvement of catalyst performance are desired.

Generally speaking, it is assumed that a catalyst should be used in a thermal equilibrium reaction field; however, in this mission area, we focus on the development of a catalyst that is highly active in a thermal non-equilibrium reaction field or in its reaction field, which means we are calling for proposals for new reactions and reaction processes that are not observed in conventional reaction fields. As the means for supplying energy to a new reaction field, we may think of electromagnetic waves, supersonic waves, magnetic fields, electric fields, and some complex thereof. As for the reactions, our scope includes the currently ongoing reactions in which a large amount of energy is consumed for the production of general-purpose chemical products that are profusely produced, and the compatibility of a high-yield and low-energy application to the reaction that is difficult to make.

In making a proposal, it is necessary to evaluate the superiority of the new process compared to the conventional production process from the viewpoint of input energy amount and CO_2 reduction amount.

③ Carbon neutral technology using chemical processes and bio-technologies

R3-B13 Technologies for large-scale and efficient conversion of CO_2 into methanol, olefins, and other chemicals

Currently, chemicals are produced from fossil resources is the source of energy. But, being, finally, discharged into the air it becomes the source of CO_2. The ultimate ideal in the production of chemicals in our low carbon society is to embody the carbon circle, in which chemical products are synthesized from the chemical raw materials resulting in CO_2 reduction with CO_2-free hydrogen.

As one of the courses in the development of the CCS technology, the technologies to separate and collect CO_2 have been strenuously studied around the world. Some of them are in the phase of verification tests. However, except for the production of polycarbonate, the development of technology to recycle collected CO_2 (CCU) rarely advances now.

This time, proposals are called for the establishment of a technology for efficiently acquiring resources from CO_2 at a large-scale, which is one of the important elemental technologies. Specifically, our issues include the synthesis of methanol from CO_2, reaction to synthesize FT from CO_2, synthesis gas production by property improvement of CO_2, general-purpose polymer materials directly synthesized from CO_2, efficient application of the partial oxidation reaction of methane, and etc. CO_2 free hydrogen is necessary for the large-scale resource recovery of this type of CO_2, but since this technological development is a long-term issue, combination with existing technologies such as methane, which produces relatively little CO_2, is accepted in this call for proposals.

The proposal requires the clear indication of target values for efficiency and cost.

R3-B14 Development of highly efficient greenhouse gas separation membrane and sorbent

The amount of CO_2 emissions that are caused by the use of greenhouse gas, especially fossil resources, is enormous; to reduce such emissions, the development of a technology for saving energy and the moving to CO_2-free, recyclable energy have been in progress. However, we, under the current circumstances where we cannot help depending on fossil energy, the practical application of large-scale storage (CCS) and effective utilization (CCU) of CO_2 separated and recovered from large emission sources is an urgent issue.

An estimation (IEA-ETP 2017 report) that CCS should bear about 14% of the cumulative CO_2 reduction by 2060 is presented. CCS The cost of CCS depends largely on the source of CO_2 emissions, the separation/recovery method, and the storage conditions, but it is estimated to be more than 5,000 yen/t-CO_2 for the chemisorption method (using amine-based absorbent), which is currently the most widespread method. Of the CCS costs, the cost for separating and collecting CO_2 covers 50 to 60 % of the total. This is one of the bottlenecks that are preventing CCS from being accepted in general.

There are various methods for CO_2 separation and recovery such as chemical absorption method, physical absorption method, membrane separation method, cryogenic separation method, adsorption separation method, but it is necessary to develop innovative technology that surpasses conventional methods in any of the methods to achieve a significant cost reduction. Furthermore, in order to realize a decarbonized society, it is also necessary to develop the direct air capture (DAC) technology for capturing and storing CO_2 directly from the air.

As for the technology to separate or collect CO_2, we can think of various approaches, because the operating conditions and requirements vary depending on the type of fuel used for this purpose. We expect that as proponents submit their proposals, they should clarify the conditions of operation and the size, consider how close their separated energy would come to the theoretical amount of energy, and also keep a low-cost application of the operation and facility in view to develop an innovative absorbent liquid, absorbent material, and/or separating membrane. At the same time, we also include in our scope the proposals for the development of new modules that can make efficient use of these materials.

In addition, apart from CO_2, our scope also includes the technology to separate and collect other gases that have a large global warming potential.

R3-B15 Development of highly efficient biomass gasification processes for chemicals production

In order to suppress of increases in CO_2 concentration in the air, we want increasingly from the present time on, to make use of some source of carbon in the fossil resources and to recycle it. Biomass resources or the collected CO_2 are especially important as the sources of carbon; however, establishing a process to convert either of them into chemical products and/or usable fuel is one of our important issues.

When the production of existing chemical products and fuels is assumed, according to an estimation, converting biomass into gas is more prospective than using the collected CO_2 from a cost point of view (Proposal FY2017-PP-09, Center for Low Carbon Society Strategy, JST). However, as of now, even the market price of methanol, which is one of the core chemical products, is estimated to be approximately three times higher than that of those acquired in the process of biomass conversion; cost cutting is the major key to the wide and general acceptance of this process.

To realize this, we need to attain an energy-utilization efficiency of 85% or higher (cold gas efficiency) in the process of gas conversion with the well-known biomass types, and, in addition to this, we need to be able to provide a stable supply of some high-purity synthetic gas that does not have a negative influence on the downstream production processes of chemical products and fuel. By achieving these two types of technology, one can obtain a process that provides stable production of chemical products at a low cost.

We, on this occasion, also call for proposals for the research in relation to the enhancement of downstream processes, including the applications to low-cost synthetics, SAF (Sustainable Aviation Fuel) and high value-added chemical products, such as chemical products and fuel that use synthetic gas acquired from biomass conversion.

When you apply such technology to practical use, you can aim to make use of the potential of the abundant biomass resources in our country and, thus, to use domestically produced low carbon energy; you can contribute to the realization of a low carbon society and, by promoting the use of biomass, contribute to the activation of forestry as well.

R3-B16 Efficient exploration and application technology of new biological resources for a low-carbon society

Several microorganisms, such as *Escherichia coli* and yeast, are widely used for bio-production, but industrially, innovative microorganisms that are easier to use are desired and are being explored worldwide. Also, conventional microbial cultivation techniques have only been able to cultivate about 1% of the microorganisms, leaving uncultivated microbial resources. Recently, unknown microbial groups have been revealed one after another, such as the discovery of a huge biosphere in the deep underground and the deep sea, and it can be said that an enormous amount of biological resources remain untapped. Also, genetic information analysis, such as metagenomic analysis and long read analysis, has made dramatic progress in recent years, and it has become clear that there are many genes with unknown functions (dark matter), such as gene sequences that cannot be annotated with current information and non-ATG start proteins. It is important to search for these unknown microbial resources and their genes that have new functions that contribute to a low-carbon society and to develop production processes that utilize these molecules. However, it still takes an enormous amount of time and effort to discover new biological resources and understand their functions, and therefore, new technologies are expected to be developed that can simultaneously analyze gene functions and gene-gene interactions. Furthermore, Japan is rich in indigenous plant species, and discoveries of a wide variety of phytochemicals and biosynthetic genes are expected to lead to the production of useful substances. For this reason, this project invites proposals for the development of technologies to efficiently search for new biological resources (microorganisms, plants, their genes) that contribute to a low-carbon society, and applied technologies to produce new materials and energy by applying the obtained biological resources. Specifically, the following R&D proposals are possible.

- The search for and utilization of useful new microorganisms and biomolecules will revolutionize conventional bioproduction. For example, microorganisms that can store an overwhelmingly large amount of products inside the cell, microorganisms that selectively discharge products outside the cell, microorganisms that can easily capitalize on CO_2, microorganisms that can grow in an inexpensive medium as well as in a eutrophic medium, microorganisms that can maintain growth and production regardless of temperature, and microorganisms and biomolecules that can efficiently degrade and recycle compounds under low-energy conditions (e.g., low-temperature conditions).
- Search technology and application of new plant resources and plant-derived gene groups that contribute to a low-carbon society.
- Technology that uses satellite information, ecosystems, and other macro information that can be easily incorporated into consortia and cell modifications.
- Elucidation of unknown gene functions and methods for rapid analysis of gene functions, and their use. Technology that facilitates large-scale genome modification. Development of highly efficient gene transfer to plant cells and plant body regeneration technologies.
- New technologies related to bioinformatics and microbial analysis contribute to a low-carbon society.
- Microorganisms and biomolecules with energy-creating and condenser-like functions that efficiently store and release necessary energy for material circulation, and robustness to avoid stress.

R3-B17 Technologies for improving biomass productivity with minimum resource input

The methods for increasing the amount of biomass production of plants contributing to CO_2 reduction include the expansion of the habitat and productivity increment and enhancement. In either case, it is understood that the effective measures here include the feasibility of the culture with a small amount of water and nutrients and the development of plants that can sustain their yields and growth in various unsuitable environments by being extremely durable against environmental changes, and resistance against disease and vermin; however, there is no technology for any drastic solution yet. Furthermore, investing in water, nutrients, and other resources means, in other words, investing in energy; moreover, suppressing such energy investment is important from the viewpoint of energy efficiency per yield. Moreover, the states of the growing of plants are largely different depending on the difference in the soil; the difference in microbial florae may be regarded as one of the important factors to make such difference, but its clarification and its efficient control are among the issues in the future. Abiotic development such as information analysis and programs to realize these breeding is also important.

With these considerations, we are calling for proposals for the development of revolutionary plant thremmatology for growing plants even with extremely little amount of resource investments to obtain plants that are robust against the environment, for instance, such as the following:

- Development of breeding techniques by promoting the intake of substances into plants and/or the transfer in plants and enabling the use of a nitrogen source that cannot be used up until now, by adding a new metabolic pathway
- Development of technology to realize optimum design and/or breeding so that we can maintain the balance of a plant at a high level as a whole by way of some link to photosynthesis, metabolism, hormone,
- Development of technology to use microorganism agents by isolating and identifying those symbiotic microorganisms that contribute to the acceleration of growth and improve resistance against diseases and vermins, based on the understanding of the interactions with the microorganisms cohabiting with plants and the chemical compounds that can control environmental microorganism groups
- Research on identifying the optimal composition of microbial florae for excellent culturing fields; development of technology to cultivate plants that maximizes the functionality of microbial floras to establish the use of microorganism in technology to increase the production of plant biomass resources for practical use; and R&D on using genome information to modify plants.
- Information analysis with respect to the plants and soil in culturing fields, and development of data-based breeding prediction modeling program
- Development of innovative methods of producing low-energy biomass resources from the viewpoints of engineering with respect to the plants

R3-B18 Synthetic biological technology and innovative bioprocess technologies for designing cells with high productivity for useful substances

When you introduce a bio-process to the production of a substance and, thus, reduce the energy required for the production, you can expect a reduction in CO_2 emission. When you aim for the generalization of bio-processes and scaling them up, and when you advance omics analysis, system biology, flux analysis, genome editing, and genome synthesis technology, then you can introduce an artificial metabolic pathway in microorganisms and impart a new ability to produce the substance. These kinds of researches are expected to develop technologies to synthesize chemical products from a variety of sugar sources and low molecular weight gas such as CO_2 and methane. The production of substances from CO_2 by photosynthetic microorganisms is also expected.

However, even if a pathway is introduced, it has been frequently observed that we cannot attain any sufficient productivity because of factors such as the short duration, the absorption into redundancy, the failure to attain the expected degree of effectiveness, the deterioration of the growth speed caused by some disorder in the balance of metabolism in cells or of energy, oxidation, and reduction resulting from the alteration and/or introduction of the pathway. In addition, it is necessary to reduce the amount of energy input for the production of the substance; for this purpose, it is necessary to develop a new method after determining the functions of autotrophic microorganisms. Furthermore, there is another issue: target products present toxic characteristics and, thus, their productions are not feasible. There is also a hurdle to overcome in large-scale cultivation: unlike in the laboratory, tends to have low productivity.

In order to solve these issues, we are calling for proposals on developments contributing to the synthetic biological technology for the designing of cells to realize the overall optimum production of substances by, for example, combining an artificial metabolism pathway with reduced energy and power supply systems. The development of optimal microbial and cellular designs for large-scale culture is also open to the public. For instance, we are expecting the proposals such as the following.

- The development of high-efficiency ATP and/or reduced power regeneration systems that can be introduced commonly to a variety of microorganisms
- The technology to use the functions of autotrophic microorganisms, including the ability to supply electrons, the ability to supply chemical energy, and the ability of carbon fixation
- The establishment of a method that can realize an efficient creation of artificial enzymes necessary for artificial metabolism pathways
- The establishment of a rational method of designing genetic circuits that can produce even highly toxic substances with enhanced yields and energy efficiency
- The development of the designing tools for synthetic-biological designing by using the above-mentioned ways
- The development of the platform host cells suitable for synthetic-biological developments
- The development of robust microbial optimal for large-scale culture
- The new process development to easily connect / link both biological and chemical processes

④ Creation of recycling-oriented polymer materials to realize a low carbon society

R3-B19 [Management method by harmonized various technological seeds] Creation of recycling-oriented polymer materials to realize a low carbon society

There is no doubt that polymeric materials (plastics, elastomers, etc.) have provided convenience and benefits to our lives for many years since their invention and that they are useful materials in the future. On the other hand, it becomes a big problem that polymer material waste is less effectively used compared to metals etc. (effective use rate of plastic packing container waste wholly in the world is 14%[6]), in Japan is 84%[7])). Even in Japan, where the effective utilization rate of plastic container and packaging waste reaches 84%, the breakdown shows that material recycling is only 23%, chemical recycling is only 4%,

[6] "Single-use plastics: A roadmap for sustainability" (UN environmental plan, 2018)

[7] "The status of production, disposal, recycling and treatment of plastic products 2018" (Plastic Waste Management Institute)

thermal recycling is 57%, simple incineration is 9%, and landfill is 7%. Finally, 66% of the whole is incinerated and become a source of carbon dioxide gas.

The total amount of plastic produced by humanity between 1950 and 2015 reached 8.3 billion tons, but the production of plastic is increasing by 5% per year from now on. If it continues as it is, it is estimated that a total of more than 33 billion tons of plastic will be produced by 2050[8]). Therefore, if it proceeds as it is, a large amount of plastic waste will be discarded, and the problems of facility shortage and waste treatment (heat recovery and incineration) will cause CO_2 emission that affect global warming. This issue will be raised in extremely high possibility. Recently, there is concern about the outflow of plastic waste from land to the ocean, and it is predicted that plastic exceeding the weight of fish will flow into the marine environment by 2050.

In order to fundamentally solve the above concerns and problems, this time, we expect the proposal of the high-risk and high-impact fundamental research and fundamental technologies aiming “Creation of recycling-oriented polymer materials to realize a low carbon society.”

Here, “circulative polymer materials” means the polymer materials (plastics, elastomers, etc.) which can contribute to the realization of the low carbon society as the result of cyclic use in ecosystem in a sustainable manner. In order to do it, the effort to enable such materials made from limited resources to be easily reproduced is required. Specifically, biomass plastics[*1], biodegradable plastics[*2], easily recyclable plastics[*3], long-lasting plastics[*4] or similar elastomers can be mentioned. The purpose of realizing each material is as follows.

*1: Biomass plastics: carbon neutral
*2: Biodegradable plastics: Creation of materials that completely degrade the environment, and reduction of marine pollution caused by plastics.
*3: Easily recyclable plastics: reducing incineration waste by recycling
*4: Long-lasting plastics and self-healing plastic: reducing incineration frequency by long life

For these polymeric materials, the following materials and technologies for their creation can be illustrated (all materials include elastomers).

1. Biomass plastics

・Biomass-based plastics and novel monomer synthesis systems as the basis of biomass-based plastics, which have characteristics exceeding those of petroleum-based plastics in terms of high heat resistance, high strength, impact resistance, and long-term stability.
・Development of high functional materials composited with nano-cellulose
・Development of high value-added materials based on natural rubber
・Monomer synthesis technology under low environmental load conditions (aqueous system, normal temperature, and pressure, non-metal catalyst, fermentation technology)

・Production (polymer polymerization and molding) technology for materials that enable performance control of flowability, mold release, flexibility, toughness, etc., and facilitate molding and fiber conversion.

2. Biodegradable plastics

・Biodegradable plastics that have a function to respond to physical, chemical and biochemical special stimulus, and it is triggered to break down

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8 Roland Geyer, Jenna R. Jambeck and Kara Lavender Law, Production, use, and fate of all plastics ever made, Science Advances 2017; 3: e1700782 (19 July 2017)

・Biodegradable plastics in which physical, chemical and biochemical degradation functions in a continuous or parallel manner
・Biodegradable plastics in which physical, chemical and biochemical degradation rates can be controlled
・Degradation of general-purpose plastics by microorganisms
・Development of biodegradable adhesives, additives, and fillers
・Relationship between plastic structure and biodegradation bacteria and its optimization

3. Easily recyclable plastics
・A decomposition mechanism for chemical recycling is incorporated into the plastics, and activating it after recovery allows the plastics to be easily recovered as it is a low molecular weight polymer
・Development of adhesives, additives, and fillers (including biomass-derived) that facilitate material recycling, and technology for controlling the interface between composite materials

4. Long-lasting plastics and self-healing plastic
・Plastics with self-healing function and plastics of which molecular weight doesn't decrease
・Plastics that improves their performance with use
・Plastics with a controllable lifespan
・Elucidation of the function expression mechanism of the above plastics

5. Technology relating to monomer production for the synthesis (polymer polymerization) of the above plastics 1 to 4

6. Fundamental technology required to advance the above 1 to 5
・Analysis of the mechanisms of degradation, self-healing, and deterioration of plastics
・Nano-structure analysis and physical property correlation of plastics
・Data accumulation for designing above plastics and simulation technology of ideal structure using it

To achieve the above issues 1-6 regarding polymer materials and technologies, and to realize the social implementation of recycling-oriented polymers, it is important to utilize science seeds from various fields such as biotechnology, chemistry (catalysts, polymerization), analysis, database construction, and simulation, as well as research collaboration (fusion). Examples of possible fusion cases include the synthesis and degradation simulation of biodegradable plastics and the addition of self-healing functions to biomass plastics. Please describe the concept of fusion between the proposed research and other seeds (other than the research conducted in this project is also acceptable) in "6. Others" of the R&D proposal (Form 3).

* About the management method by harmonized various technological seeds

In FY2019, we introduced “management method by harmonized various technological seeds” in the Sub-Theme “④Creation of recycling-oriented polymer materials to realize a low carbon society." This is an attempt to create new social value by combining technology seeds from different fields and other systems about the technological issues which bear a large social expectation and are more challenging.

Multiple small-scale technology seeds created in different fields and other systems are selected and nurtured, and after the stage-gate evaluation, fused into a large R&D project for a specific Sub-Theme. After the fusion, team formation will be carried out to promote R&D aimed at achieving goals in full R&D project.

- In feasibility study, R&D is conducted on an individual basis, and receives the stage-gate evaluation at least once during the feasibility study period (there may be minor fusion at this stage). Large-scale fusion is based on the stage-gate evaluation at the time of transition to full R&D project with the aim of achieving the POC in a large R&D project.
- Research expenses for the selected sub-theme are different from other sub-themes. See "● R&D period and costs" below.
- Please enter the name of the other system or project in which this technology seed was created, the issue name, the R&D representative and the period in "6. Others" of the R&D Proposal Document (Form 3).

●Assumption on where achievements are applied

In this mission area, the challenging R&D are advanced for the solution of the bottleneck issues stated above; therefore, some of the technologies included here may take years to be applied to a practical use. This is why we start cooperation at early stages with other programs at JST and programs provided by other governmental bodies; besides the transfer of the achievements to the industrial sector, we will examine transferring the issues requiring further endeavors to other R&D programs that are closer to a practical application.

● Cooperation with relevant programs

We will promote the cooperation with, among the pilot research programs of NEDO, "Untrodden Challenge 2050" started in 2017. Cooperation begins in the evaluation process. To create innovative R&D for the realization of the low carbon society in the year 2050, JST promotes solutions of the bottleneck issues by mainly focusing on the fields of academia, whereas NEDO aims to solve the issues, viewing the needs of the industrial world, mainly based on cooperation between the industries and academic institutions.

● Organization for the projects

In the case of feasibility studies, we have a strong awareness of the exits while adopting challenging research themes. In the case of the assessment at the stage-gate, we assess whether research is heading for the realization of a low carbon society in the future or, namely, if a proposal contributes to the targets in this mission area. The assessments at the stage-gate are not merely the means for "sifting out proposals" but rather "for the correct awareness of the direction of excellent research and, at the same time, for its effective enhancement and growth." Therefore, this is a method of fostering the technologies that may have a great contribution to the reduction in CO_2 emission in the future.

In the phase of full R&D project, we, being well aware of "the possibility of the contribution to a low carbon society," take management to accelerate the R&D for the implementation in the society.

● Policies for R&D management

JST, since year 2010, has been continuing "Advanced Low Carbon Technology R&D Program" (ALCA). In the ALCA, we have adopted "the Small Start & Stage-Gate method" as a program that is specialized for the R&D to realize a low carbon society. This method is an endeavor for adopting a large number of relatively less budget-consuming issues when we adopt them (small start), and, once they have successfully passed our stage-gate assessment, we expand the scale of the research by placing focus on them.

Besides this, we have more endeavors such as cooperating with the Ministry of Economy, Trade and Industry and other governmental bodies in relevant programs and projects etc., providing the measures for accelerating R&D aiming at the implementation of the achievements and transferring it for practical applications in the society in around year 2030.

In this mission area, we follow the principles of the ALCA management and advance the R&D with more challenging targets, aiming to contribute to the significant reduction in greenhouse-gas emission by around the year 2050. In addition, we, as part of the ALCA, will advance R&D programs with the same goal, i.e., the realization of a low carbon society, aiming at synergy effect (Fig. 2).

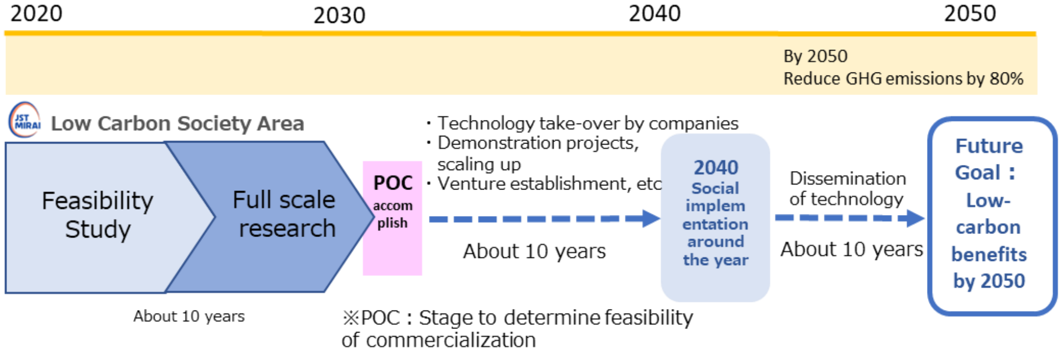

Fig. 2 A roadmap for the realization of a low carbon society

Furthermore, in this mission area, when a large impact is estimated on the society and/or the industrial world based on the solution of a bottleneck, we can expect a rapid implementation and/or application in the society and/or the industrial world; therefore, even if the period of a feasibility study is incomplete, we will proactively examine the transfer to full R&D project. Moreover, if the R&D Supervisor determines the necessity for the maximization of the social and/or economic impact, we may integrate two or more R&D issues and reorganizing research teams, etc.

● Stage-gate evaluation

In this mission area, the transition to “full R&D project” is carried out in FY2026 in principle.

In this mission area, there are two types of stage- gate evaluation, one for evaluating the progress of research (achievement of milestones) in feasibility study, and the other for evaluating whether the project can proceed to full R&D project. Each project needs to receive the stage- gate evaluation for milestones at least once prior to the stage- gate evaluation for the transition to full R&D project. The timing of the milestone and stage- gate evaluation will be decided after the adoption, by taking interviews with the responsible R&D management committee members. Depending on the progress as a result of stage- gate evaluation, the early transition to the full R&D project will be also considered.

● R&D period and costs

① Feasibility Study

For FY2021, a feasibility study should be planned with a period of up to four and a half years (up to end of FY2025) and a total cost of up to JPY 123 million (direct costs) for the whole feasibility study period. In this mission area, the initial budget is small (small start), and after the stage-gate evaluation, the budget is prioritized. In consideration of the purpose of the small start, we may request a review of the budget plan after the adoption.

② Full R&D project

In this mission area, the period and the budget for the full R&D project are determined based on the stage-gate evaluation of the feasibility study; the period of the full R&D project at the proposal phase is five years at the maximum; the upper limit of the R&D cost in your plan must be JPY 380 million (direct costs) in total, covering the whole period.

* About the management method by harmonized various technological seeds

① Feasibility Study

Plan the feasibility study period with the maximum period of up to four and a half years (up to end of FY2025), and the R&D cost of up to JPY 5.0 million (direct costs) per year. Depending on the results of stage-gate evaluation, the budget may be increased due to the narrowing of R&D issues and fusion with other issues.

② Full R&D project

Plan the full R&D project with a maximum period of five years, and the R&D cost of up to JPY 380 million (direct costs) covering the whole period (this JPY 380 million is the maximum amount for the result of the fusion of multiple issues).

6.1.7 Common Platform Technology, Facilities and Equipment

R&D Supervisor (Program Officer: PO):
OSAKABE Nobuyuki
(CSO, Smart Life Business Management Division, Hitachi, Ltd.)

I. Goal of the Mission Area

This mission area was established to cover common platform technologies supporting a wide range of R&D activities and advanced research instruments in the FY2018.

R&D has served as the fountainhead of innovative knowledge and products that impact future society. In order to strengthen the research capacity of our country currently in a disadvantaged position in terms of number of researchers and R&D budgets compared to the United States and China, we have to promote more efficient and effective R&D activities by realizing innovative common platform technology, facilities and equipment for R&D. However, the number of published papers, an indicator for R&D vigor, has not increased much in recent years. It is feared that the R&D capability of Japan may be declining with the rise of other countries and changes in Japan's demographic structure. To reverse this declining trend, it is necessary to steadily promote research to meet needs of R&D activity as well as research toward an exit to social needs.

In consideration of background as this, "Realization of common platform technologies, facilities and equipment that create innovative knowledge and products" has been set up as the prioritized theme in this mission area and the following three points are focused:

(1) Development of high-risk and high-impact advanced measurement and analysis technologies/instruments
(2) Development and systemization of applications, such as data analysis and processing technologies
(3) Technology development that contributes to improving productivity of research fields

We will aim to realize totally new values for the construction of the common platform technology to improve resolution, accuracy and throughput, etc. by integrating two achievements, i.e., the development of measurement and analysis technologies and devices (see by eye) aiming for systemization and facilitation from the above perspective and enhancement of mathematical analysis and simulation (see by machine) based on mathematical science and mathematical engineering which have rapidly developed in recent years (Fig.1).

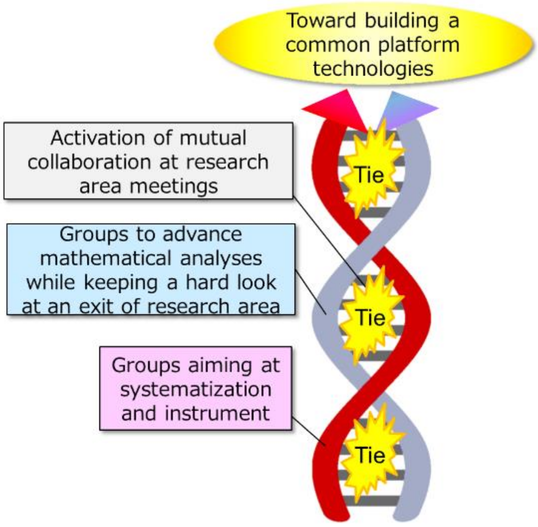

Fig.1 Policies of Mission Area management

II. Prioritized theme

Realization of common platform technologies, facilities and equipment that create innovative knowledge and products

(1) About the theme

<Background>

A disruptive technology is one which displaces an established technology and shakes up the industry or even creates a completely new industry. R&D is no exception. Existing R&D techniques are being replaced by new technologies, such as atomic level structure analysis for membrane proteins and single molecules by cryo-electron microscope, which earned Jacques Dubochet, Joachim Frank and Richard Henderson the 2017 Nobel Prize for Chemistry, massive parallel genome sequencing, and the gene editing technology like CRISPR-Cas9.

For example, the human genome project cost USD 3 Billion from 1990 through 2003, whereas next generation sequencers can analyze genomes of five persons per day with the cost of USD 1,000 apiece. The marked decrease in analytical costs expanded its applications from a technique in R&D laboratories to a medical testing technology indispensable for realization of tailor-made medicines. This technology spawned Illumina, which owns the technology and grew to a market capitalization at JPY 3.6 trillion as of March 2020.

Innovations have proceeded also in research site of materials development. An example is the “material genome initiative,” which has been promoted in the United States since 2011. It aims to take advantage of data-driven science to halve the 20-year period from material development to practical application fielding. It is a grand plan, to which more than USD 500M is said to have been invested thus far. China has followed suit by producing many results. The National Institute of Materials Science, a National R&D Agency, has played a central role in R&D in Japan.

Japan, which has fewer researchers and a smaller research budget than the United States or China, should perform efficient and effective R&D based on its basic science capabilities to improve research. This requires an innovative common platform.

<Goal>

Common platform technologies created in this mission area are expected to contribute to any of the following goals:

Goal 1: To Take Advantage of Common Platform Technologies to Improve the Research Capability of Japan
Goal 2: To Convert Common Platform Technologies to Commercialization that Strengthen the Industrial Competitiveness of Japan

This program aims for realizing the Proof of Concept (POC) within a period of full R&D project. A POC for this mission area is required to show a level in which a prototype should be used to verify usefulness of the outcome in R&D laboratories (a level of determining if corporations are capable of commercializing the outcome). The outcome of this mission area is expected to (1) improve research capabilities of Japan, and (2) lead to creation of business that can directly contribute to industry and services, thus impacting the society, in addition to the systems and equipment themselves growing to big business.

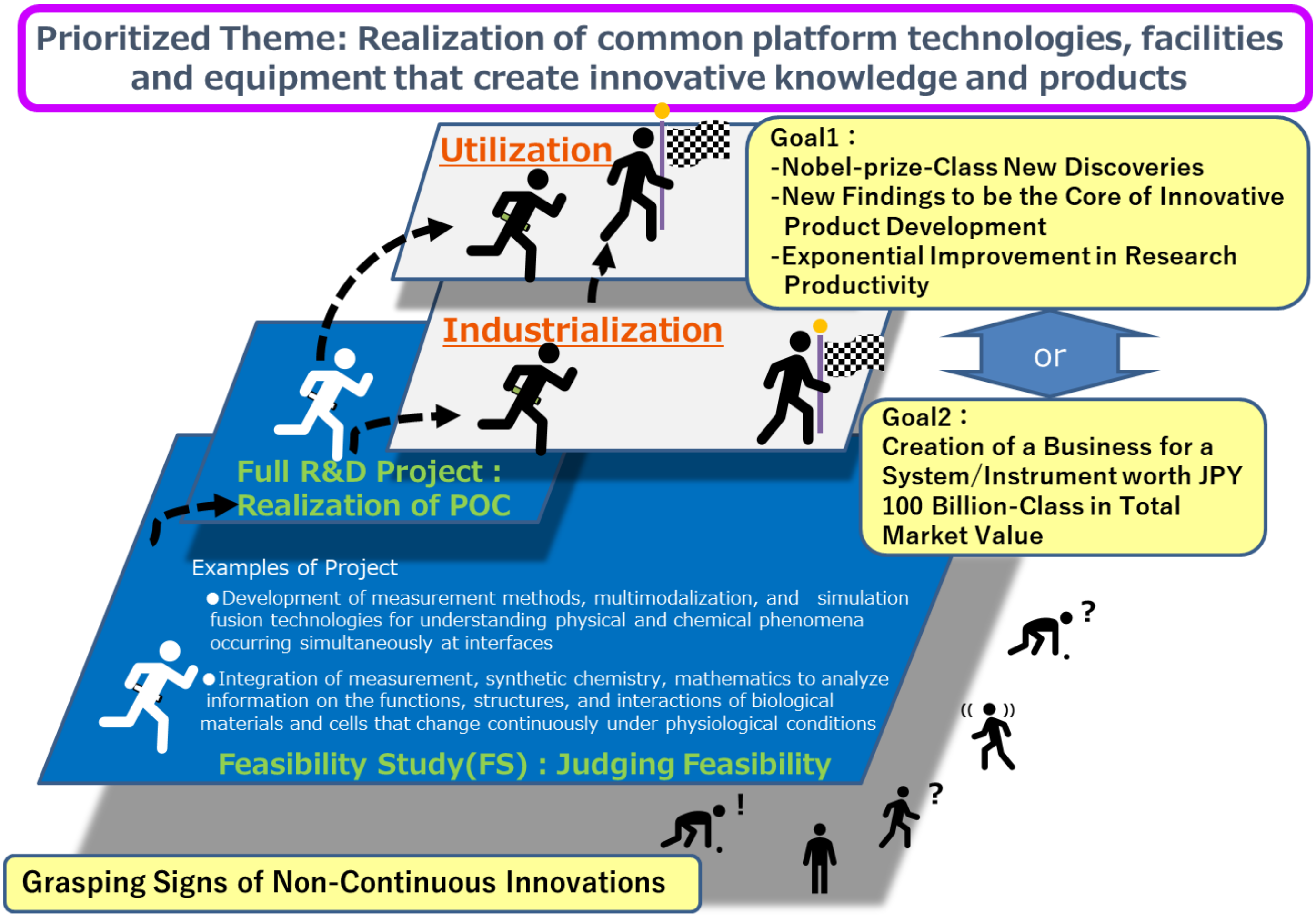

Fig. 2 Conceptual illustration of the goals of the prioritized theme and R&D phase

(2) R&D Supervisor's policies for proposal selection, and R&D management

- **Proposals up to now**

To achieve these challenging objectives of Prioritized Theme set forth in this mission area, we have to share these objectives and make progress on mutually-linked multiple issues simultaneously. To do this, ten sub-themes (Fig. 3) roughly classified according to a wide variety of research requirements were called for FY2018 based on the following three concepts:

① Development of high risk, high impact advanced measurement and analysis technologies and instruments, etc.

② Development and systemization of applications including data analysis and processing technologies

③ Development of technologies for improving productivity in research fields, etc.

In FY2019, while continuing to solicit a variety of new R&D proposals under 10 sub-themes to realize the prioritized themes, R&D in this mission area began to focus on the direction of R&D proposals, and the following two "priority proposals" were newly established and solicited. The two following proposal selection are: one for the advancement of multimodal and multiscale analysis, and the other for the advancement of high-throughput analysis for the realization of smart laboratories.

• Y01: Development of measurement and analysis technologies/instruments capable of advancing comprehensive understanding of an atom, molecule and cell up to living body/materials
• Y02: Development of innovative technology that helps reduce workload in research fields and contributes to making super high-quality experiments (sampling, cultivation, synthesis, etc.)

In FY2020, while continuing the 10 sub-themes and two "preferred issues for proposal" from FY2019, the following perspectives that were lacking in Y01 and Y02 were identified, and R&D proposals that would contribute to the fulfillment of these perspectives were adopted.

• Y01 Focus: Call for R&D proposals that contribute to the "structure and function analysis of materials and molecules under real environments" that will lead to the elucidation of the functions of material interfaces and biomolecules.
• Y02 Focus: Focuses on R&D proposals that aim to realize a smart laboratory for materials development research in preparation for full R&D project. In particular, proposals for organic material synthesis and high-throughput evaluation were selected.

● Policies for proposal selection

· In addition to the 10 sub-themes, two new "preferred issues for proposal" will be established and focused on.
· The following points are taken for new proposals aiming for transition to full R&D project in “preferred issues for proposal” (for details, refer to “Description on R&D” below):

Y01: Analysis technology for clarifying physical and chemical changes of material interfaces

To innovate products and devices with complex hierarchical structures, technologies to observe physical and chemical phenomena at interfaces using advanced and multimodal measurement technologies and to understand the gaps between multi-scale phenomena by combining simulation (coupled analysis) based on proposal selection are sought.

*Applicable call categories: Sub-themes ST03, ST04-06, ST09

Y02: Analysis technology for clarifying expression mechanism of biological function and interaction under physiologic condition

To create analytical instruments and drugs based on the technologies to measure the factors that cause the dynamics and interactions of substances, intracellular organelles, and cells that are continuously changing under physiological conditions, and to elucidate the mechanisms of biological functions and interactions by combining analysis methods of acquired data, molecular dynamics (MD) methods, etc. are welcomed.

*Applicable call categories: Subthemes ST04, ST03, ST05-06, ST09

· Regarding “component technology type,” proposals are limited to ST09 “Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data” same as FY2020.
· Six to nine proposals are planned to be adopted.

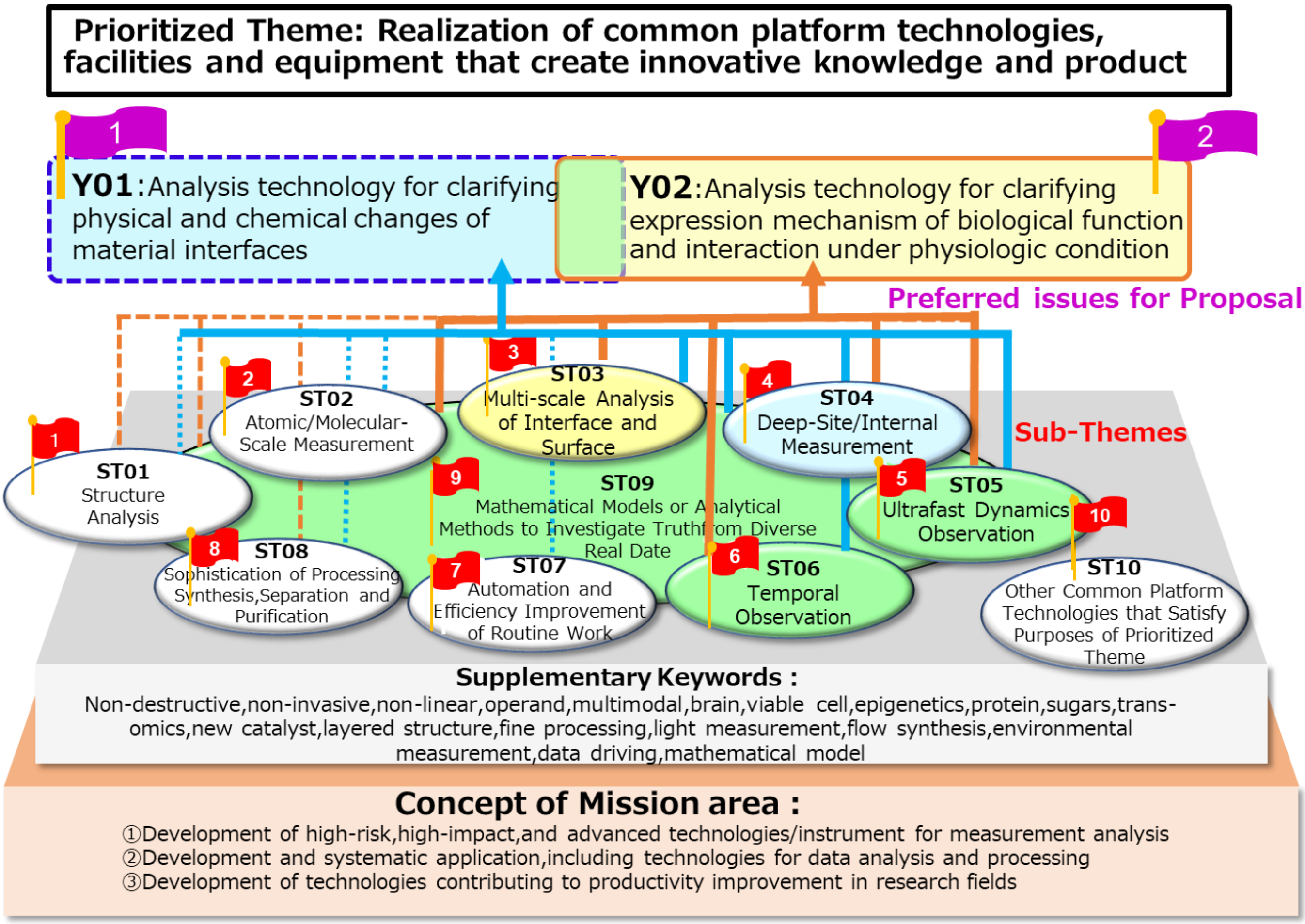

Fig. 3 Preferred issues for proposal and sub-themes in the "Common Platform Technology, Facilities and Equipment" mission area (FY2021 version)

● **Proposals for Component technology type**

In addition to research proposals aiming for transition to full R&D project, proposals of "Feasibility Study (Component Technology Type)," which contributes to the achievement of the prioritized theme in full R&D project in this mission area, are called for (for details, see "2.1.1 About the "Small-start Type" and "2.1.3/2.1.5 Guidelines for entry in "Small-start Type (Component technology type)" R&D proposal documents (forms)").

The R&D representative who performs the component technology type R&D <u>is asked to take on the R&D and introduce the outcome into full R&D project under the prioritized theme, not transfer the outcome itself to full R&D project, and establish a component technology for achieving the POC.</u>

Proposals on component technology type are limited to ST09 "Mathematical models or analytical methods to investigate truth from diverse real data." Details are shown in in the description of ST09.

(Note)
Proposals for FY2021 on the component technology type are limited to ST09. It should be noted that proposals for ST01 to ST08, ST10, and Y01 to Y02 are not accepted, and <u>the application is not evaluated if it is for any of those which are excluded.</u>

The research representative in this mission area is recommended to carry out R&D while taking advice from the theme manager.

● **Theme Managers**

Theme Manager
AIHARA Kazuyuki
(University Professor, Office of University Professor, The University of Tokyo)

Theme Manager
OKAJIMA Hiroshi
(Project General Manager, R&D and Engineering Management Div., Advanced R&D and Engineering Company, Toyota Motor Corporation)

Theme Manager
SATO Taka-aki
(Senior Fellow, Director, Life Science Research Center, Technology Research Laboratory, Shimadzu Corporation/Director, Center for Precision Medicine, University of Tsukuba)

● **Description on R&D**

In FY2021, relevant technologies to the following two “preferred issues for proposal” will be requested as described in the Policies for proposal selection.

Also, excellent proposals that conform to the Sub-Themes to be described hereinafter will be applicable to adoption regardless of relevance to the two issues listed below. For both R&D proposals, it is requested that as much as possible be presented in terms of the magnitude of the social impact when the problem is solved, the clarification of the gap between the current situation and the existing technology to be realized, and the policy to fill it, comparison with international competitive technology analysis, and whether companies and other POC takers are participating with high expectations (including plans).

In addition, selection is not conducted independently for the unit of preferred issues for proposal or sub-themes, but all are compared and reviewed at the same time. As a result, a multiple number of issues may be adopted for a sub-theme while nothing may be adopted for another sub-theme.

① **Preferred issues for proposal**

Classification	Title of preferred issues for proposal
Y01	Analysis technology for clarifying physical and chemical changes of material interfaces
Y02	Analysis technology for clarifying expression mechanism of biological function and interaction under physiologic condition

1) Analysis technology for clarifying physical and chemical changes of material interfaces [Classification: Y01]

Japan holds a large share of the global market for the materials industry and products such as electronic components and automobiles that are based on these materials. Under such circumstances, the performance requirements for materials that directly relate to the solution of problems have become diverse, including not only high functionality but also the compatibility of two contradictory functions, and thus the difficulty of how to efficiently promote materials development is being faced.

In products and devices with complex hierarchical structures, such as batteries, semiconductors, composites, tires, and catalysts, there are interfaces between and within different materials at various levels, and physical and chemical phenomena at the interfaces play a major role in performance and durability. Therefore, it is no longer possible to achieve high performance and high durability by simply combining materials with superior performance. Therefore, in addition to measuring the interface directly, it is extremely important to understand the physical and chemical phenomena occurring at the interface from a bird's-eye view through simulation technology for interfaces that cannot be measured, to achieve dramatic improvements in the performance and durability of products and devices.

There are several types of interfaces: solid/solid, solid/liquid, solid/gas, liquid/liquid, liquid/gas, and gas/gas. All of these types can be covered, but the focus here will be on solid/solid and solid/liquid.

In the FY2021 call, proposals for R&D are sought that objects at the interface of products and devices with complex hierarchical structures; Physics of the device interface; Sophistication of measurement technology to understand chemical phenomena; Physics of interfaces using multimodalization and mathematical modeling; Connecting chemical phenomena to multiple scales.

Physical and chemical phenomena at the interface include the movement of electrons, ions, and matter; the potential and ion distributions created by the space charge layers of ions; structural changes such as the propagation of defects and cracks, the precipitation of metals, and the penetration of atoms into the interface; and the products of chemical reactions.

The following are specific examples of the technological content desired, divided into technologies for measuring these changes and simulation technologies.

- In the advancement of measurement technology, semiconductors are shown as an example. FinFETs, a type of field-effect transistor (FET), are being miniaturized to channel lengths of 10 nm or less. In the past, secondary ion mass spectrometry (SIMS) could not analyze the composition of the gate electrode/interlayer dielectric interface, due to its spatial resolution of 1 μm. The latest three-dimensional atom probe microscope has a spatial resolution of 0.5 nm, which is comparable to that of a transmission electron microscope (TEM), and can measure a needle-shaped FinFET with a tip diameter of 100 nm, which enables atomic-level structural analysis of the desired interface, but requires a lot of sample preparation. However, the sample preparation process is time-consuming. In the R&D proposal, set the target interface to be measured, and clarify the advantages of the analysis technology, such as spatial and temporal resolution, throughput, and sample preparation method, in comparison with conventional technologies.

- In the multimodalization of measurement technology, all-solid-state batteries will be used as an example. In all-solid-state batteries, the space-charge layer with a thickness of several nm formed at the electrode/solid electrolyte interface, and the grain boundary of the solid electrolyte play an important role in performance and durability. There are cases where different analysis techniques are used to simultaneously measure different spatial scales of the interface, such as mesoscale (nm to μm) and atomic-scale (nm), and cases where two analysis techniques are combined into one probe even at the same scale using multi-probe technology. For example, the interface between a cathode and a sulfide solid electrolyte can be measured by combining angle-resolved XAFS and electrochemical measurements using synchrotron radiation to understand the effect of chemical reactions at the interface on the performance of all-solid-state batteries. In the R&D proposal, define the interface to be measured and clarify what kind of physical and chemical changes at the interface are to be observed by combining the analytical techniques.

- As measurements are carried out over time, consider and propose as an issue the construction of a loop to apply real-time feedback on the next measurement conditions and identify the conditions under which measurements will be carried out under more optimal conditions.

- When it is difficult to directly observe and measure interfacial reactions, it is extremely important to understand the physical and chemical phenomena at the interface using simulation techniques. There are various simulation techniques such as first-principles calculations on the atomic scale, molecular dynamics (MD) calculations, coarse-grained models on the mesoscale, and finite element methods on the macro scale (mm). In this course, simulation techniques using mathematical models and calculation methods that enable " Coupled Analysis/Multiphysics" are sought, in which multiple physical (current, magnetic field, fluid) and chemical phenomena are connected on multiple scales and understood from a bird's-eye view.

- A lithium-ion secondary battery is shown as an example. The volume change of a composite electrode consisting of active materials, conductive aids, binders causes degradation due to charging and discharging, and when scaled up from a single cell to a battery pack, the macro-scale temperature and volume distributions have a significant impact on performance and durability. It is desirable to extend the fundamental understanding of interfacial reactions to predictive simulation techniques for device characteristics, performance, and durability in a continuous manner. In your R&D proposal, indicate how you aim to connect the physical and chemical phenomena at the interface on multiple scales, simulation technology using mathematical models to understand the physical and chemical phenomena at the interface from a bird's-eye view, and finally, how you aim to correlate them to the performance and durability of products and devices.

2) Analysis technology for clarifying expression mechanism of biological function and interaction under physiologic condition [Classification: Y02]

To accelerate research in the field of health and medical care, where competition is intensifying worldwide, technologies that can analyze the expression mechanisms of continuously changing substances; intracellular organelles; and cell dynamics and interactions under physiological conditions corresponding to the in vivo environment, such as in the presence of foreign substances or highly concentrated conditions assuming intracellular conditions, are sought, in contrast to the conventional measurement methods that are optimized for each measurement device.

In this category, R&D proposals are expected to be based on technologies that are widely applicable to the fields of drug discovery; cell therapy; medical devices; agrochemicals; functional foods, to achieve POC. In your R&D proposal, compare it with competing technologies and clearly state the superiority and the expected social impact when the POC is achieved as much as possible.

The following is an overview of the current status of measurement analysis technology and equipment in each field. This section provides examples of the necessity and required performance of analysis as well as analytical techniques for clarifying the mechanisms of biological functions and interactions under physiological conditions.

- In the field of neuroscience, the study of neural network mechanisms is attracting attention as a way to analyze the network between brain regions and cells. In particular, to elucidate the pathogenesis of neurological diseases such as Alzheimer's disease, it is necessary to observe in real-time not only the activity of individual neurons but also how the neural network itself is connected and how information processing proceeds. However, conventional electrophysiological methods are limited in their spatio-temporal resolution.
  For example, technology that can simultaneously stimulate multiple arbitrary neurons arranged in 3D space, technology that can measure the response to the stimulation in 3D space with a spatial resolution of fewer than 1 μm and a temporal resolution of less than 1 msec, and technology that can perform molecular expression analysis (transcriptome analysis) of cells that have obtained functional connectivity information by adding technology for marking target cells, are expected to advance integrated understanding.

- In the field of cancer research, it is expected that integrated understanding will be advanced by adding technologies such as those for molecular expression analysis (transcriptome analysis) of cells for which information has been obtained. In the field of cancer research, much attention has been paid to cell-cell interactions in the microenvironment surrounding cancer cells, which consists of normal cells (immune cells, fibroblasts, lymphocytes, etc.), biomolecules, extracellular matrix, blood vessels, and immunosuppressive molecules. The microenvironment also influences the size and proliferation of cancer cells, and it is thought that the regulation of the cancer microenvironment, which consists of various cells, is important for elucidating the mechanism of cancer growth. However, the mechanisms by which these interactions occur are not fully understood.

To elucidate the mechanism of complex cell-cell interactions caused by multiple factors (e.g., infiltration mechanism of immunocompetent cells), it is necessary to develop measurement technologies that dramatically improve the information obtained from optical and electron microscope images and to integrate information that has been treated separately in the past, such as a large amount of image information and analytical genomic information, into a highly accurate system. It is also expected to develop technology to integrate information that has been handled separately in the past, such as genomic information, with high precision (e.g., extracting characteristic information that can discriminate between abnormal and normal cells using machine learning and data analysis technology from the high-dimensional data obtained here).

- It has been suggested that cellular organelles such as mitochondria are deeply involved as a cause of neurological diseases and cancer, but conventional techniques are insufficient for observing the localized location and dynamics of intracellular substances.
  To elucidate the mechanisms that contribute to the treatment of these diseases and the promotion of drug discovery research, it is necessary to analyze the structure and dynamics of various intracellular molecules (averaging about 20 μm) under physiological conditions, for example, and new analysis techniques and equipment that enable measurements with a spatial resolution of fewer than 1 μm and a temporal resolution of less than 1 ms are needed. New analysis techniques and equipment are needed to enable measurements with a spatial resolution of fewer than 1 μm and a temporal resolution of less than 1 ms. New analysis techniques and instruments are needed to enable measurements with a spatial resolution of fewer than 1 μm and a temporal resolution of less than 1 msec. Also, a measurement method with a temporal resolution of less than 1 msec and a spatial resolution of less than 100 nm is expected.

- To realize the above analysis, it is important not only to improve the spatial and temporal resolution of measurement technology and equipment, but also to integrate measurement technology with computational science, such as molecular dynamics (MD), which enables the simulation of the movement of proteins and small molecules with a time resolution of milliseconds or less, to observe proteins, intracellular organelles, and cells under physiological conditions without impairing their functions (non-invasive chemical probes, transparency). It is also important to integrate measurement technology with computational science, such as molecular dynamics (MD), which enables us to simulate the movement of proteins and small-molecule compounds with sub-millisecond time resolution.
  Also, to understand living organisms in an integrated manner from micro to macro perspectives, it is necessary to integrate experimental information from different conventional samples, different analysis methods, various imaging information, and various omics data such as genome and proteome, etc. R&D proposals including simultaneous measurement technology using the same sample, mathematical models, mathematical data analysis technology, information processing technology are continually welcome.

② List of Sub-Themes (continued)

Classification	Sub-theme name
ST01	Structure Analysis
ST02	Atomic/Molecular-Scale Measurement
ST03	Multi-Scale Analysis of Interface and Surface
ST04	Deep-Site/Internal Measurement
ST05	Ultrafast Dynamics Observation
ST06	Temporal Observation
ST07	Automation and Efficiency Improvement of Routine Work
ST08	Sophistication of Processing, Synthesis, Separation and Purification
ST09*	Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data
ST10	Other Common Platform Technology, Facilities, and Equipment that Satisfy Purposes of Prioritized Theme

* Proposals for FY2021 on the component technology type are limited to this classification. Note that the upper limit of R&D costs for ST09 are different from that for other sub-themes (see "R&D period and costs" described later).

* When you apply via the e-rad, please select appropriate number from "Preferred Issues for Proposal" (Y01 or Y02) or "Sub-Themes" (classification ST01 to S10) (multiple selections possible).

* Keep in mind that different type of format is required for a proposal for the component technology type (see "2.1.3/2.1.5 Guidelines for entry in "Small-start Type (Component technology type)" R&D proposal documents (forms)"). Select "ST09" for the component technology type when you apply via the e-rad.

1) Structure analysis (ST01)

This Sub-Theme performs common platform technology development of structure analysis for substances of complex structures.

The field of material science has many needs for grasping a detailed structure of a newly prepared material to elucidate a relationship between the structure and properties for designing a new material. Structure analyses of multidimensional materials, non-homogeneous materials, and complex polymer materials are an issue, along with how to grasp structural defects and the positional information of dopants. Difficulty of analyzing light atoms has long been a problem. Techniques are still sought for solving the problem and developing simpler and more accurate analyses.

In the field of life science, structure analysis of various molecules in a living body is an important element of development, especially in the field of health care, therapy, and drug discovery. For example, attention is paid to such drug discovery targets as higher structures of chromatin, complex proteins, membrane proteins, 3D structures of peptides, and sugar chains.

A broader conceptual view of structure analysis would find intense needs for sequencing DNA. We request technology development to make marked improvement in existing techniques for subsequent generation technologies beyond the so-called “next generation sequencers,” which are the mainstream at present, is being requested.

In particular, the need for structural analysis of ultra-trace samples has increased in recent years. For example, conventional crystal structure analysis needs to make crystals sufficient for measurement, and this has been a major restriction in conducting research, such as limiting the compound types that can be analyzed or requiring a long time for crystallization process. If structure analysis becomes available even if this is a relatively small crystal or mixed state, knowledge of the structure, not known to date, may be obtained, and the R&D efficiency is expected to be largely improved.

2) Atomic/Molecular-Scale Measurement (ST02)

This Sub-Theme develops techniques for measuring various subjects in an Atomic/Molecular-Scale that exert various effects on whole systems.

To understand properties and specific characteristics of a material, the material science field demands measurement of electric/magnetic fields, photons, phonons, spins, electronic states, oscillations, and fluctuations.

The field of life science demands observation of a single molecule, not average values of a group of molecules. Current needs are for single molecular analyses of membrane protein structures, especially G-protein-coupled receptors and Channel; their relations with a ligand; single molecule separation by microfluid dynamics; evaluation of its functions; and, analytical technology for analysis of single molecules in a viable cell.

3) Multi-scale Analysis of Interface and Surface (ST03)

This Sub-Theme attends to interfaces and surfaces for performing R&D for measuring localized sites and for micro-, meso- and macro-scale analyses.

The material science field requires evaluations from micro- to macro-viewpoints in research of material design and tribology. Development of technologies is desired for detailed and wide-ranged analyses as part of R&D for substance evaluation and improved performance. The research is being expected to realize development of reliable and durable products and to contribute to resource and energy savings.

The life science field seeks to analyze not only part of the cell membrane but also the molecules that are distributed throughout the whole membrane. Membrane proteins on cell surfaces are an important subject of analysis for communications between a cell and extracellular space. For example, an R&D field that tries to implement substance production using cells in a society seeks detailed analyses for elucidating phenomena.

4) Deep-Site/Internal Measurement (ST04)

This Sub-Theme performs R&D for measuring structure of deep/internal sites of a substance and internal phenomena.

The field of material science seeks measurement of internal degeneration for checking and evaluating the quality of structural materials and batteries, detecting internal impurities, and observing internal chemical changes to analyze situations of function expression.

There is a need for deep measurement for intracellular organelles, cell-cell interaction in cancer mission areas, intravascular cell dynamics, single-cell analysis in organs, brain analysis (Neuroplasticity analysis), etc. For details, refer to the explanation of the application category Y02.

Low/non-invasive or non-destructive manipulation to avoid situation changes during observation is important for all fields. Development of measurement technologies should take these into consideration.

5) Ultrafast Dynamics Observation (ST05)

This Sub-Theme performs R&D that aims to make marked improvements in time-resolution of existing measurement methods as technology for observing ultrafast dynamics, including transitional situations of chemical reactions.

Electrons, for example, move too fast to be directly observed by ordinary measurement techniques. However, research fields of various areas may need to build a hypothesis to explain ultrafast dynamics for the elucidation of physical properties in product development. The ultrafast dynamics requires observation technology for its verification. New techniques should be established by controlling femtosecond and attosecond lasers or by raising the level of pump–probe methods through improving detection performance.

6) Temporal Observation (ST06)

This Sub-Theme develops technologies required for research subjects in individual fields and for high-impact temporal observations.

The material science fields desperately need technologies to observe internal heat conduction in an all solid battery and to observe and understand what triggers material degeneration in addition to needs for observation and measurement of chemical reaction progress on a catalyst. New findings are sought for time-consuming elucidation of creep phenomena and new measurement methods of efficiently testing accelerated degeneration. Development of the above technologies are being expected to improve durability and reliability of products.

The life science field demands new technologies such as new probes that can measure on a weekly to monthly basis for temporal observation of pharmacokinetics and other parameters for quantitative analysis of gene expression, chronological modifications, such as DNA methylation, various omics analyses of protein and metabolites, and temporal observations of drug dynamics.

7) Automation and Efficiency Improvement of Routine Work (ST07)

This Sub-Theme automates and makes efficient work already sorted by type in research fields to realize exponential improvement and acceleration of research productivity and to aim to reach results in a shorter time.

Various needs and subjects are presumed.

In the field of material science, for example, technology exists for preparing a novel material possessing a desired atom sequence by stacking individual layers one-by-one. This is a task requiring specialized skills. Therefore, demand exists for automation, robotic efficiency, and passing technology down through generations. Automated preparation of a chemical compound library in combinatorial chemistry is also needed.

The field of life science requires automation, improved efficiency, and high speeds of various biochemistry and molecular biology experiments. A specific example is the standardization of the pretreatment for omics analyses and automated measurement are given as specific examples. The field of life science requires automation, improved efficiency, and high speeds of various biochemistry and molecular biology experiments. A specific example is the standardization of the pretreatment for omics analyses and automated measurement are given as specific examples.

8) Sophistication of Processing, Synthesis, Separation and Purification (ST08)

This Sub-Theme conducts R&D for raising levels of universal technologies in research fields, including processing, synthesis, separation, and purification technologies.

<Processing/synthesis technology>

In the material science, crystal growth technologies, fine processing technologies and layered structure technologies need to be enhanced. For example, one problem that has been pointed out is that fine parameters of a prepared sample are altered by the equipment used for crystal growth for novel drug discoveries. A fundamental solution is in demand.

In the life science, there are discussions about utilization of artificial intelligence for chemical synthesis processes and of building modular flow synthesis systems for efficient substance production. The realization of such a device is expected to enable higher purity and lower costs as well as shorten the development period for functional peptides, which are expected to be used not only in medicine but also in various industries such as food and cosmetics, and RNA and antibodies, which are attracting attention as vaccines for infectious diseases.

<Separation/purification technology>

In the field of life science, technology for protein purification from a living body sample is discussed. Especially, there are strong needs for complex proteins and proteins in an elementary process among them, not only as research elements but also as drug discovery targets. Separation and purification of intracellular particles and exosomes released from cells have many problems of yield and purity, for which universal technologies are being sought.

Previously, purification was a precondition for measurement in the fields of both material science and life science. But, now a measurement technology without pretreatment of purification is desired.

ST08 partly overlaps ST07, automating technologies for processing, synthesizing, separating, and purifying existing materials already sorted by type. ST08 contains basic element technologies that have not yet been realized for processing, synthesizing, separating, and purifying. That is how we distinguish ST08 from ST07.

9) Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data (ST09)

This sub-theme seeks to develop new mathematical techniques that can lead to fundamental reorganization of mathematical models, analytical techniques and measurement technologies for expressing or extracting “essential information” to obtain the predictability of the target characteristics or performance.

In the field of material science, the importance of the utilization of big data in property assessment and materials informatics has been well recognized. New mathematical models and analytic techniques resulting from data accumulation are largely expected to play essentially important roles for understanding real phenomena. Specifically, data such as electrochemical or catalytic reactions has been accumulated at the R&D site, but complicated reaction control of material under development becomes possible and material development is accelerated only when a cycle of, for example, collaboration with experts on site, organization of materials using machine learning and Bayesian optimization, etc., definition of descriptors, and elucidation of appropriate parameters using sparse modeling etc. is constructed.

In the field of life sciences, mathematical platform technologies for constructing new methods and calculation methods for analyzing large amounts of measured data is also important. For example, the measurement information of life dynamics observed in ST06 requires more integrated mathematical data analysis to understand life phenomena. Deeper understanding of life phenomena is required through the elucidation of the comprehensive network structure including the interaction of layers, not mere analysis of individual layers (molecule, cell, tissue, individual level), by proposing a new mathematical model enabling the handling of multi-level omics data that integrates technologies for visualizing the dynamics of molecular groups (omics layers) with different physical properties such as RNA, DNA, proteins and metabolites, or intracellular organelles, and conducting mathematical science or engineering analysis to process signals which could not be handled with conventional analysis equipment.

In the component technology type, the concepts in this mission area are emphasized, especially centering on the proposals for R&D of new mathematical methods that can lead the fundamental reforms of mathematical models and analysis methods for explaining and extracting “essential information" related to measurement and analysis and data processing field. We mainly seek proposals such as the development.

For example, molecular dynamics (MD) methods, which enable the integration of measurement and simulation technologies, mathematical models, computational methods, and data analysis (such as coupled analysis that combines first-principles calculations and finite element methods) are required in all fields to simplify and accurately connect multi-level data and multiple physical and chemical phenomena and bring them closer to real-world solutions. Also, based on the multidimensional and neurogenic time-series data obtained from the research field, the nonlinear dynamics of the system that generated the data are estimated and converted into a mathematical model to extract the laws behind the data-driven mathematical model-building technology. Based on the recent progress in such as AI and machine learning, new dynamic information processing methods such as the "Reservoir Computation Method" (a computation method that obtains what is desired by multiplying complex responses in a network by appropriate weights), which is being applied to optoelectronics, spintronics, life sciences, robotics, are expected to significantly reduce learning time and have diverse applications in sensors and complex time series analysis. These new dynamic information processing methods are expected to significantly reduce learning time and have a variety of applications in sensors and complex time series analysis. We also expect proposals that apply these mathematical models based on new ideas to the “preferred issues for proposal”.

In this sub-theme, we are expecting the entry of new mathematical scientists and engineers who have the flexibility and versatility to develop mathematical models and analyze mathematical data through close discussions with experts in various fields.

* Propose a proper budget according to the proposal contents. No lower limit is set.

10) Other Common Platform Technology, Facilities, and Equipment that Satisfy Purposes of Prioritized Theme (ST10)

Proposals are requested not only for cases that relate to the nine Sub-Themes described above but also the R&D projects that meet the purpose of this prioritized theme and preferred issues for proposal and create common platform technologies that you consider is in need “now” in the field of research.

Fresh ideas that meet the concepts of this mission area are welcome in every R&D field.

If the selection of category from ST01 to ST09 is difficult, you should select this sub-theme (ST10). We are waiting for proposals that can be a scientific technology solution for “visualization” of things previously not visualized and “measurable” of things previously not measurable

● Presumed applications of results

This mission area collaborates with other JST programs [Adaptable and Seamless Technology Transfer Program through Target-driven R&D (A-STEP), Support Program of Capital Contribution to Early-Stage Companies (SUCCESS) and Program for Creating Start-ups from Advanced Research and Technology (START) etc.] and programs of other ministries at opportune times. This is to allow other R&D programs closer to actual application, to build on results of projects needing a longer-term approach and for passing results to start-up firms and industries.

● **Collaboration with related programs**

To aim for the procurement of innovative knowledge and products and promoting challenging R&D that impacts research activities, this mission area closely collaborates with other JST programs and those of other ministries to positively promote utilization of results of programs at a research stage.

Also, many R&D tools have been made available for practical use by now in various programs including the Advanced Measurement and Analysis Systems Development Program of JST (finished in FY2020), which preceded this mission area, and it will be appreciated if you visit the website of this program when considering a proposal in this mission area.

Furthermore, collaboration with facilities and equipment for joint use is encouraged from the viewpoint of promoting R&D by considering users' needs (Please see 4.12 "Promotion of the Joint Use of Research Facilities and Equipment").

● **Policies for R&D management**

In approaching challenging R&D projects, this mission area positively promotes multidisciplinary collaboration without constraints of conventional academic boundaries, participation of young researchers, and collaboration with business firms and academia to emphasize diversity of research teams and incorporation of novel ideas. At the R&D management committee, including theme managers, we will establish a management system that can provide appropriate advice and guidance through reviews of research plans and site visits, study groups and so on. The R&D management committee, including the R&D Supervisor, the R&D management committee members and the R&D practitioners work together to reorganize research techniques and realize a common platform system/instrument that procures innovative knowledge and products.

For the transition from feasibility study to full R&D project, it is envisioned that teams participating in R&D projects will be integrated or restructured.

● **R&D period and costs**

For FY2021, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2023), and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period, or for the component technology type, JPY 23 million (direct costs for ST09 only). Every researcher is required to undergo a stage-gate evaluation for transition to a full R&D project at the time designated by the R&D Supervisor before the end of FY2023.

A full R&D project should be planned with a period of up to five years and with a total cost of up to JPY 570 million (direct costs) for the whole period. However, propose a proper budget according to the proposal contents for a proposal of ST09 "Building Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data" (no lower limit is set.)

After adoption, we will flexibly allocate the budget according to the R&D content.

6.2 Large-scale Type

The technology themes of large-scale type that are believed to be important for forming the bases of future technologies, has been determined by the Ministry of Education, Culture, Sports, Science and Technology based on the information analysis on science and technology innovations. For the 2020 fiscal year, proposals are sought for large-scale R&D projects relating to the technology themes described herein.

R&D Supervisor (Program Officer: PO):
OISHI Yoshihiro
(Senior Research Fellow, General Manager, Think Tank Unit, Mitsubishi Research Institute, Inc.)

6.2.1 Management policies for projects in large-scale type

(1) R&D Supervisor's policies for proposal selection, and R&D management

In the large-scale project type, R&D is conducted to reach a stage (proof of concept: POC) to determine the possibility of selecting advanced technologies for creating a future society, making technologies practicable and socially implementable. After the achievement of POC, the outcome is expected to be applied or deployed for solving social issues, realizing a future society and creating new industries as a platform technology exerting impacts in a wide range of fields.

Technology themes for large-scale project-type are set by selecting the technical fields that should be noted from the above viewpoint. The R&D representatives (program manager, PM) themselves are expected to define the POC that will lead to the implementation of these technologies in society. PMs should set high and challenging goals, aiming to achieve them with high aspirations so that the results will lead to the solution of social issues and the creation of new industries. At the same time, the PM is requested to draw a vision of social implementation to lead to the development after the achievement of the POC, assume a specific outcome which may bring innovation to the future society and industry, and make a plan that leads to the business purpose of creating a future society.

It is crucial for projects to boast the highest level of R&D capability and knowledge. See "2.2.2(4) Selection viewpoints" for a description of the evaluation criteria for the adoption of proposals in large-scale type. During the R&D process, projects are expected to be managed to use those opportunities to merge with various technology fields, appropriately share the function and collaborate with researchers or research organizations, including opportunities to recruit new members or obtain new findings or technologies.

The large-scale projects are also required to attract investment from private sectors during the R&D process preceding the POC. In order to attract private investments, we recommend an early entry of companies and in particular, we are seeking for introduction of funds of a certain size from the target institutions in the first stage-gate evaluation (Be sure to refer to 3.4.2 "Evaluation in large-scale type").

We strongly hope that PM determines the timing of POC tests based on his/her original and excellent R&D concept, creates a milestone backcast for achieving that in anticipation of deployment after POC, and manages R&D while actively and flexibly communicating with the companies etc.

In making a R&D plan, we will provide a certain period for preparation by the instruction of the PO. After the R&D starts, we consider local and overseas R&D trends and changes in the social environment to boldly review our R&D plan for flexible management.

(2) R&D Supervisor's policies for proposal selection, and R&D management

Innovative microwave measurement techniques for a safe, secure, and smart society

As part of Society 5.0, which calls for the realization of a sustainable and robust society through the fusion of cyberspace and physical space, research and technological development that contributes to digitalization, such as enabling the measurement and detection of objects, which has been difficult in the past, is expected to become a key issue in the future. It is an important foundation for solving various social issues, such as dealing with the increasing severity of weather disasters caused by climate change and the aging of social infrastructure.

In recent years, microwave measurement technology, which is less susceptible to changes in the surrounding environment and can sense various conditions on the ground and in space, is expected to apply to a wide range of fields including weather observation, medical diagnosis, and infrastructure management. Microwave measurement technology can be broadly classified into radar technology, which irradiates microwaves onto an object and measures their reflection and scattering, and radiometer, which passively observes microwaves emitted by an object. To expand the application of these technologies in the future, there are still many bottlenecks that need to be overcome, for instance, conventional radar can only measure one frequency with one device, and microwave radiometers, which measure weak microwaves, have a short lifetime due to wear of the antenna rotation drive. In this technical theme, challenging R&D subjects are solicited to realize innovative microwave measurement technologies that eliminate these bottlenecks.

PMs are required to identify the social issues that need to be addressed now with an eye to the future society, and then present the R&D concept by positioning the role of the proposed innovative microwave measurement technology in the scenario for contributing to the solution of those social issues. Also, since the numerical targets and the path to social implementation are expected to differ depending on the final destination and application, specify the specific destination and application, and provide the numerical targets. At the same time, indicate the position of the project in comparison with global benchmarks and domestic and international R&D. Furthermore, with an eye on the practical application after an early termination, we expect you to establish an industry-academia collaborative R&D system that considers the entire value chain, including not only the providers of the technology, product, or service but also the end-users.

Total R&D costs for R&D projects initiated in FY2021 is up to JPY 1,080 million (direct costs) for the 1st to 4th year, up to JPY 270 million (direct costs) per year, and up to JPY 2,700 million (direct costs) for the whole R&D period (nine and a half years).

New

6.2.2 Technology theme

(1) Theme name

Innovative microwave measurement techniques for a safe, secure, and smart society

(2) Outline

Society 5.0 aims to create innovative ideas. In order to achieve this, microwave measurement techniques would be a vital and fundamental technology that is not easily affected by the changes in the surrounding environment and can sense various conditions on the ground and in space. Microwave measurement techniques can be broadly classified into radar technology, which irradiates microwaves onto an object and measures their reflection and scattering; and radiometer technology, which passively observes microwaves emitted by an object. Radar and radiometers used for meteorological observation are used as important social infrastructure. And with the advancement of data processing technology, it is likely we will see even more advanced technology on breast cancer detection, buried object surveying, nondestructive infrastructure inspection, security gates, and automotive radar.

As the role of microwave measurement techniques expands and its importance increases, there is a need to overcome the problems in the current techniques. For example, in meteorological radar, current phased array antennas are limited to observation at a single frequency but the recently developed phased array antennas can electronically change the measurement direction, enabling high-speed and three-dimensional observations. Therefore, newer technology on the accuracy on weather forecasting from the use of multiple frequencies to enable early detection of guerilla rainstorms and linear precipitation zones is expected to develop in the near future. Moreover, in order to expand the observation range of microwave radiometers, the antennas are rotated to change the measurement direction and perform simultaneous measurements at multiple frequencies, but problem arises from extended use of the antennas and deterioration of the rotation drive unit. Therefore, simultaneous measurement at a plurality of frequencies using phased array antenna that can electronically change the measurement direction is also expected.

Taking the most recent technological advances into account, innovative microwave measurement techniques is expected to achieve and resolves issues arising from the conventional ones. Innovative microwave measurement techniques also expand the possibilities of microwave measurement in a wide range of fields, thereby contributing further to the implementation of Society 5.0.

(3) Goal

The goal of this project is to establish innovative microwave measurement techniques contributing to a safe, secure, and smart society that prevents potential dangers and efficient exploration of natural resources. While envisioning specific situations in which the technology will actually be implemented in society (such as, meteorological radar, breast cancer detection equipment, buried object surveying, nondestructive infrastructure inspection, microwave radiometer, etc.), R&D will be carried out in an integrated manner up to the stage where it can determine whether practical application is possible (Proof of Concept: POC), based on the evaluation of technical superiority and market competitiveness against conventional technologies. In promoting R&D, it is ideal to clearly set specific goals for social implementation for each elemental technology. For example, four years after the start of R&D, ultra-wideband and wide-angle antennas and ultra-high speed signal processing technologies should be developed; and these technologies should be assembled as a measurement system and demonstrated on the ground. Ten years later, the antennas should be made smaller and lighter, the ultra-high-speed signal processing circuits should be upgraded and made more power-efficient. In this case, it is necessary to develop a roadmap for practical use after project completion. And in doing so, it should be noted that an industry-academia collaborative R&D system should be established with an eye on the entire value chain from the manufacturer to the provision of services to end-users, with the practical application in mind after project completion.

(4) Future society image to be kept in mind while conducting research

It is expected that the implementation of R&D will lead to the development of the society in the future, as described below:

- A safe and secure society that enables disaster prevention and mitigation based on improved prediction accuracy of weather such as guerilla rains, and linear precipitations belts by using multi-frequency ground-based meteorological radar capable of simultaneous observation of rain, clouds, and snow to accurately measure conditions before rainfall, development of cumulonimbus clouds and, rainfall.
- The application of ultra-wideband microwave measurement to short-range sensing, such as breast cancer imaging, detection of subsurface pipelines, and identification of damaged infrastructure, will lead to a safe and secure society that prevents potential dangers in our lives.
- A society in which sea surface temperature measurement using satellite-mounted microwave radiometers enables data to be acquired close to the coast, and smart fisheries, such as efficient data-based search for fishing grounds, can be achieved in a wide range of ocean areas, including coastal fishers and aquaculture.

(5) Specific R&D examples

A good example of these R&D may include:

- R&D of self-compensating antenna elements capable of ultra-wideband and ultra-wide-angle measurements (for example, frequency range of about 1-41 GHz, wide angle of about 110º), and the development for miniaturization and weight reduction.
- R&D of ultra-high-speed analog-to-digital (AD) conversion and ultra-fast signal processing technology for field-programmable gate arrays (FPGAs) to enable measurement of ultra-wideband microwave spectra in the desired direction and energy-saving. (for example, processing speed: about 30 GSPS, number of measurement frequency channels: about 5000).
- R&D of optimization of the number and arrangement of elements for phased array antennas using wideband and ultra-wide angle antenna elements.
- Development and ground-based demonstration of a microwave measurement system that combines a phased array antenna using wideband and ultra-wide angle antenna elements with ultrafast signal processing technology.

(6) R&D trends

R&D on microwaves have been steadily increasing since 1990, mainly in China, the U.S., India, France, Germany, and Japan, and related fields such as meteorology, medicine, and fisheries have been expanding in various ways. In addition, Japan is developing the world's first microwave mammography technology that uses weak radio waves to detect breast cancer cells with high accuracy; non-destructive testing of lithium-ion batteries; corrosion monitoring of reinforced concrete structures; super security gate, etc. The possibilities of microwave measurement techniques are expected to expand further in the future. Moreover, microwave radiometers for microwave observation are developed and operated in Japan, the U.S., Europe, and China for on-board satellites use, and is sold in the U.S. and Europe for ground-based observation. Japan's on-board radiometers have the world's highest resolution (10km@36GHz, 50km@7Ghz) and is making a significant contribution internationally. In this context, Japan has developed the necessary elemental technologies for the advancement of microwave measurement techniques, such as design simulation of wideband and wide-angle antenna elements, development of an ultra-wideband microwave measurement device using a single element antenna (world's first), demonstration of ultra-wideband microwave measurement using two element antenna (world's first), and development of a two-element phased array antenna (world's first), numerical model for determining the number and configuration of phased array antenna, multi-parameter phased array meteorological radar (world's first), and research on multidimensional electromagnetic wave image analysis by integrating radar and tomography are all underway.