Application Guideline-Annex

Chapter 6 Prioritized Theme and Technology Theme for Research Proposals

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6.1 Small-start Type

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

About research areas for setting a prioritized theme by JST, National R&D Agency, in JST-Mirai program (Tentative translation)

JST, the National R&D agency, sets research themes (prioritized themes, hereafter) for the JST-Mirai program (small-start type). There are five areas for these themes as explained below based on the 5th Science and Technology Basic Plan.

A review of prioritized themes must reflect the purpose of this project to rigorously examine a technologically challenging target that is both economically and socially impactful. The review must also be strategic while paying attention to a wide collection of novel and diverse ideas, be consistent with various policies of the government, and avoid the duplication of prioritized and challenging R&D performed by other National R&D Agencies.

① “Realization of a Super Smart Society(Society 5.0)” area
This research area is set as a transdisciplinary (lateral skewered) area from the viewpoint of creating new values toward the creation of industries and reformation of future society. Specifically, it includes spreading the utilization of networks and IoT not only to manufacturing industries but also to R&D in various other fields and strengthening base technologies (base technologies necessary for building a common platform through the effective utilization of IoT and base technologies that are a core of Japan’s strength in creating new values, including advanced measurement technologies) for maintaining and strengthening the competitiveness of Japan as a super smart society. It also includes technologies related to space, such as satellite position measurement, satellite remote sensing, satellite communications, and satellite broadcasting.

② “Realization of a Sustainable Society” area
This 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.

③ “Realization of the most safe and secure society in the world” area
This is an area for responding to natural disasters; securing food safety, the living environment, industrial safety and health, and cyber security; and responding to national security problems.

④ “Realization of a Low Carbon Society, a global issue” area
This area includes the stable securement and efficient utilization of energy (energy-saving technologies, improvement of renewable energy efficiency, and technologies for stabilizing energy utilization with hydrogen and energy storage) for the targeted large reduction of greenhouse gas

emissions in 2050.

⑤ “Common platform technology, facilities and equipment” area

This is an area set to target common platform technology and cutting-edge research equipment that support a wide variety of research activities. This area makes it possible to open up a new interdisciplinary field, support capabilities of basic science in Japan as a basis for bringing world-leading research results, and contribute to create sustainable science and technology innovation.

6.1.1 “Realization of Super Smart Society (Society 5.0)” Area

Research and Development Supervisor (Program Officer: PO):
Akira MAEDA
(Former Corporate Chief Engineer, Information & Communication Technology Business Division, Hitachi Ltd.)

I. Goal of the “Realization of a Super Smart Society (Society 5.0)” Area

As set out in the Fifth Basic Plan of Science and Technology and the Comprehensive Innovation Strategy, Society 5.0 is defined as “a society centered on people that, through the merging of cyber space and physical space, provides goods and services that precisely respond to various needs and potential needs to support both economic development and solutions for social issues and allows people to live comfortable and active lives.”

This area assumes that a “super smart society” (synonymous to Society 5.0) is considered a “society in which things of the real society are incorporated with intelligent software for sophisticated functions (making it smart), and things cooperate to automate societal systems for high efficiency as well as facilitate new functions and services.” As a difference from merely a “smart society” or the conventional “information society” referred to as in Society 4.0, this is considered “a super smart society which incorporates intelligence of information technologies into a physical entity, such as electrical power systems, transportation systems, service robots, and similar entities, for them to interact for the expansion of the range of automation and autonomy as the whole system, and possesses a mechanism for sustainable creation of new services and businesses, when information technologies are for sophisticated information and data processing in cyber space,” and R&D for achieving this will be promoted in this area.

Based on this concept, we set up a prioritized theme titled “Establishment of a Service Platform that Enables Collaboration between Various Components and Creation of New Services” in FY2017 with the aim of creating a society in which new services are provided continuously by system collaboration.

In FY2018, we added a prioritized theme titled “Modeling and AI that Connects the Cyber and Physical Worlds” aiming for creating a society in which the industrial and social systems are streamlined using advanced cyber and physical systems. Here, we identified “Technology that Secures Real-time Performance and Reliability using Modeling and Simulation to Realize the Function to Control Objects and Systems in the Real Space with API” as an independent issue and also identified AI and big data analysis technology as a key technology to establish a new service platform.

For making use of AI and big data analysis technologies, we set up a new prioritized theme titled “Innovative AI technologies for sophisticated integration of cyber and physical world” in FY2019 aiming for a society where spread of AI systems is promoted by solving issues in social implementation of AI, such as difficulties in collaboration with humans due to inexplainable nature of perception and reasoning results, or difficulties in collection of big data on exceptional events or application of it to an ever-changing environment, in addition to the issues of real-time performance and reliability designated in FY2018.

Recently, new values have been created in society as everybody and everything are connected and a large amount of knowledge and information are shared with the spread of IoT and SNS. At the same time, problems that confuse society have also emerged. For example, it takes time to identify evacuation orders in the event of a disaster or the infection route in the event of a pandemic due to flood of both genuine and false information, or hoaxes spread on the Internet.

Hence, we will strive this fiscal year to solve social issues that have become obvious with the development of information technology as AI systems have been more ubiquitous and practical in society which is the base for supporting our lives and economic activities, while continuing to be aware of the issues in the prioritized theme of the previous year. For this purpose, viewpoints of people and society must be taken into account in technological development, and this must actually solve social issues. That is way co-creation across various fields including not only information science but also human and social sciences is important. With this in mind, we set up a prioritized theme called "Making full use of AI and simulation technologies across different fields for a human-centered society" as an addition of analytical technologies and technologies accelerating behavior modification based on the behavior of people and society to the theme for FY2019 to guarantee the explainability and reliability in AI and simulation technologies.

Under this theme, researchers are requested to clearly determine specific application targets (backcast from social issues and the social image to realize), and technical issues and pathway to realize them. In addition, an approach that integrates and combines knowledge and technologies in a wide range of fields including human and social sciences is needed to solve these issues. Furthermore, collaboration between academia and industry is also a key. We expect many researchers to make R&D proposals in line with the purpose of the theme.

New

II. Prioritized theme

1. Making Full Use of AI and Simulation Technologies across Different Fields for a Human-Centered Society

Theme Manager
Takashi WASHIO
(Professor, Institute of Scientific and Industrial Research (ISIR) Osaka University)
* A theme manager who assists the R&D management of the Program Officer is to be assigned to this prioritized theme.

(1) About the theme

With the spread of IoT and SNS toward “Realization of a super smart society (Society 5.0),” new value has been created in society as everybody and everything are connected and various knowledge and information are shared. Meanwhile, problems that confuse society have also been coming to the surface. For example, it took some time to identify evacuation orders in the event of Great East Japan Earthquake and last year’s typhoon 19, or the infection route in the event of the pandemic of new coronavirus (COVID-19) due to flood of both genuine and false information, or hoaxes spread on the Internet.

AI and simulation technologies are expected to solve these problems and build a wholesome society, but it is not possible by simply enhancing these technologies to control complicated behavior of society and people. Measures are hardly effective in these situations.

In addition, there are issues on AI technologies to solve, including the difficulty of people to understand the analysis results of deep learning because the process is in a black box, insufficient ability of AI to cope with exceptional events such as malfunction, and necessity of real-time operation in an ever-changing environment.

We therefore set up a prioritized theme for this fiscal year titled “Making full use of ai and simulation technologies across different fields for a human-centered society” to solve two problems: “inability to capture the complex behavior of people and society and take effective measures to solve social issues” and “issues on social implementation of AI technologies.” Including the prioritized theme for FY2019, “Innovative AI technologies for sophisticated integration of cyber and physical world,” this theme broadens its scope with objectives of establishing AI and simulation technologies in consideration of social structure and human behavioral principles and implementing them in society.

The technologies subject to R&D in this theme to realize a society that Society 5.0 aims for include the following:

- Technologies for improving data reliability and quality (fact check, bias removal) and efficient data collection
- AI and simulation technologies that incorporate complex models of people and society

- Technologies for value transformation and implementation of analysis results (behavior change, incentive design)
- AI technologies that can explain the results to make users convince their validity, and technologies to ensure the safety and reliability of AI when incorporated into a system
- AI technologies adaptive to exceptional and sudden events which make data collection difficult
- Technologies to ensured execution speed and accuracy in an environment requiring real-time performance

In the development of these technologies, it is necessary to understand human behavioral principles, values and social structure, etc., choose appropriate issues, and design incentives for social implementation. We believe that a "cross-disciplinary co-creation type" research approach based on knowledge from human and social sciences is useful. In collaboration with human and social sciences, the validation and enhancement of existing theories and models may be promoted by not only incorporating knowledge from these sciences into information science, but also making use of data on human behavior and social activity which is available now from SNS, etc. on a massive scale in real time. We therefore expect that a new level of cross-disciplinary co-creation will be developed from this prioritized theme. We also expect that continuous technological development will take place by rotating the cycle as shown below.

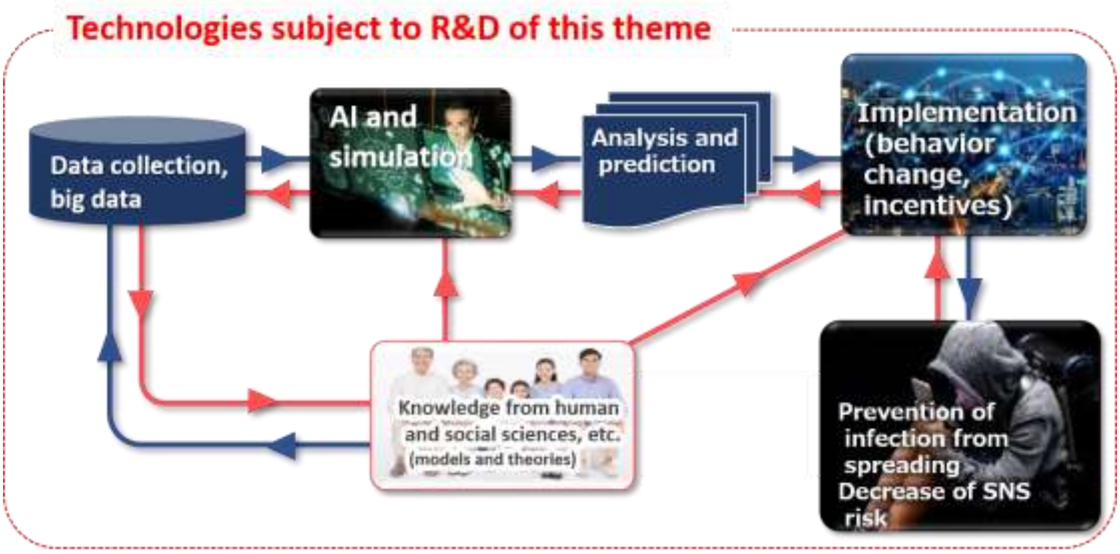

Fig. 1: Cross-disciplinary co-creation type research cycle

Using this cycle, the development of “next-generation AI and simulation technologies” is intended for visualizing the complicated human and social structures beyond the level of the current AI technologies, "data-centric analysis and prediction," and contributing to the optimization of decision-making and social mechanisms.

We assume specific contents of research and development as explained below based on the above cycle in the anticipation that the results can be applied to the real world, including R&D contributing to measures against infectious diseases. These are, however, examples, and proposals for other contents are also welcome as far as their direction is consistent with the purpose of this theme.

a. Prediction of impact of infectious diseases on people, society and economy, and decision-making system
   - Prediction of propagation of infectious diseases including asymptomatic cases through human behavior models and multi-agent simulations

- Incentive design for anti-propagation behavior based on nudge theory and community formation theory
- Product and service development using AI-human collaboration technology that dynamically determines the optimal role allotment according to the user's situation

b. Evaluation of fake news, online hoaxes and flames, and relevant support services
- Prevention of hoax spread by formulating effective information correction measures using human behavior and information diffusion models
- Industrial and consumer products and services based on explainable AI using the integration of recursive and deductive reasoning or real world models
- Development of products and services using AI technology that guarantees safety and reliability

c. System and services that support the proposal and execution of appropriate responses in the event of emergency or disaster
- A system that predicts and estimates the actual state of social phenomena in real time from a small quantity of observation data
- A service that improves and verity efficiency of various measures while promoting behavior change by managing the entire cycle of information transmission and feedback

Although social implementation at the end of the full-scale research is not mandatory, achievement to the stage of determining whether or not practical use is possible (Proof of Concept; POC) is assumed.

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

① Policies for proposal selection

Challenging proposals are called for to safely and securely operate a complicated, constantly changing social system of Society 5.0 including people, and produce new value. We believe that active collaboration between information science and human and social sciences is essential under this prioritized theme, and request researchers to be aware of the importance of this aspect. If collaboration is difficult at the time of proposal, an initiative for collaboration must be planned later.

Proposals may be accepted even if the target technology is in a hypothetical stage or the R&D organization is not completely established on the assumption that they are eligible to be considered according to the policies described below.

We are calling for R&D projects that draw images in 10 to 15 years, by which time the outcome of full-scale research will be implemented in society. For example, the proposed R&D project may be backcast from social issues to solve or an ideal image of society with the aim of:

- solving social issues currently unsolved and may exist even after 10 to 15 years;
- solving emerging issues that are assumed to be major issues in 10 to 15 years; or
- presenting an ideal image of society in 10 to 15 years and the way to achieve it.

The proposal should provide specific consideration about how to apply AI and simulation technologies to systems, applications and services for achieving a desired future image, and what value (social and economical impact) is to be created by applying these technologies. In the light of the present circumstances, technical issues causing bottlenecks should also be identified and show the ways of solving them. The superiority and originality of the proposal should also be explained based on R&D trends in Japan and abroad, not as an extension of conventional technologies.

The scenario for future social implementation should also be provided as far as possible in addition to the POC throughout the full-scale research period and the R&D plans for achieving it. If the social and economic impact or scenario is unclear, surveys to clarify it may be included in the feasibility study.

(About team composition)
In this prioritized theme, it is not necessary to initially form a team that covers the whole plan. Proposals that include building a team system during a feasibility study are acceptable. In such a case, clearly describe the following in the proposal documents:

- What researcher(s) do you want to collaborate with to perform research?
- What activities do you plan to carry out in collaboration?

There may be cases in which JST advises collaboration between proposing researchers based on the collaboration plan in their R&D proposal documents after selection or adoption.

② Policies for R&D management

A feasibility study is positioned as preparation for full-scale research, which is conducted for five years in principle. A feasibility study has a period of two and a half years, in principle (up to end of fiscal year 2022). A feasibility study is presumed to take on the following specific research:

- Verify the social/economic impacts that the research will bring about in the future and its scenario.
- Specify technological development targets and a research plan by verifying technological feasibility.
- Proceed to form an effective team including AI/model researchers and business firms, as required.

Furthermore, the premise for a shift from a feasibility study to full-scale research is not only selection and concentration but also a bold re-composition of the research team, including reorganizations of sub-teams within a project team. A project (R&D project) may proceed to full-scale research sooner, depending on research progress.

③ R&D period and costs

For the R&D projects initiated in FY2020, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2022) and a total cost of up to JPY 25 million (direct costs) for the whole feasibility study period. Every researcher is required to undergo a stage gate evaluation for transition to full-scale research at the time designated by the Program Officer by the end of FY2022.

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period.
After adoption, we will flexibly allocate the budget according to the R&D content.

6.1.2 “Realization of a Sustainable Society” Area

Research and Development Supervisor (Program Officer: PO):
Hideyo KUNIEDA
(Senior Advisor, JST / Councilor, Nagoya University)

I. Goal of the “Realization of a Sustainable Society” 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 research 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 research 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, a new theme “Creation of innovative food production technologies responding to future changes in climate and social demands” has been added to the above two themes.

In this fiscal year, we make the second call for proposals on “Enhancement of product durability and usability for resource efficient society” set in FY2019. Also a new prioritized theme “Breakthrough technologies to accelerate breeding and strain improvement in biological production for a sustainable society” is set for 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 area actively takes on the appointment of young researchers and the construction of multidisciplinary research systems.

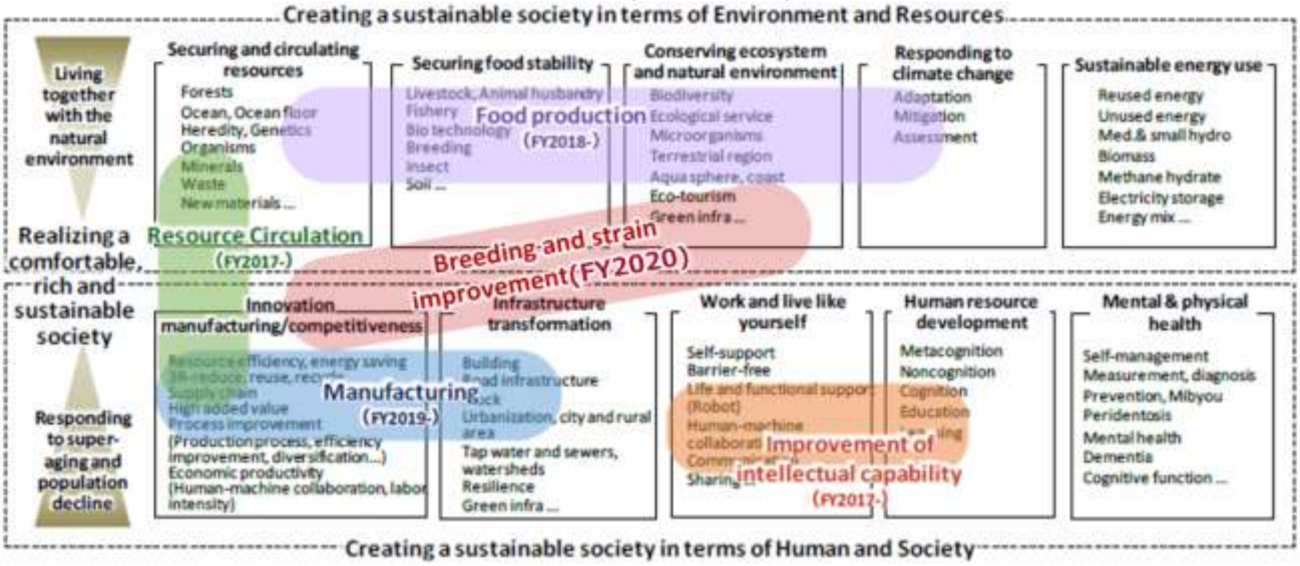

Fig.1: Designing process of the prioritized themes for the “sustainable society” area

II. Prioritized Themes

1. Enhancement of product durability and usability for resource efficient society

(1) About the theme

This prioritized theme aims to promote continuous use and reuse of composite materials, of which the global market is expected to grow, use the minimum necessary resources through optimized design, and achieve longer life and highly functional material design by elucidating the principle of fatigue and degradation, which is a complex set of phenomenon and the mechanism leading to breakage and destruction, and establishing technologies to estimate the life (residual life) of products with a high degree of accuracy.

Technologies to minimize the amount of materials used while maintaining product functionality are the foundation of production not only connecting directly to cost reduction, but also leading to effective utilization of resources and the minimization of transportation and movement costs (energy saving). Specifically, R&D of composite materials, which are composed of multiple materials with different properties and have two apparent characteristics, high strength and light weight, has been promoted with the social and economic demands for energy and resource saving. Furthermore, focusing on the heat resistance and shaping (molding) properties of composite materials, their application to a new domain of manufacturing, impossible with conventional materials, is expected, and now that our sense of values has changed significantly “from disposal to circulation” and “from ownership to sharing," they are expected to be used widely in manufacturing and value creation, i.e., continuous use and reuse, as the need to be ahead of the times.

However, the use of composite materials is limited to a specific area at present, and application that takes advantage of their characteristics and dissemination are hardly promoted. Composite materials combine two distinguishing characteristics of high strength and light weight, and are expected to be used in various industries as materials requiring strength, but in some cases, merits of being lightweight are not fully utilized because of the quantitative uncertainty of the effect of fatigue and deterioration associated with use on damage and fracture, and there is no choice but to design them with an increased thickness to ensure safety and reliability. In addition, quality assurance is difficult and continuous use and reuse are not promoted because changes in material due to fatigue and deterioration are not understood in detail, and this makes accurate evaluation of the function and lifespan of used products and parts difficult. Insufficient scientific understanding of the basic process of fatigue and deterioration thereby damage and fracture and composite phenomena due to complexity of interfaces between different raw materials and correlating phenomena disturbs the use of the inherent characteristics of composite materials, high strength and light weight, as efficiently as possible.

In this prioritized theme, we intend to contribute to Goals 9 and 12of the UN Sustainable Development Goals (SDGs), “improvement of resource utilization efficiency and promotion of sustainable consumption and production patterns,” and strive to realize an environmentally and economically sustainable society while meeting the changing needs of society and people by bringing innovation not only to manufacturing but also to usage through scientific understanding of unexplained phenomena in composite materials, and maximization of their performance and function.

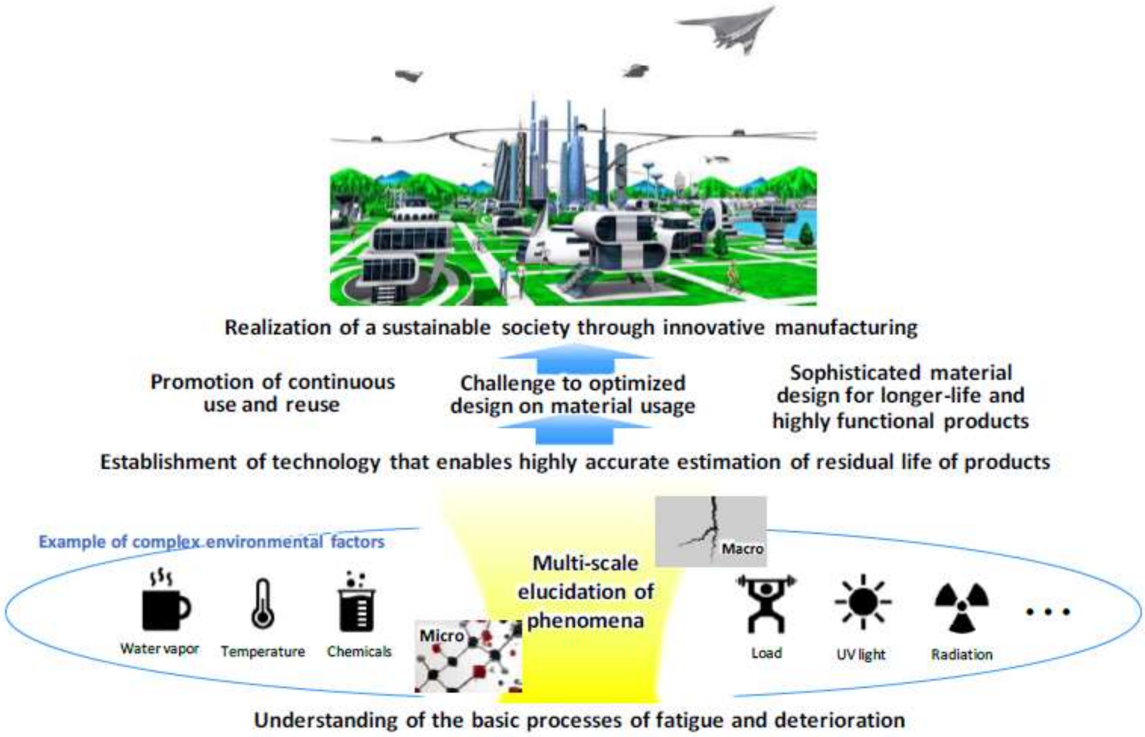

Fig. 1: The whole image that this prioritized theme aims

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

① Policies for proposal selection

In this prioritized theme, we will call for R&D proposals that enable longer life and higher function material design, etc. by returning to scientific principles to clarify the fatigue and deterioration processes and mechanisms causing damage and fracture of composite materials composed of a base material and reinforcing materials, and developing highly accurate remaining life estimation technology.

In FY2020, in addition to the proposals of R&D projects aiming for transition to full-scale research, proposals of component technology that contributes to the realization of the prioritized theme are called for as “Feasibility Study (Component Technology Type)” (hereinafter “component technology type”).

i. Proposal of R&D concept aiming for transition to full-scale research

The proposal needs to be backcasting from a specific application that has a social impact, such as continuous use, reuse, optimized design and feedback to material design. It is mandatory to deepen scientific understanding of elementary steps of fatigue and deterioration including those which are currently unknown, elucidate the mechanism leading to damage and destruction, and develop highly accurate remaining life estimation technology (e.g. technology to identify physical property values or minute structural changes caused by fatigue and deterioration, or highly accurate remaining life estimation simulation technology based on the fatigue mechanism model) as the POC.

The proposal should be planned as a series of R&D based on a clear concept from physical imaging using elementary steps to the final remaining life estimation and feedback to design for making the best of the function of materials. At that time, it is necessary to consider the complex environmental factors such as temperature, water vapor, ultraviolet rays and repeated load in fatigue and deterioration.

Particularly regarding the perspective of elucidating the life of things, we will call for a proposal capable of estimating the remaining life based on the principled elucidation of mechanism, not on the extension of conventional methods such as life simulation models by statistical processing based on destruction test data. For example, it may be necessary to include the following R&D elements:

- Understanding of elementary steps of fatigue and deterioration
- Elucidation of multi-scale phenomena that progress from micro to macro

This theme aims to develop a remaining life estimation technology that contributes to the development of a wider range of products and new materials, not limited to the combination of specific base and reinforcing materials or the combination of specific products and operating environments. In FY2020, we will call mainly for a proposal that assumes new composite materials based on innovative ideas, utterly new functions and concrete applications, not limited to composite materials such as CFRP and CMC that have already been on the market.

We welcome proposals from new fields beyond existing research fields and those for collaboration across technical fields. We also expect challenging proposals that are not an extension of conventional technology.

In feasibility study, R&D should focus on the solution of the largest technical bottleneck and confirmation of feasibility, which are key points to achieve POC. Also required are the examination of an optimal structure of R&D teams composed of companies and academia aiming for achieving POC toward full-scale research, and refinement of the concept of full-scale research.

Be sure to include the following in the R&D proposal documents as concretely and quantitatively as possible:

- The concrete image of social implementation with the proposal, and the magnitude of the social and economic impact that is assumed in reality.
  - With an eye on impactful and concrete applications including continuous use, reuse, highly optimized design and material design
- POC aiming for achievement at the end of full-scale research (at a stage where society or industry can determine the practical use of outcome)
- Concept of full-scale research aiming for achievement of POC
  - R&D for not only an independent research such as observation means to elucidate the mechanism or physical property tests but also a series of R&D from physical imaging using elementary steps to the final remaining life estimation and feedback to design for making the best use of the function of materials
- Goals and contents of feasibility study for full-scale research
  - Feasibility study is for confirming the feasibility toward achieving POC, and it is necessary to focus on the solution of the largest technical bottleneck and its feasibility

A proposal for R&D concept aiming for transition to full-scale research may be accepted according to its content on condition that it is applied as the component technology type R&D.

ii. Proposal for component technology type

As mentioned in Chapter 2 of the application guidelines, the component technology type does not proceed to full-scale research by itself, but aims for establishing the component technology required to achieve POC regarding the R&D project conducted under the prioritized theme. This type of proposal should be intended to indicate the feasibility of component technology (solution for the largest technical issue or confirmation of the feasibility).

We call for the proposal regarding the following technology this fiscal year:
Technology capable of measuring changes in micro structure (e.g. molecular level minute voids) unknown until now and in relation to the elemental steps of fatigue or deterioration of CFRP or CMC.

Please be sure to include the following in the proposal documents:

- Goals of this R&D project
  - Describe quantitatively the kind of structural change, level of spatial resolution, accuracy or temporal resolution, etc. for either or both CFRP and CMC.
- Methods of achieving goals and details of R&D
  - Describe proposed specifics about technical issues to solve and new techniques for solution.

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 meetings, site visits, study groups, etc., and the R&D management committee, including the R&D Supervisor, and the R&D practitioners work together to promote R&D, aiming to achieve the theme goal.

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). In addition, when a proposal of R&D project, intended to be transferred to full-scale research, is assumed to be quickly applied to society and industry once significant impacts on society and economy are revealed, transition to full-scale research is positively reviewed even during a feasibility study period.

③ R&D period and costs

For R&D projects initiated in FY2020, a feasibility study aiming for transition to full-scale research should be planned with a period of up to two and a half years (up to end of FY2022) and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period. Every R&D project is required to undergo a stage gate evaluation for transition to full-scale research at the time designated by the R&D Supervisor by the end of FY2022. The component technology type R&D should be planned with a period of one and a half years (up to end of FY2021) and a total cost of up to JPY 12 million (direct costs).

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period.

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

New

2. 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

This prioritized theme calls for R&D proposals for innovative technologies to efficiently derive new breeds and strains mainly in plants, microbes and insects.

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-scale research 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. Also required are the examination of an optimal structure of R&D teams composed of companies and academia aiming for achieving POC toward full-scale research, and refinement of the concept of full-scale research.

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.

- Technologies that enable genome editing of varieties and gene regions which is currently impossible
- Technologies for efficiently discovering genome sequences that represent useful traits
- Technologies for significantly enhancing new breed and strain production

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-scale research
  - 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-scale research
  - 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 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 meetings, site visits, study groups, and so on. The R&D management committee, including the R&D Supervisor, 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-scale research 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 the R&D projects initiated in FY2020, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2022) and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period. Every R&D project is required to undergo a stage gate evaluation for transition to full-scale research at the time designated by the R&D Supervisor by the end of FY2022. The component technology type R&D should be planned with a period of one and a half years (up to end of FY2021) and a total cost of up to JPY 12 million (direct costs).

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period.

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

6.1.3 “Realization of the Most Safe and Secure Society in the world” Area

Research and Development Supervisor (Program Officer: PO):
Ken-ichi TANAKA
(Senior Engineer, Mitsubishi Electric Corporation)

I. Goal of the “Realization of the most safe and secure society in the world” Area

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

This research 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 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.”

The prioritized theme for FY2019, “Self-management of health based on the action mechanism of daily behaviors such as food, exercise and sleep” focused on physical health of people based on daily behaviors such as food, exercise and sleep. The prioritized theme for FY2020 is “Realization of wellbeing by feedback based on psychological states evaluated by objective methods.” With these two themes, both physical and mental “safety and security” are pursued.

In the new prioritized theme, "Realization of wellbeing by feedback based on psychological states evaluated by objective methods," we aim for the development of techniques to objectively estimate psychological states and provide appropriate feedback according to psychological states to realize the wellbeing of individuals. In addition, regarding the continuation of the prioritized theme, "Self-management of health based on the action mechanism of daily behaviors such as food, exercise and sleep,” the focus is given to R&D to elucidate the action mechanism of daily behaviors, mainly “food” and/or “exercise” on health based on the results of selection and adoption in the last fiscal year, and realize a society of health and longevity through self-management based on objective indicators.

For details of the theme under which proposals are called for in FY2020 and the relationship with the prioritized themes to date, please refer to the schematic below.

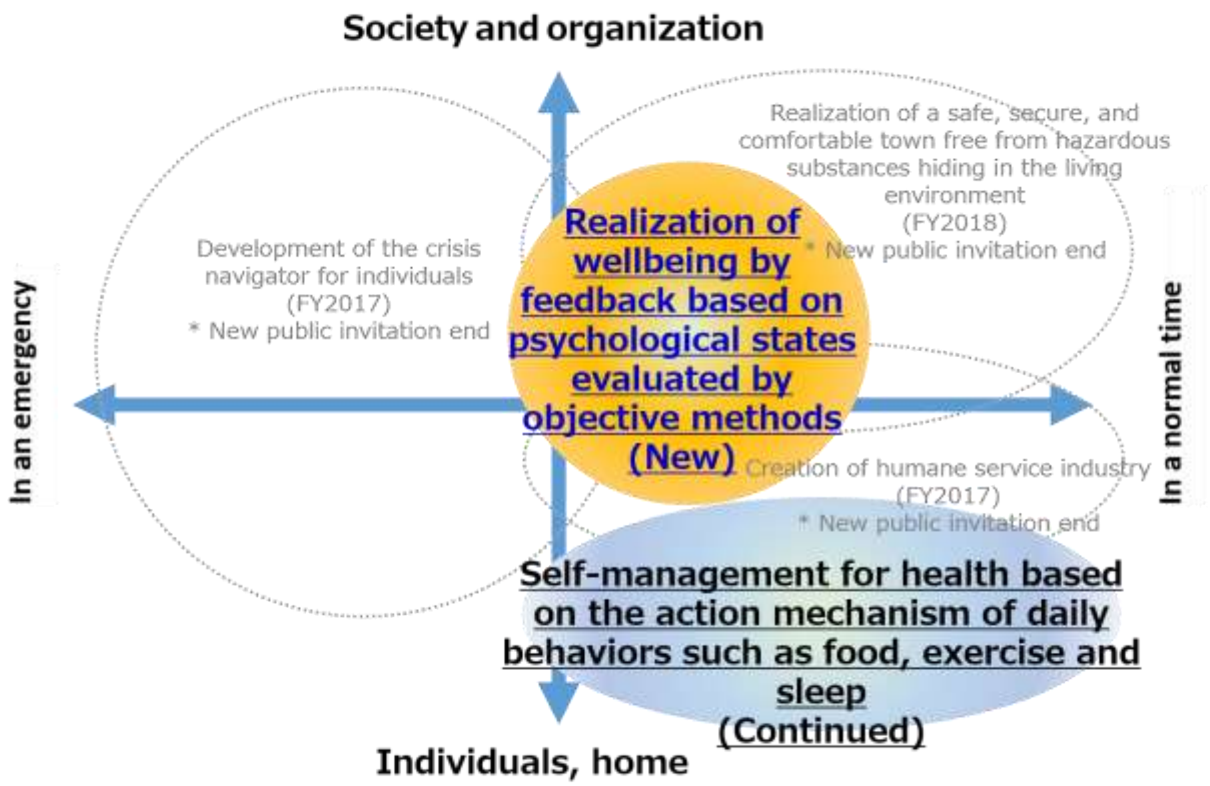

Fig. 1: Positioning prioritized themes for “safety and security” area (outline)

Continued

II. Prioritized themes

1. Self-management of health based on the action mechanism of daily behaviors such as food, exercise and sleep

(1) About the theme

Under this prioritized theme, we expect a wide dissemination of self management for health maintenance by elucidating the mechanisms of actions in the living body, such as food, exercise and sleep, which are the base of health maintenance, and providing scientific evidence that triggers truly effective behavior. We also largely expect this to allow us to build a foundation for continuously creating services that can introduce and promote health activities optimal for individuals to realize a society of health and longevity.

Japan has entered a super-aging society, and medical costs are soaring as the proportion of people who complain of physical disorders and unhealthy people increase. This puts pressure on national finances, and may give serious effect on the continuity of social security such as medical insurance. To solve these social issues and realize the extensive and active life of individuals, the prolonged healthy life expectancy is very important.

Appropriate "food" "exercise" and "sleep" are said to be the three basic elements vital to maintain good health, and daily behaviors such as balanced diet, moderate exercise and adequate rest and sleep are considered to give significant impact on how long we can stay healthy throughout our lives (healthy life expectancy). Therefore, when the effect of daily behaviors such as "food" "exercise" and "sleep" on health is elucidated and we can manage our daily behaviors ourselves based on objective indicators that can be measures in daily life, we can contribute to the realization of the extensive and active life of individuals. Furthermore, if we can find the symptoms of illness at an early stage and restore health condition through our daily behaviors without taking medical treatment, we can also contribute to the continuity of social security.

There are various information around us about daily behaviors effective for maintaining health at present, but much of it is merely an interpretation based on correlation between daily behaviors and health condition, because what kind of action mechanism of daily behaviors such as "food" "exercise" "sleep" affects our health is not known well. However, as studies of action mechanism are progressed, it became obvious that such correlation-based interpretations were not always correct. For example, the conventional explanation about lactic acid accumulated in muscle during exercise was that it is a substance causing fatigue based on the correlation data obtained from epidemiological studies, but studies of correlation between lactic acid and fatigue were advanced later, and now, we gradually come to understand that lactic acid is rather effective to suppress fatigue. Likewise, it is still the case that many of our daily behaviors depend on the information which is not entirely true due to insufficient elucidation of action mechanism. Further study of action mechanism is required to elucidate the effect of daily behaviors such as "food" "exercise" and "sleep" on health as the first step to promote appropriate behaviors for maintaining our health and realize a society of health and longevity.

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

Key points for FY2020• For the prioritized theme in FY2020, mainly called for is R&D to elucidate action mechanism of daily behaviors affecting health, specifically by focusing on "food" or "exercise," with the aim of realizing a society of health and longevity through self-management based on objective indicators. Continued from the last fiscal year, the proposal should include research into the elucidation of action mechanism.

① Policies for proposal selection

In this prioritized theme, a method of self-management of daily behaviors based on objective indicators is established by elucidating the action mechanism of daily behaviors such as "food" "exercise" and "sleep" that affect health, and grasping these daily behaviors in a comprehensive way to realize the extensive and active life of individuals. Based on the R&D projects adopted under this theme in FY2019 (see the webpage for this project), mainly R&D focusing on "food" or "exercise" is called for this fiscal year.

For example, when "food" and health are concerned, information about what and when to eat is important for good health. Recent development of analytical techniques has contributed to elucidating the functions of various nutrients (proteins, lipids, carbohydrates, vitamins, etc.) and non-nutrients (dietary fiber, polyphenols, etc.), which compose foods, within the living body, but It is thought difficult to prevent health problems caused by "food" related lifestyle such as obesity based only on such information. In this call for proposal, we expect R&D to elucidate the action mechanism of "food" on health by taking into account the eating rhythm such as when to eat and the neurotransmission of appetite and preference as eating behaviors, in addition to the functions of food components in the living body and biological responses.

Regarding "exercise," biological responses such as muscle activity, humoral regulation and activation of the immune system are caused by physical irritation applied to cells, and this is thought to contribute to the maintenance of homeostasis of organs and systems. Therefore, "exercise" is considered effective to prevent lifestyle-related diseases such as high blood pressure and diabetes. As the action of "exercise" on organs and systems is extensive, and its action mechanism has not been fully understood, the actual strength and amount of exercise required, for example, to maintain health is not defined scientifically. The R&D called for this time should deal with the elucidation of the action mechanism of "exercise" on organs and systems (muscles, bones, blood vessels, etc.), and the quantification of the strength and volume of exercise particularly require for maintaining individual health.

As mentioned above, we put a focus on R&D to identify the factors related to "food" and/or "exercise" among the daily behaviors from those which are used as objective indicators (markers) of the recovery from the early stage of Mibyou and promotion of health, and establish self-management of daily behaviors based on these indicators. A series of R&D to achieve self-management of daily behaviors based on objective indexes derived from action mechanism is strongly requested. Furthermore, we also value a proposal with a clear vision to widely recommend and disseminate self-management of daily behaviors to every generation including workers and elderly people by combining various means including the nudge effect and gamification.

These indicators cannot be used for self-management of our daily behaviors unless they can be easily measured at home, school, company, day care center, drug store, and the like. Researchers are requested to present a highly feasible concept in view of deploying new services and widely disseminating them in our lives.

* Proposals other than those focusing on “food” and/or “exercise” are acceptable if they handle daily behaviors including “food” “exercise” and “sleep” in a comprehensive way and present the POC that gives significant impact to realize a society of health and longevity.
* Continued from the last fiscal year, the proposal must include research to elucidate the action mechanism of daily behaviors such as “food” “exercise” and “sleep” on health.
* Cohort studies such as follow-up survey of healthy people are not assumed, but proposals based on long-term observation data accumulated in other cohort studies are welcome.
* Multiple R&D projects under this prioritized theme may be integrated or adjusted as required after the stage gate evaluation following the end of feasibility study period and before transition to full-scale research.

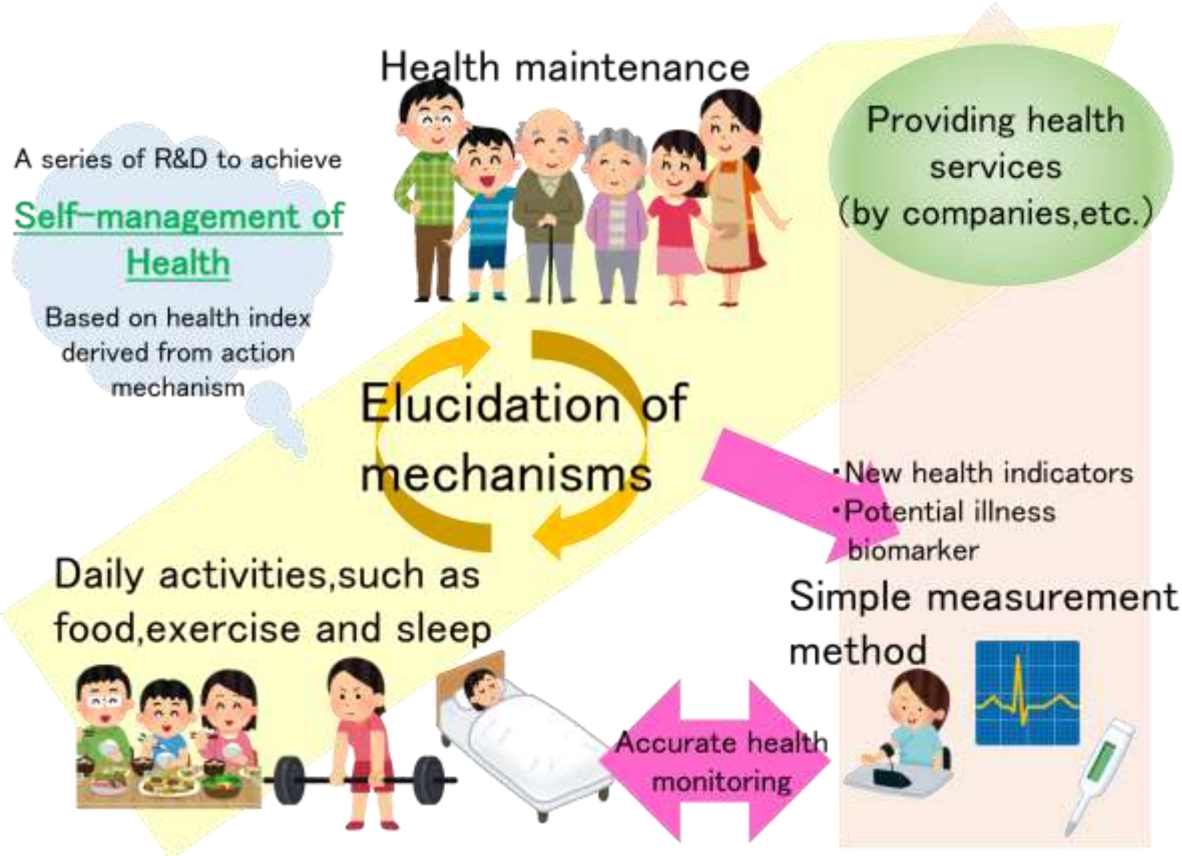

Fig. 2: The whole image that this prioritized theme aims

② Policies for R&D management

R&D in this area should incorporate innovative ideas using the diversity of research systems, including active promotion of cross-disciplinary study that is not confined to conventional academic fields, participation of young researchers, and active collaboration between companies and academia. We will also commit ourselves to make concerted efforts together across individual fields for creating R&D

outcome that exert a strong impact on society and economy by organizing a research management system that can provide advice and guidance through the reviews of research plans and site visits by members of the R&D management committee.

For transition from feasibility studies to full-scale research, we may restructure the system, such as reassignment or cancellation of individual groups that participate in research projects and of research themes.

③ R&D period and costs

For the R&D projects initiated in FY2020, feasibility study should be planned with a period of up to two and a half years (up to end of FY2022) with a total cost of up to JPY 30 million (direct costs). Every researcher is required to undergo a stage gate evaluation for transition to full-scale research at the time designated by the Program Officer by the end of FY2022.

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period.

New

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

(1) About the theme

This theme aims to elucidate the relationship between the data measured in daily life and psychological states, develop technologies for objectively estimating psychological states using data from multiple sources, and develop an appropriate method of feedback according to psychological states based on scientific evidence. The goal is to realize the wellbeing of individuals by promoting their psychological state to demonstrate their abilities.

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 the like. 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 things, 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.

To estimate an accurate psychological state in daily life and changes of it, 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, under the present healthcare system, a person asks a counselor or psychiatrist for interview or goes to a hospital for diagnose or treatment only when he or she feels poor mental health. If, however, the psychological state can be objectively estimated from the data continuously measured in daily life at school, workplace, etc., signs of mental disorders can be detected early, and this prevents the disorders from getting serious by improving the psychological state through the routines of everyday life. Identifying nutrients effective for improving depressive mood and developing foods based on their functional evaluation are, for example, expected to lead to the practical methods for improving mental health in daily life.

If these technologies not only improve poor mental health but also muster motivation, the wellbeing of individuals will be improved. For example, recent studies have revealed that the interaction between the senses of touch and hearing of a person who draws pictures or letters by hand is effective for raising motivation. Therefore, researchers are requested to elucidate the relationship between various stimuli and human senses, perceptions and psychological states and develop a feedback method using the results of elucidation to promote psychological states encouraging individuals to demonstrate their abilities.

Accordingly, this prioritized theme aims for elucidating the relationship between the data that can be continuously measured in daily life and psychological states, developing a new technology to objectively estimate the psychological state from the measured data, and developing an appropriate method of feedback according to psychological states to realize the wellbeing of individuals by promoting psychological states encouraging individuals to demonstrate their abilities.

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

① Policies for proposal selection

This prioritized theme calls for the proposal consistently focusing on the development of technologies for objectively estimating psychological states using data that is continuously taken from multiple sources and the development of an appropriate method of feedback according to psychological state based on scientific evidence on the assumption that they are implemented in everyday life including school or workplace etc. We are looking for total R&D proposals from the development of technologies for objectively estimating psychological states to the development of an appropriate method of feedback according to psychological state for the realization of the wellbeing of individuals.

Regarding the objective estimation of psychological states, R&D for elucidating the relationship between psychological states and specific sensing data such as linguistic information, dynamic information (voice, facial expression, movement, etc.), biological information (heartbeat, blood pressure, sweat, etc.), biochemical information (hormone, etc.) is called for. The psychological state must be supported by multiple methods including behavior observation and questionnaire surveys, and based on evidence. On that basis, an analytical model and algorithm must be developed for the objective estimation of complicated human psychological states such as poor mental health or motivation using the sensing data collected from multiple sources.

Since it is required to detect data characteristics and changes in a noisy environment, we welcome interdisciplinary proposals incorporating mathematical science techniques in the development of analytical models and algorithms. Any type of psychological state will be accepted in this call for proposals, but the specifically targeted psychological state should be indicated in the proposal.

Although brain activity information (electroencephalogram, fMRI, etc.) is considered to be useful in estimating psychological state, it is expected that there will be problems in daily measurement. In this prioritized theme, brain activity may be included in the target sensing data, but in that case as well, the proposal aiming for continuous measurement of data in daily life, such as the search of other sensing data correlated to brain activity data, is required in consideration of the implementation of the outcome in daily life.

In addition, we call for proposals to develop an appropriate feedback method according to each of estimated psychological states in order to promote psychological states encouraging individuals to demonstrate their abilities. For example, the development of behavior modification applications and functional foods effective for improving psychological states such as anxiety and depression, or the development of a method to enhance psychological states such as motivation by applying the interaction of various senses such as touching and hearing is assumed. We call for a proposal that specifically describes the image of implementation in daily life by combining the technology to estimate the psychological state and the appropriate method of feedback according to a specific psychological state.

Some examples of expected R&D projects are listed below, but they are given for only information. Please feel free to propose R&D themes.

R&D project example 1:

Children learn in various situations such as school, home, and cram school. During learning, negative emotions may occur due to external factors such as indoor environment as well as internal factors such as weakness, and how to prevent and respond to such negative emotions during learning is important issue. It is also important to utilize the positive feelings of delight and amusement felt by children during learning to promote learning effects. Therefore, we will elucidate the relationship between the psychological state and the sensing data such as the facial expression, line of sight, and behavior of the child, and develop a model for estimating the psychological state of children such as fun, comfort, frustration and anxiety. By applying this technology to school, home, cram school, and other related sites, we can objectively estimate the psychological state of children who actually learn indoors. By understanding the psychological state of children in real time, parents and teachers can provide suitable support and select suitable teaching materials, in addition to the development of new teaching materials to increase children's motivation for learning based on the interaction of various senses such as seeing, hearing and touching, leading to the environment in which children can learn with positive emotion anywhere.

R&D project example 2:

The largest cost factor related to the health of employees is said to be "presenteeism (a situation in which the employee is present in workplace, but work efficiency is reduced due to some health problem)." Poor mental health is deemed to account for the largest percentage in this category. We aim to automatically detect signs of poor mental health of employees, which used to be mainly determined by interviews with counselors, etc., in the actual work environment. A model to be developed is able to identify markers such as biological or biochemical information correlating with brain activity, elucidate the relationship of this sensing data with psychological states, and estimate the psychological state leading to mental disorders such as anxiety and depression with high accuracy. In addition, a work environment where everyone can work proactively should be built by developing a behavior change application useful for improving psychological states such as anxiety and depression, and providing feedback such as optimal advice to employees who are showing signs of poor metal health.

In addition to the learning support and labor productivity improvement shown in the above R&D project example, there are a wide variety of areas to which the technology that objectively estimates the human psychological state can be applied, including, manufacturing, marketing, nursing care support and community activation. Freewheeling ideas are encouraged. In particular, 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 without limiting to the above examples 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.

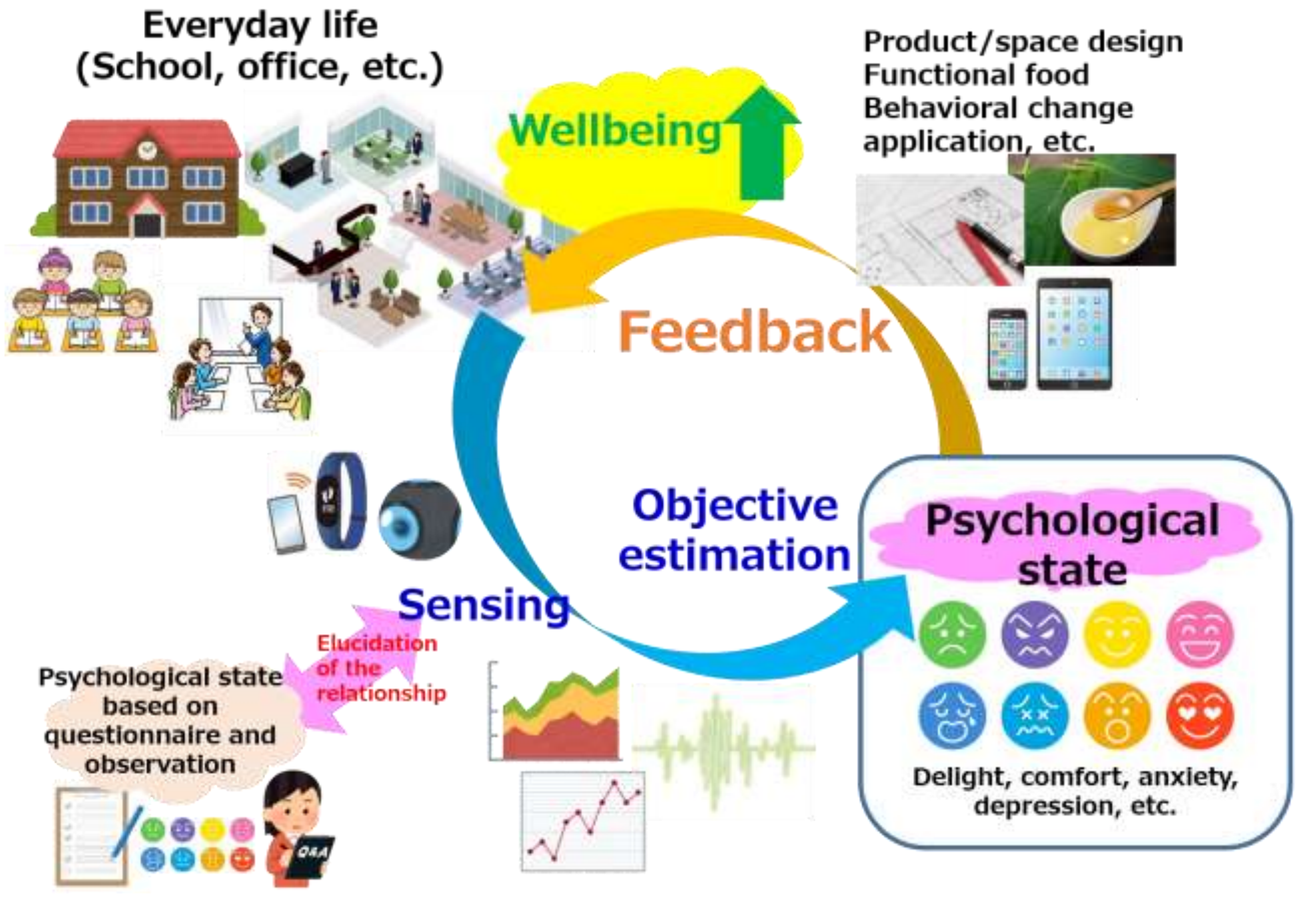

Fig. 3: The whole image that this prioritized theme aims

② Policies for R&D management

We will establish a research management system that can provide advice and guidance through the reviews of research plans and site visits by members of the R&D management committee, and aim to realize a "society in which everyone feels protected"

We are eagerly looking for proposals that consistently address the realization of the wellbeing of individuals by promoting psychological states encouraging individuals to demonstrate their abilities in real daily life by developing an analytical model and algorithm that objectively estimates the psychological state from the sensing data and a feedback method based on estimation results. We also expect joint proposals of researchers in psychology, biochemistry, engineering, etc., in which researchers in biochemistry or engineering give advice on the items to measure for the knowledge of psychologists on psychological states, measuring methods using relevant devices, and data processing and feedback based on the theory of psychology.

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

③ R&D period and costs

For the R&D projects initiated in FY2020, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2022) and a total cost of up to JPY 30 million (direct costs) for the whole feasibility study period. Every researcher is required to undergo a stage gate evaluation for transition to full-scale research at the time designated by the Program Officer by the end of FY2022.

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period.

6.1.4 “Realization of a Low Carbon Society, a global issue” Area

Research and Development Supervisor (Program Officer: PO):
Kazuhito HASHIMOTO
(President, National Institute for Materials Science)

I. Goal of the “Realization of a low carbon society, a global issue” 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 fiscal year 2020.

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 fiscal year 2019, “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 last fiscal year, we reset our bottleneck issues to call for more research-and-development 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	B1	Highly durable / highly efficient Pb-free perovskite solar cell
	B2	Photovoltaic cell based on a new concept realizing twice or more conversion efficiency than conventional solar cells
	B3	Solar cell manufacturing technology featuring “a device thinner than ever before”
	B4	Tandem solar cells exceeding theoretical limit of single-junction solar cells
	B5	Organic solar cells with conversion efficiency of 20% or more
	B6	Artificial photosynthesis aiming for dramatic improvement in efficiency
②Energy-saving technology based on physical/chemical processes	B7	Energy saving and high efficiency related technologies for electric power/power conversion systems
	B8	Fundamental technologies of green electronics for energy saving data communication and innovative information processing
	B9	Development of innovative thermal energy utilization technologies
	B10	Process intensification using high-efficiency, high-performance separation technologies
	B11	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	B12	Technologies for large-scale and efficient conversion of CO_2 into methanol, olefins, and other chemicals

chemical process and bio-technologies	**B13**	Development of highly efficient greenhouse gas separation membrane and sorbent
	B14	Development of highly efficient biomass gasification processes for chemicals production
	B15	Development of photosynthetic microorganisms robust against changes in environmental conditions for large-scale production
	B16	Technologies for improving biomass productivity with minimum resource input
	B17	Synthetic biological technology and innovative bioprocess technologies for designing cells with high productivity for useful substances
	B18	New synthetic technologies for high-efficiency production of high-performance/high-functionality materials from biomass raw materials
	B19	Technologies for controlling layer structures to create next generation nano-cellulose materials
	B20	Technologies for chemical modification/composition to create next generation lignin materials
④**Creation of recycling-oriented polymer materials to realize a low carbon society**	**B21**	[Management method by harmonized various technological seeds] Creation of recycling-oriented polymer materials to realize 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 (①-④), Classification of Proposals (B1 - B21), 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 B1: Highly durable / highly efficient Pb-free perovskite solar cell

* We have not set bottleneck issues related to storage batteries this year, but in “next-generation storage batteries (ALCA-SPRING),” a special priority technology area of the Advanced Low Carbon Technology Research and Development Program (ALCA), which is a separate project, we are planning to add a joint R&D organization to conduct research into the separation technology for solid electrolytes and air batteries based on new materials to R&D teams conducting existing R&D projects according to the advice by the relevant evaluation committee. For details, visit the following web site:
https://www.jst.go.jp/alca/alca-spring/archive/2020/04/30/group-expansion/index.html

(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 area.

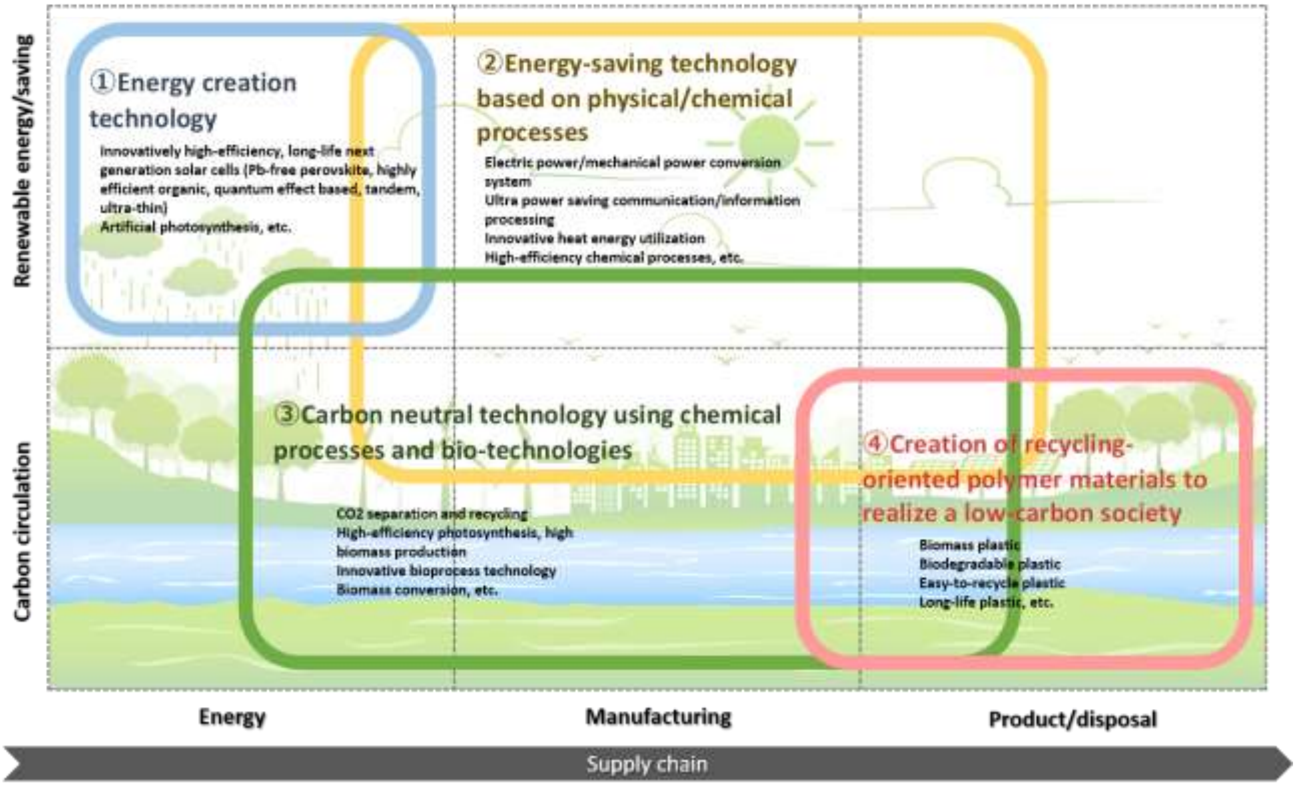

Fig. 1: An overview of the "Realization of a Low-Carbon Society, a Global Issue" area

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 research and developments 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 area agrees with these strategies and we will promote the research and developments that are closely connected to the public interest.

Furthermore, we, considering the research and development 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 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 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 research and development).

・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 (5) Viewpoint of Selection,” but in this 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 in selection criteria 1.

● Description on research and development

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 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 area.

In this 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 last fiscal year, 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

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. 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 for long-term use. It is guaranteed that the solar cells currently in use can be used 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 and application to solar cells
- Development and improvement of encapsulation materials that achieve high durability and realization of high-efficiency Pb-free perovskite solar cells

B2 Photovoltaic cell based on a new concept realizing twice or more conversion efficiency than conventional solar cells

The conversion efficiency of the cells used in Si solar cells has reached approximately 25%; the logical maximum efficiency of the single-junction-type solar cells is said to be around 30%. Ordinary solar cells cannot absorb light that has energy lower than the band gap; therefore, in the case of light with high energy, the residual energy is converted to heat and is then lost. However, in the case of quantum dot solar cells, it is possible to form an intermediary band in the band gap; thus, it has been pointed out that it becomes possible to convert a large portion of the energy from light into electricity. In the case of an intermediary-band solar cell, it is said that an efficiency of 60% or more, logically, can be attained with a concentrator type. The actual conversion efficiencies are still low. In addition to the fundamental and principle-based examinations including the adequacy and feasibility of the theoretical model, we need to optimize quantum dots or other intermediary-band materials, the method of formation, the structural of solar cells, and more. With these conditions considered in this area, we call for challenging proposals for the designing principle of the use of new concepts such as quantum effects or photon management to embody conversion efficiencies twice or more as high as that of single-junction-type solar cells, for the structure of solar cells and the construction of the formation method based on such principle, and for the embodiment of these. There is no restriction on materials or mechanisms; our evaluation points shall be that the proposals probe the superiority to conventional solar cells, and furthermore, step up to propose the specific methods of production. For example, 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

B3 Solar cell manufacturing technology featuring “a device thinner than ever before”

Almost all crystalline Si wafers, which are commercially produced at present, are produced by wire saw technology and optimized with a wafer thickness of 180 μm, almost the lowest limit. If it is made thinner than this by the wire saw technology, not only yield loss will occur, but there will be an inappropriate situation in terms of manufacturing cost that the amount of Si shavings (kerf-loss) generated with cutting will increase. In wire saw technology, contamination of Si shavings with lubricating oil is a problem, and appropriate collecting technology has not been developed. This is a major challenge in terms of the effective use of expensive materials. In this field, in addition to the unconventional technology to produce the ultra-thin (1/4 or less of the existing thickness) crystalline Si wafers, we call for the solar cell manufacturing technology which can achieve the cell efficiency of 23 % or more from the crystalline Si wafers of such thickness. We also call for challenging proposals aiming to produce ultra-thin film solar cells made of new materials that allows lightweight, flexibility and high efficiency applicable to flexible electronics and elastic electronics which have high potential in the future. Proposals such as the following are expected:

- Development of ultra-thin solar cells using new technologies such as the epitaxial lift-off method
- Proposal of new structure that can suppress reduction in solar cell efficiency due to thinning and weight reduction
- Development of bendable ultra-thin, high-efficiency crystalline Si solar cells
- Production of ultra-thin inorganic compound semiconductor on film substrate and realization of excellent solar cell characteristics

B4 Tandem solar cells exceeding theoretical limit of single-junction solar cells

In order to realize drastic enhancement in the conversion efficiency of 30%, which is the theoretical limit on single-junction-type solar cells, it is expected to laminate semiconductor materials of different band gaps to expand the absorbing wavelength band for tandem-type solar cells; however, this has not brought any sufficient enhancement in terms of efficiency. As the solar cells in the bottom layer, Si and CIGS solar cells (band gap 1.1 eV), are optimum as they have high conversion efficiency and exhibit excellent durability. As the solar cells on in the top layer, the semiconductor layer solar cells with the band gap of approximately 1.5–1.7 eV have been studied; however, any solar cells with low-cost, high efficiency and high durability are yet to be realized. For instance, perovskite solar cells (band gap - 1.5 eV), chemical compound semiconductors (CuGaS), and others have been studied as a top layer. Keeping practical use in mind, we are looking for challenging proposals aiming to realize significant improvement of power generation performance of tandem solar cells at low cost, taking into account the electrical and optical performance of the modules and the entire system. For example, proposals such as the following 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
- Pb-free perovskite and perovskite tandem solar cells

B5 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 for thin-film solar cells, the conversion efficiency has rapidly improved, such as the efficiency exceeds 17% in a single cell, and reportedly reached 17.3% in a tandem cell, and it 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 good Jsc and Voc. The high design characteristic of organic compounds is the most appropriate for the light absorption matching of each cell required for tandem cell development. We call for challenging proposals that elucidate the molecular mechanism of electron and hole-transport, develop materials and battery structures based on that to achieve a new solar generation system. 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 solar cells
- Development and improvement of voltage loss control method for organic solar cells
- Establishment and improvement of tandem type and new structure organic solar cell design method

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. 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. The development of unconventional, efficient artificial photosynthesis technology for generating methanol from carbon dioxide using sunlight is also an important issue. 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

② Energy-saving technology based on physical/chemical processes

B7 Energy saving and high efficiency related technologies for electric power/power conversion systems

The gross power consumption of our country is 1000 TWh, of which almost 50 % is used for the driving power of motors. There is a strong demand for further power saving of motors and their driving systems for effective use of energy resources. The driver-power conversion efficiency of motors in present-day use exceeds 90%; however, even 1% increase in efficiency contributes to large energy saving due to an enormous amount of motor power consumption.

We call for innovative proposal in the following technological fields regarding high-efficiency power/energy conversion systems:

(1) Technology that reduces iron and copper losses and improves torque by improving the structure of the motor stator and rotor
(2) Integrated power module consisting of digital control ICs and power converters (inverter, converter)

for high-efficiency drive according to motor operating conditions and load, and motor control method

(3) Hard magnetic material with high coercive force and soft magnetic material with low iron loss and high saturation magnetic flux density

(4) High-power switching element for inverters and regenerative converters with excellent trade-offs of breakdown voltage, on-resistance and operating speed

In the proposals for structure, system, circuit or device development, the superiority to the existing systems should be indicated by prior theoretical prediction and 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.

- Motor drive system that can efficiently regenerate energy into the storage battery in electric vehicles
- Sensorless control system capable of low-speed operation with good response in brushless motors
- High-performance, low-cost rare earth magnets such as neodymium magnets that do not require dysprosium and samarium iron-nitrogen magnets that can be sintered
- 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

B8 Fundamental technologies of green electronics for energy saving data communication and innovative information processing

We are concerned about soaring power consumption in communication networks to collect an enormous amount of information (big data) from sensors attached to things such as electric appliances, buildings, transportation equipment and agriculture, etc. and people for the realization of the future society (Society 5.0) that Japan aims for. In addition, in terms of mobile communication equipment, the needs for 4K/8K and other video content, as well as for high-resolution static images for security, educational content, medical content, and others have been rapidly increasing. The amount of data communication keeps on rapidly increasing. For instance, for the next-generation 5G communication systems, a capacity increase of one-thousand times or more and speeds exceeding 10 Gbps are expected; to satisfy the expanding demand for telecommunications in the long run, it is required to reduce the communication power consumption per bit to a tenth or lower.

The issues we should solve in this area of technology (communication bottlenecks) are everywhere in the communication paths from edge side to the cloud side; we have to solve the bottlenecks in information processing and communication paths using various technologies including those for saving energy in power amplifiers for wireless communication, edge information processing chips and high-speed router devices.Specific examples of the proposals are shown below, but we are looking for innovative power saving technologies without limiting to these examples.

- Communication system hardware technology that significantly reduces the amount of

communication power per bit
- Information processing devices based on new architectures such as quantum computing
- Optical wiring technology between LSI chips with small data transfer delay
- Information compression chip (edge side) that dramatically reduces the amount of data transferred to the cloud side, such as real-time image recognition

B9 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. 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, 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, speeding up of heat transport and storage by enhancing heat transfer of reaction layer, 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

B10 Process intensification using high-efficiency, high-performance separation technologies

The productivity of production process in the chemical industry and their energy-saving performance are largely depend on the separation, recovery and recycling processes for non-reactional raw materials, products and solvents in addition to the improvement of yield in production process. 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, in order to achieve low carbonization in the chemical industry, it is a major issue to develop high-efficiency and high-performance separation technologies to improve the energy saving of the production process.

To solve this issue, in addition to the separation membranes with innovative separation performance and high-performance separation processes and the hybridized various separation technologies (such as membrane separation, phase separation, adsorption, extraction, crystallization, etc.), the reaction separation technologies such as the membrane reactor, reactive absorption, reactive crystallization and reactive distillation, are included in the targeted technologies. In particular, membrane separation process is expected as the separation technology, with high-efficiency and energy-saving, replacing the reactive distillation. 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 research and development 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.

B11 Innovation of bulk chemicals production technologies based on a new reaction field to save energy required for causing chemically difficult reactions

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. Also, 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.

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 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

B12 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.

B13 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.

Although an estimation (IEA-ETP 2017 report) that CCS should bear about 14% of the cumulative CO_2 reduction by 2060 is presented, the current CCS cost is estimated to be JPY 6,000/t-CO_2 or more with the most popular chemical adsorption method (using amine-based absorbent) at present, and a substantial cost reduction is essential for practical application. 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.

B14 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 70% 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 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.

B15 Development of photosynthetic microorganisms robust against changes in environmental conditions for large-scale production

There has been considerable interest in the production of chemical products and fuel from microalgae, cyanobacteria, or other photosynthetic microorganisms because we can produce substances from CO2 during photosynthesis. Till date, there have been researches for the efficient production of a target substance based on the examination on cultivation conditions and the technology to control genes. Some of these achievements involve the production of value-added chemical products or the like, which seem to be prospective for their practical application; various types of large-scale verification tests have been attempted for the practical applications. What has been revealed that there are several high hurdles in large-scale cultures we should overcome and that they are different from those in laboratories. The topmost issue is that the productivity, in the cases of large-scale cultures, is extremely low compared to the analyses at laboratories. For instance, the appropriate light intensities are different depending on the types of microalgae, and in a laboratory, you can use an ideal light and temperature environment for the microalgae of your subject. However, the light and temperature environments outdoors vary considerably depending on the weather, which cannot be artificially controlled. This variance of the intensity makes it impossible to maintain a high-density culture outdoors, leading to the degradation of the productivity of a subject, contamination, and the issue of a cost recovery. In addition, not only in the case of a large-scale closed-system cultures outdoors but also in the case of such cultures indoors, there are issues completely different from those in the analysis systems in a laboratory; these include the difference in the cell environments in the surface layer and the deep layer of a culture tank, stirring issues, and the issue of the necessity of illumination to light up deep area.

Therefore, we are calling for proposals for the development of photosynthetic microorganisms robust against environmental changes to overcome the bottleneck of large-scale productions, for instance, as indicated below. Moreover, if an effective fracturing technology is linked to the extraction of chemical compounds from the collected fungus bodies, the feasibility of a practical application becomes even higher.

- Development of microalgae that can maintain productivity regardless of light intensity or culture tank depth
- Development of microalgae that can obtain high cell density even under weak indoor lighting

B16 Technologies for improving biomass productivity with minimum resource input B23

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 research and development 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

B17 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.

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.

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. We also include the innovative development of (cell-free) bioprocesses using these synthetic biological findings. 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 innovative development of new (cell-free) high-efficient bioprocesses to replace conventional chemical processes
- The new process development to easily connect / link both biological and chemical processes

B18 New synthetic technologies for high-efficiency production of high-performance / high-functionality materials from biomass raw materials

An important issue is the development of a new technology for the high-efficiency production, in an energy-saving process, of chemical products and/or polymeric materials that are useful for our daily lives and/or for industrial use from saccharide and/or lignin collected via component separation of biomass resources (woody plant- or herbaceous plant-related materials). In recent several years, a variety of processes have been proposed to pertinently separate mainly the three constituents—cellulose, hemicellulose, and lignin—from woody or herbaceous plant materials; the development of the separation technologies, each with special characteristics, has been progressing rapidly. Consequently, now it is possible to produce cellulose, saccharide, lignin, etc., of a relatively high purity.

To develop a bio-refinery system for this country, it is necessary to contribute to the low carbon society and to simultaneously make it profitable. Therefore, the first bottleneck is to develop a new chemical/biological synthesis method of converting cellulose, saccharide, and lignin, which are produced from bio-mass resources, efficiently into the high-performance and/or highly functional chemical products and/or polymeric materials that are wanted by the society. In addition, it is also necessary to develop the technology to convert terpene, polyphenol, etc., which are not attracting attention because they include only small amounts of biomass resources, into some functional products with high added value. The second bottleneck is the development of the technology that can produce general-purpose chemical products, such as organic acids and alcohol, from biomass resources at a low cost. When these bottlenecks are solved, petroleum-based platforms can be converted into biomass-based platforms for the first time ever, and thus, after a low carbon society, a genuine carbon-circulating society will be realized.

On this occasion, we are calling for challenging proposals on the development of a new synthesis technology to realize the efficient production of high-performance or high-function chemical products or polymeric materials by using energy-saving processes and materials including those in the first bottleneck, that is, cellulose, saccharide, lignin, terpene, and polyphenol.

We are expecting the proposals such as the following. Cellulose, saccharide, lignin, terpene, polyphenol, or the like is not converted into inexpensive general-purpose chemical products or energy sources such as organic acid or alcohol but, instead, into, for instance, the following:

・Some high-performance or high-function chemical products or polymeric materials by making use of the skeletal structure such as the biologically originated six-membered ring contained in, e.g., cellulose, sugar chain, lignin, terpene, and polyphenol converted by a chemical or biological synthesis technology
・The chemical products that are expected to be in short supply in the future because of the difficulty in the production based on natural gas or shale gas, which is expected to be produced more profusely in the future; an example is C4 or more chemical compounds and aromatic compounds produced at a low cost efficiently by using cellulose, saccharide, lignin, terpene, polyphenol, or the like based on the developed synthesis technology
・Since lignin is a cross-linked polymer, it is known that it decomposes in a short time only under severe reaction conditions such as high temperature and pressure, and that it is extremely difficult to obtain efficiently the low molecular weight compounds such as aromatic compounds from it. Technological development on lignin degradation reaction and its process to solve this problem.

B19 Technologies for controlling layer structures to create next generation nano-cellulose materials

The development of technology to efficiently separate, from biomass resources, nano-cellulose of approximate thickness 20 nm (cellulose nanofiber (CNF), cellulose nanocrystal (CNC), etc.) has advanced; domestically and abroad, some test productions for the industrial use of nano-cellulose have begun. The tensile strength (3 GPa) and the modulus of elasticity (140 GPa) of nano-cellulose are generally the same as those of aramid fiber and other ultrahigh-strength fibers, and its thermal deformation is small, too; therefore, nano-cellulose has much potential as a high-performance material. In addition, nano-cellulose has a large surface area, and its surface has such a large number of hydroxyl groups that you can introduce various types of functional groups after chemical modification, or make metal ions and metal nanoparticles adhere on the surface of nano-cellulose at high density; nano-cellulose has a great potential as a highly functional material, too.

However, to use hydrophilic nano-cellulose solely or in a composite with some other material to produce a high-performance or high-function material, you need to develop technology for the accurate structure control of each layer of the primary, secondary, and tertiary-layered structures of the materials on the platform of nano-cellulose. We are calling for challenging proposals in relation to the technology development to use nano-cellulose for the design and creation of next-generation materials.

We are expecting the proposals such as the following.

・The technology to control crystalline regions and non-crystalline regions
・The technology to remove moisture with the evenly dispersed super-structure in water maintained
・The technology to control hydrophilic/hydrophobic characteristics for the complete dispersion over hydrophobic polymers or rubber
・The technology in consideration of a new function resulting from layered structures and/or of a drastic improvement in the performance (hygroscopicity, heat resistance, etc.)
・The technology to add some robust and flexible characteristics and/or shock-resistance performance for applications in fabricating automobile bodies and/or some other components

B20 Technologies for chemical modification/composition to create next generation lignin materials

Conventionally, the metamorphosis of lignin advances with the preprocess of paper making, which is collected in the form of a blackish liquid (black liquor) mixed with a chemical used for the preprocess, and thus used as fuel for some industrial use. However, to reuse lignin as a material for chemical products or polymers, research and development has been enthusiastically pursued to decompose lignin into low-molecular-weight substances and to convert the acquired low-molecular-weight chemical compounds into chemical products or to polymerize them into polymers. However, there are several serious issues including the slow reactions, low yields, multiplicity of phases in the processing, and high energy consumption; at present, there is no perspective on practical application. Nevertheless, as the research and development to separate lignin has been advancing in recent years; it is gradually becoming possible to acquire pure lignin, generally free of metamorphosis from biomass resources. Lignin has many hydroxyl groups; therefore, it is an attractive material that has the possibility of recycling as a high-performance and high-function material that has never been before when it is chemically modified it and various functional groups are introduced, or it is composited with some other material. We are calling the challenging proposals in relation to the technology development to convert lignin as a polymer into a next-generation material without decomposing it as in conventional approaches.

We are expecting proposals such as the following.

・The technology to control its quality by understanding the structure of lignin and by solving the relation between its structure and characteristics, because lignin is a chemical compound that has different basic structures and characteristics depending on the type of its raw material
・The technology to recycle lignin as a high-performance and high-function material by chemically modifying it and by introducing various functional groups to make it complex with a polymeric material or an inorganic material, because it has many hydroxyl groups

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

B21 [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%a), in Japan is 84%b)). 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%, 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 2050c). 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.

*1: Biomass plastics (carbon neutral)
*2: Biodegradable plastics (used as fertilizer for plant growing)
*3: Easily recyclable plastics (reducing incineration waste by recycling)
*4: Long-lasting plastics (reducing incineration frequency by long life)

In addition, the following issues can be illustrated as the bottleneck.

1. Biomass plastics (including elastomer)
- Plastics that use biomass as a raw material and are preferable than the 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

2. Biodegradable plastics (including elastomer)
- Biodegradable plastics that have a function to respond to physical, chemical and biochemical special stimulus, and it is triggered to break down
- 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

3. Easily recyclable plastics (including elastomer)
- A decomposition mechanism for chemical recycling is incorporated into the plastics, and activating it after recovery allows the plastics to be easily recovered, for example, as it is a low molecular weight polymer
- By activating the decomposition mechanism after recovery, it is possible to easily recover the components / parts from the material, part or system combined with plastics
- Plastics that can be recycled as it is, because it is stable and easy to refine
- A composite material that can restore its original excellent physical properties (such as mechanical strength) by re-forming even if it is crushed and recovered after use

4. Long-lasting plastics (including elastomer)
- Plastics with self-healing function
- Plastics of which molecular weight doesn't decrease
- Plastics that improves their performance with use

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

6. Fundamental technology required to advance the above 1 to 4
・Analysis of plastics decomposition mechanism
・Nano-structure analysis and physical property correlation of plastics
・Data accumulation for designing degradable plastics and simulation technology of ideal structure using it
・Relationship between plastics structure and biodegradable bacteria and its optimization

In order to achieve the tasks 1 to 6 above, it is important to utilize science seeds in all fields such as bio, chemical (catalyst, polymerization), analysis, database construction, and simulation.

a): "Single-use plastics: A roadmap for sustainability" (UN environmental plan, 2018)
b): "The status of production, disposal, recycling and treatment of plastic products 2018" (Plastic Waste Management Institute)
c): 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)

* 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 a new 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 research and development project for a specific Sub-Theme. After the fusion, team formation will be carried out to promote research and development aimed at achieving goals in full-scale research.

- 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-scale research 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 area, the challenging research and development 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 research and development 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. To create innovative research and development 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 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-scale research, we, being well aware of “the possibility of the contribution to a low-carbon society,” take management to accelerate the research and development for the implementation in the society.

● Policies for R&D management

JST, since year 2010, has been continuing "Advanced Low Carbon Technology Research and Development Program" (ALCA). In the ALCA, we have adopted "the Small Start & Stage Gate method" as a program that is specialized for the research and development 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 research and developments aiming at the implementation of the achievements and transferring it for practical applications in the society in around year 2030.

In this area, we follow the principles of the ALCA management and advance the research and development 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 research and development programs with the same goal, i.e., the realization of a low carbon society, aiming at synergy effect (Fig. 2).

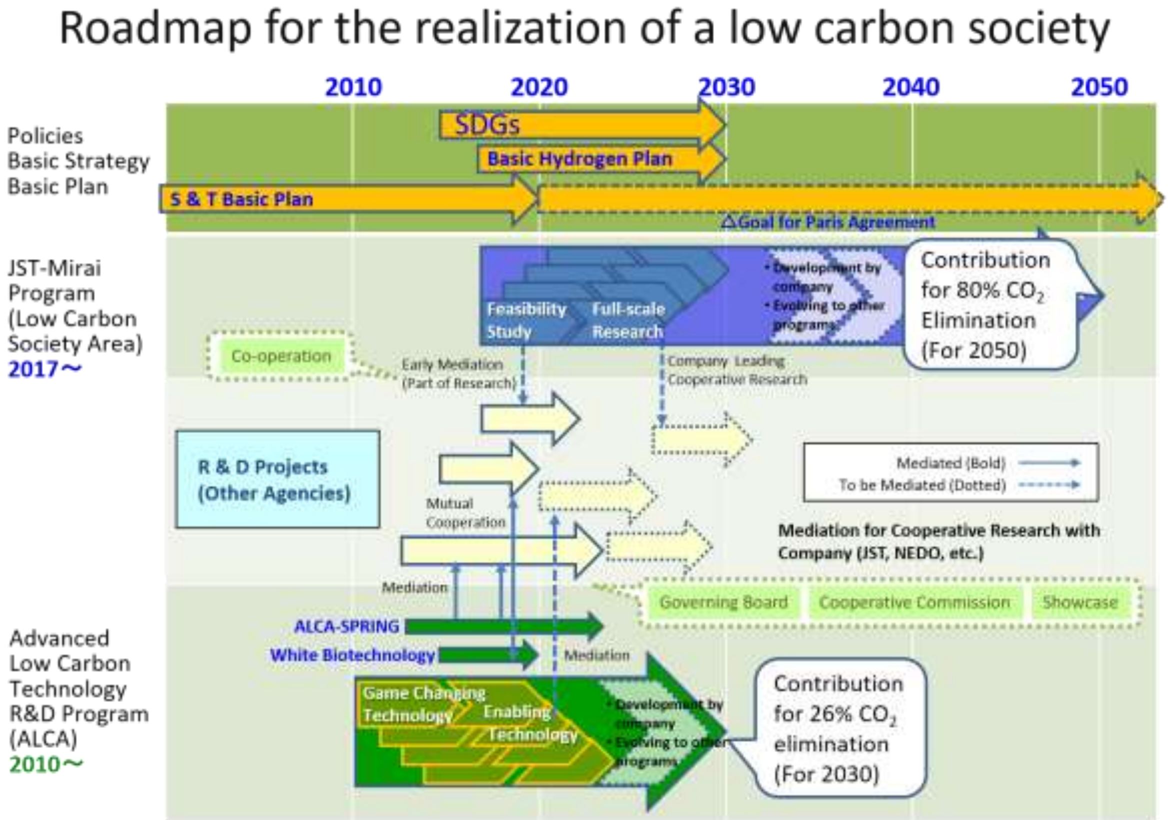

Fig. 2: A roadmap for the realization of a low carbon society

Furthermore, in this 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-scale research. Moreover, if the Research and Development Supervisor determines the necessity for the maximization of the social and/or economic impact, we may integrate two or more research and development issues and reorganizing research teams, etc.

● Stage gate evaluation

In this area, the transition to “full-scale research” is carried out in FY2025 in principle.

In this 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-scale research. 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-scale research. The timing of the milestone and stage gate evaluation will be decided after the adoption, by taking interviews with the responsible R&D operation committee members. Depending on the progress as a result of stage gate evaluation, the early transition to the full-scale research will be also considered.

● R&D period and costs

① Feasibility Study

In this area, the standard feasibility study period is up to five years until the end of FY2024 (the period in FY2020 is counted as one year regardless of the time to start R&D), the upper limit of the R&D cost in your plan must be JPY 160 million (including indirectly costs) in total covering the whole period of the feasibility study.

② Full-scale Research

In this area, the period and the budget for the full-scale research are determined based on the stage gate evaluation of the feasibility study; the period of the full-scale research at the proposal phase is five years at the maximum; the upper limit of the R&D cost in your plan must be JPY 500 million (including indirect costs) in total, covering the whole period of the full-scale research.

* About the management method by harmonized various technological seeds

① Feasibility Study

Plan the feasibility study period with the maximum period of five years, and the R&D cost of up to JPY 6.5 million (including indirect 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-scale Research

Plan the full-scale research with a maximum period of five years, and the R&D cost of up to JPY 500 million (including indirect costs) covering the whole period of the full-scale research (this JPY 500 million is the maximum amount for the result of the fusion of multiple issues).

6.1.5“Common Platform Technology, Facilities and Equipment” area

Research and Development Supervisor (Program Officer: PO):
Nobuyuki OSAKABE
(General Manger, Strategy Division, Smart Life Business Management Division/Chief Executive of Healthcare Business Unit, Hitachi, Ltd.))

I. Goal of the “Common Platform Technology, Facilities and Equipment” Area

This area was established to cover common platform technologies supporting a wide range of research and development (R&D) activities and advanced research instruments in the fiscal year (FY) 2018.

Research and development 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 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 achieve-ments, i.e., the development of measurement and analysis technologies and devices (see by eye) aiming for systemi-zation 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).

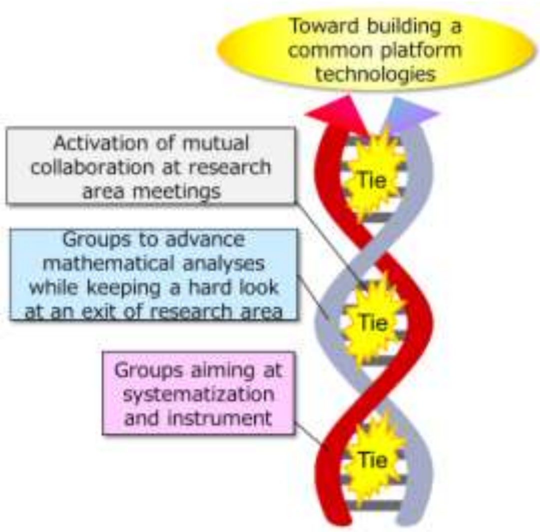

Fig.1 Scheme of Area management

Continued

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 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 program 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 Proof of Concept (POC) within a period of full-scale research. A POC for this 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 program 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.

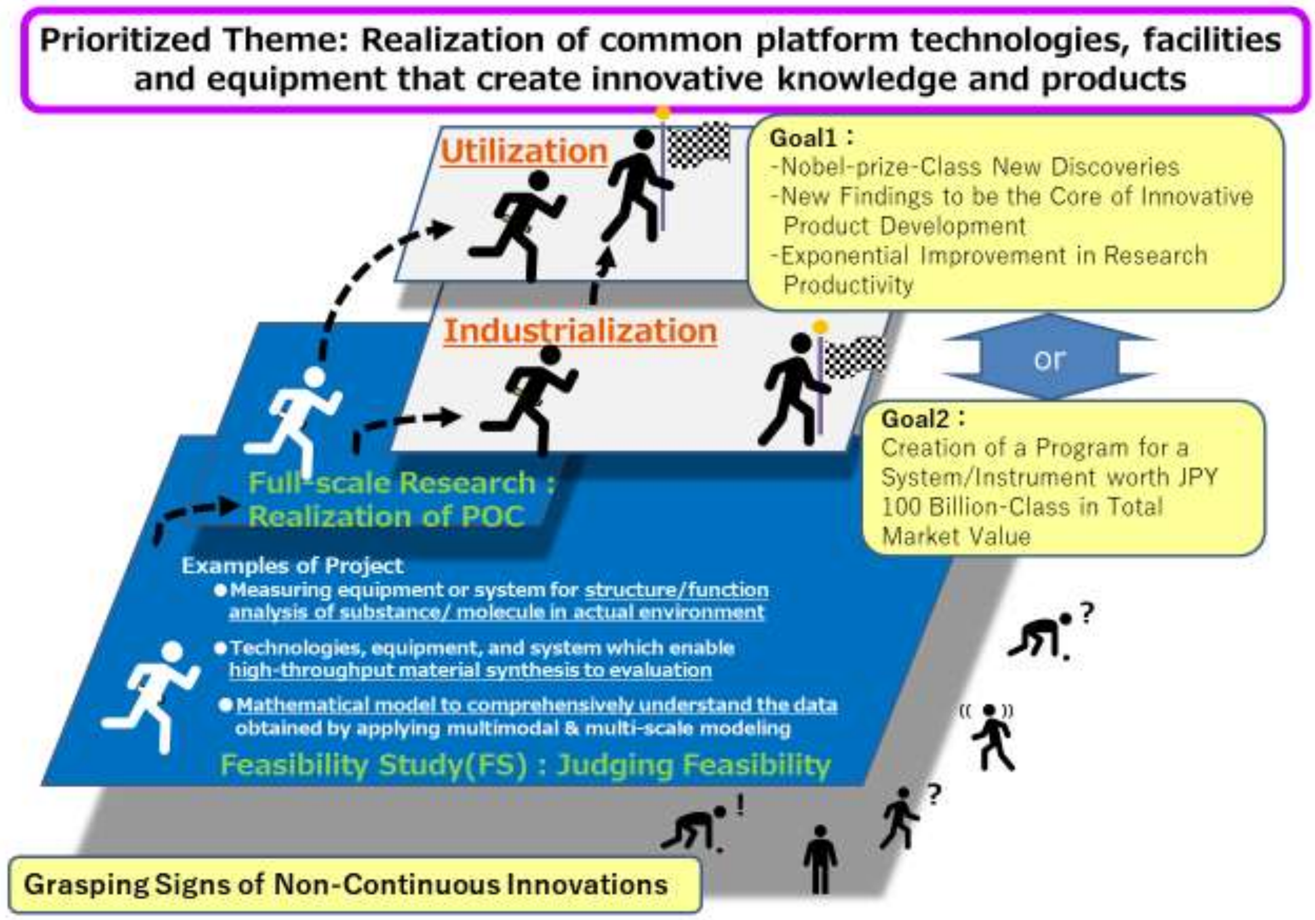

Fig. 2: Conceptual illustration of the goals of the prioritized theme and R&D phase

(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 area, we have to share these objectives and make progress on mutually-linked multiple issues simultaneously. To do this, ten sub-themes (see Fig. 3) roughly classified according to a wide variety of research requirements were called for the first year in 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.

For the second year in FY2019, two issues listed below were added as “preferred issues for proposal” to focus on the direction of R&D in this area, while continuously calling for various new proposals in relation to ten sub-themes to achieve the prioritized theme. Accordingly, proposals contributing to the progress of multi-modal, multi-scale analysis, and high throughput for realizing smart laboratories were selected.

• 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.)

* These were reviewed and determined according to the comments and ideas on the theme proposals at the web site of this program, and discussions at expert workshops.

● Policies for proposal selection

Key points for FY2020

- In FY2020, we put priority on two "preferred issues for proposal" while continuously calling for ten sub-themes.
- The following points are taken for new proposals aiming for transition to full-scale research in "preferred issues for proposal" (for details, refer to "Description on R&D" below):
  Y01: Considering the importance of "structure/function analysis of substance/molecule in actual environment" which may lead to the functional elucidation of material interfaces and biomolecules, we call for proposals potentially contributing to this theme in Y01.
  Y02: Targeting at full-scale research, we mainly call for proposals in the material science field with the aim of realizing a smart laboratory for materials. In particular, technologies for organic material synthesis and high-throughput evaluation are expected.
- Regarding "component technology type," proposals are limited to ST09 "Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data."
- Six to nine proposals are planned to be adopted.

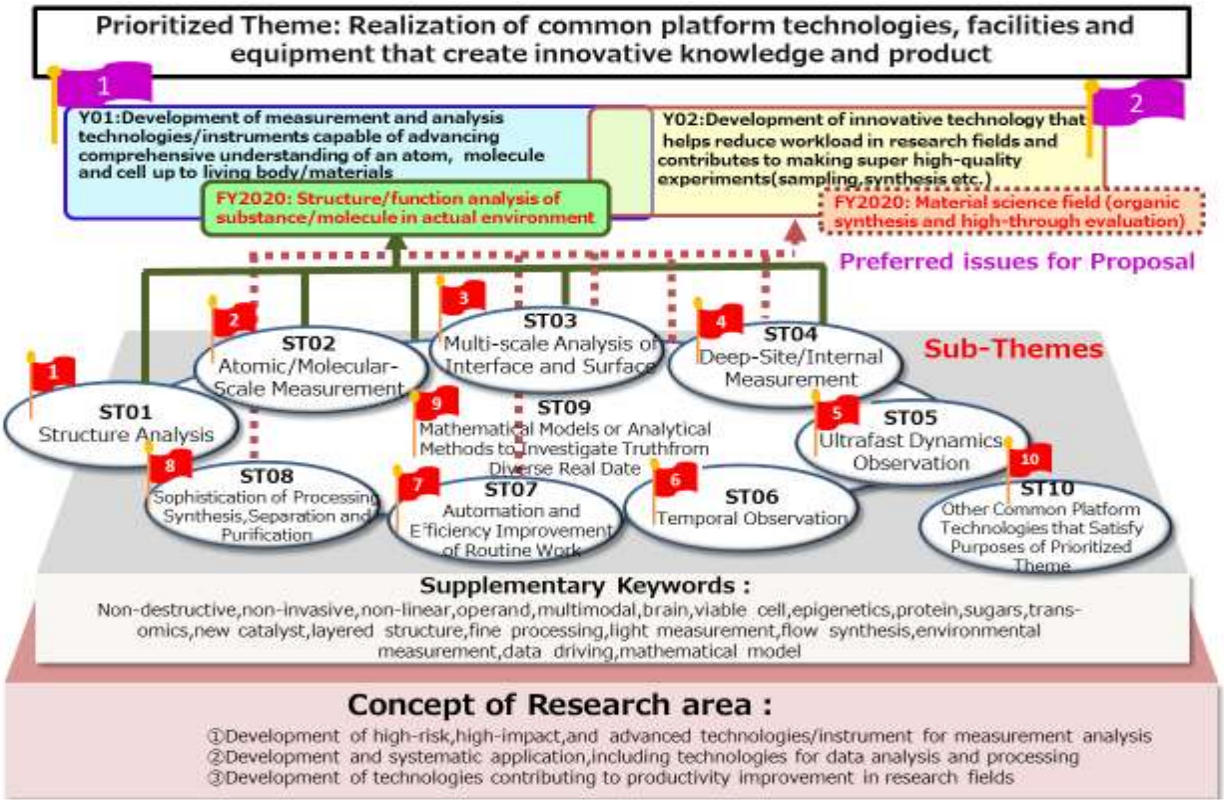

Fig. 3: Preferred issues for proposal and sub-themes in the "Common Platform Technology, Facilities and Equipment" area

● **Proposals for Component technology type**

In addition to research proposals aiming for transition to full-scale research, proposals of “Feasibility Study (Component Technology Type),” which contributes to the achievement of the prioritized theme in full-scale research in this area, are called for.

Accordingly, the R&D representative who performs the component technology type R&D is asked to take on the R&D and introduce the outcome into full-scale research under the prioritized theme, not transfer the outcome itself to full-scale research, and establish an component technology for achieving the POC.

Proposals for this fiscal year 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 this fiscal year on the component technology type R&D are limited to ST09. It should be noted that proposals for ST01 to ST08, ST10, and Y01 to Y02 are not accepted, and the application is not evaluated if it is for any of those which are excluded.

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

● **Theme Managers**

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

Theme Manager
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● **Description on R&D**

In 2020, 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. In both cases, the gap between the social impact for solving these issues, and the current situation for realizing it and existing technology should be clearly indicated, and the policy to fill the gap presented as far as possible from the viewpoint of comparison with the analysis of internationally competitive technologies, and how much do participating companies expect in the structure at the proposal state.

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	Development of measurement and analysis technologies/instruments capable of advancing comprehensive understanding of an atom, molecule and cell up to living body/materials (Structure/function analysis of substance/molecule in actual environment)
Y02	Development of innovative technology that helps reduce workload in research fields and contributes to making super high-quality experiments (sampling, synthesis etc.) (Material science field (organic synthesis and high-throughput evaluation))

1) Development of measurement and analysis technologies/instruments capable of advancing comprehensive understanding of an atom, molecule and cell up to living body/materials (Structure/function analysis of substance/molecule in actual environment) [Classification: Y01]

Development of measurement technology capable of dramatically improving the quality of information obtained from optical and electron microscope image data etc. and the development of technology for integrating different kinds of information used to be handled separately, such as a large amount of image data and analyzed genome information, in a highly accurate manner to promote research in health and medicine (drug discovery, diagnostic equipment, etc.), new material creation (matter production, functional material development, etc.) amid globally intensified competition. Looking at the more distant future, it is very important to develop breakthrough technologies from these developed technologies, such as the technology capable of four-dimensional, comprehensive analysis including the time axis.

(Focus in FY2020)
In order to accelerate the emerging research, which is intensely competitive, proposals for "structure/function analysis of substance/molecule in actual environment," available for measurement and analysis in a space where substances, molecules and ions, etc. actually function. Considering the present state of measurement, analysis and instruments, some examples of performance, etc. required for the analysis of structures and functions in an actual environment are shown below.

In the field of life science, we expect technologies that are widely applied in fields such as drug discovery, cell therapy, medical devices, agricultural chemicals, and functional foods, and proposals with a view to achieving POC. Specifically, it has been suggested that organelles such as mitochondria and target proteins are deeply related with diseases of the nervous system and cancer, but it is difficult to directly observe biomolecules inside cells (in vivo) as they are, because conventional cryo-electron microscopes require the purification of target proteins ex vivo. An alternative way is limited to the analysis of a model system that reproduces a system similar to a real environment in a test tube (in vitro) that mimics the inside of a living organism. In order to elucidate the mechanism that contributes to the treatment of these diseases and the promotion of drug discovery research, for example, the structure and dynamic mechanism of various in-vivo molecules inside cells (about 20 μm on average) need to be analyzed. This requires a new technologies and devices for analysis available for the measurement within a spatial resolution of 1 micrometer and a temporal resolution of 1 millisecond. In addition, to achieve the analysis like this, not only improvement in the spatial/temporal resolution of measurement technology and equipment, but integration of technologies (highly sensitive chemical probe, etc.) to observe protein, etc. without impairing their functions in cells or in the ecological environment and computational science that enables the dynamic simulation of protein and DNA with a temporal resolution in less than millimeters are required. In order to comprehensively understand the living body from micro to macro viewpoint, it is important to integrate different samples, different analysis methods, various imaging information and experimental information on various omics data including genome and proteome. For this reason, we also welcome proposals including simultaneous measurement technology using the same sample, mathematical model/mathematical analysis technology and information processing technologies, etc.

In the field of material science, we expect proposals dealing with technologies that are widely applied to materials such as electronic parts, semiconductors and catalysts, or biomaterials, etc., or aiming for the achievement of POC. In each proposal, an appropriate demonstration target and actual environment should be set with the accuracy required for achieving the measurement and analysis.

Specifically, for example, it is known that there is a space charge layer (a layer in which almost no ions exist) at the few nanometer long electrode and electrolyte interfaces of a lithium ion battery, and its thickness and distribution of electrons and trace ions affect the battery characteristics such as output characteristics. However, the behavioral analysis of the status and reaction of electrons and ions at the electrode and electrolyte interfaces of the lithium-ion battery under the variable voltage condition has not yet succeeded. Therefore, to realize a high-performance and highly safe battery, technologies and devices available for measurement and analysis within a spatial resolution of 1 nanometer and a temporal resolution of microseconds under the variable voltage condition are required.

In addition, for example, in the development of high-performance composite materials that contribute to the weight reduction of automobiles, the formation of materials that have excellent mechanical properties, are robust and flexible in various circumstances, and understanding of their characteristics that change under the actual environment in which the materials are formed are required. For that purpose, technologies and devices available for measurement and analysis within a spatial resolution of 0.1 micrometers and a temporal resolution of microseconds are required to analyze the state of manufacturing processes such as mixing of different materials at the nano level and chronological change of the molecular orientation and bonding state of materials during mixing with the change of parameters such as mixing speed. It should be noted that proposals are not limited to these R&D cases. Please make proposals based on a wide range of applied technologies as mentioned before.

Furthermore, we also welcome proposals that include mathematical and information processing technologies to integrate information conventionally measured by different analysis methods depending on the scale such as "compound properties - state of material interfaces - performance of actually assembled module" (see also category ST09).

2) Development of innovative technology that helps reduce workload in research fields and contributes to making super high-quality experiments (sampling, synthesis etc.) (Material science field (organic synthesis and high-throughput evaluation) [Classification: Y02]

We aim to realize a smart laboratory in addition to the contribution to “Development of the Technology That Helps Improve the Productivity in Research Fields,” which is one of prioritized point of views in this area, by automating repetitive works such as pretreatment, cultivation and chemical synthesis from large amount of same varieties to small amount of many varieties.

(Focus in FY2020)

By achieving high throughput of a series of processes required from material design to the finished product, which is the common issue in every research field, and integrating these processes, innovative efficiency improvements of R&D site, including new value creation with the accumulation of high quality data, and assurance of intellectual research time and research reproducibility will be guaranteed.

This year, the following proposals are called for mainly in the field of material science:

Various types of feasibility study have been conducted to search for new materials, and full-scale research is sought for enhancing high throughput of a series of processes including "1. pretreatment, 2. synthesis, 3. purification, 4. evaluation (analysis)" for the target materials. In this fiscal year, we especially call for proposals for the development of devices to enhance particularly the high throughput of synthesis of organic materials, and technologies for evaluation. High throughput of not only all processed from 1 to 4 above but also individual processes (including association of processes) is an important perspective from the viewpoint of overall optimization from material design to the finished product. For example, we request such proposals that optimize the synthesizing and manufacturing processes for the designed substances or materials by automating all processes or making all processes ubiquitous as much as possible, or shortening the work by eliminating some processes such as the purification process as unnecessary processes.

Furthermore, we strongly expect a proposal to combine process and synthesis technologies with mathematical science/mathematical engineering to realize data-driven R&D that contributes to powerful high-throughput production. Specifically, integration and application are mandatory to construct a mathematical model for predicting target properties and structures using a variety of data such as metadata, high-speed, large-volume experimental data, multimodal/multiscale data which is used independently or partially liked so far. This model is required to express not only specific experimental results but also material properties more comprehensively. For that purpose, it is necessary to devise descriptors. We welcome a proposal which is intended to contribute to strengthening international competitiveness of Japan by, sometime in the future, standardizing the measurement and analysis technologies and instruments and analysis equipment acquired from R&D of the proposal.

* We do not call for proposals for Y02 in the field of life sciences, but you can apply a proposal for innovative efficiency improvement of the R&D site based on new ideas in the framework of the relevant sub-theme.

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 are limited to the “component technology type” of this sub-theme.
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” (ST01 to S10) (multiple selections possible).

* Keep in mind that different type of format is required for a proposal for the component technology type (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.

The field of life science seeks deep-site measurements for cell dynamics in the blood vessel, analysis of a single cell in organs, and brain analysis (nerve plasticity).

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 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 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. By realizing such apparatus, functional peptides, which are needed for various industries, including drugs, food and cosmetics, are expected to decrease in manufacturing cost.

<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 three concepts in this 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, if the data driven type mathematical model construction technology is realized for estimating the nonlinear dynamics of the system that generated the data based on multidimensional and noisy time series data obtained from R&D sites and applying it to a mathematical model to extract the law behind, a major breakthrough is expected in various research fields, in addition to the priority research subjects aimed at in this area

In these proposals, we expect the participation of mathematical scientists and engineers who have flexibility and versatility to develop mathematical models and analysis methods through close discussions with experts in each field.

* 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 three concepts of this 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 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 an early stage. 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 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, which preceded this area, and it will be appreciated if you visit the website of this program when considering a proposal in this 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 4.14 “Promotion of the Joint Use of Research Facilities and Equipment”).

● Policies for R&D management

In approaching challenging R&D projects, this 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. A management system that provides advice and guidance through checking research plans and site visits by members of the R&D management conference, including theme managers, is prepared and aims 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-scale research project, it is envisioned that teams participating in R&D projects will be integrated or restructured.

● R&D period and costs

For the R&D projects initiated in FY2020, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2022), 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 full-scale research at the time designated by the Program Officer by the end of FY2022.

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period. However, a total is set at a maximum of JPY 500 million for a proposal of ST09 “Building Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data.”

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.

Research and Development Supervisor (Program Officer: PO):
Yoshihiro OISHI
(Senior Research Fellow, General Manager, Research and Development 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 (concept of proof: 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. The PM is requested to choose a high-level, challenging goal; create, protect, and utilize intellectual property strategically; and depict the overall vision as noble so that its achievement would solve social problems and create a new industry.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 expected 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 by technological theme

“Innovative device technologies to achieve ultra- high-level information processing in the age of trillion sensors (TSensors)”

In Society 5.0, a new value is expected to be created by having sensors acquire all information and having AI analyze the acquired information. With the increase in sensors, there is an urgent need to analyze huge amounts of information that are orders of magnitude larger than before with extremely low power consumption. To implement this advanced information processing, it is highly required for the cloud side that consolidates information to introduce optical wiring to suppress information delay and increasing power consumption due to the miniaturization of electric wiring, and for the edge side that installs sensors for generating information to develop innovative information processing devices capable of dramatically reducing power consumption. The program manager (PM) is required to have a vision and R&D management for consistent R&D up to optimization according to the application, while assuming specific situations where innovative technologies will be implemented in society, including the introduction of technologies for photonics, spintronics or combination of both, which have received attention in recent years, for the development of photoelectric interfaces to allow the effective use of optical interconnection, or edge information processing devices to realize a dramatic reduction of power consumption. Since this field changes rapidly, and is exposed to fierce international competition, it is expected to establish an academia-industry cooperation R&D organization that involves not only manufacturers but also potential users in view of practical application after the completion of projects, as well as setting the POC based on international benchmarks and road maps of development in the industry and discussing a structure as cheap and productive as possible in consideration of costs and productivity of devices for smooth social implementation.

Total R&D costs for R&D projects initiated in FY2020 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 (10 years).

If multiple subjects and/or researchers are adopted under this technical theme, the budget scale of the selected subject will be adjusted as the included number of the above budget scale.

New

6.2.2 Technology theme

(1) Theme name

"Innovative device technologies to achieve ultra- high level information processing in the age of trillion sensors (TSensors)"

(2) Outline

In Society 5.0, new values are expected to be created as every sort of information is acquired by sensors, and analyzed by AI. At that time, AI is required to analyze huge amounts of information, which is orders of magnitude larger than before, as the number of sensors increases. In order to realize this ultra-high level information processing, technological innovation regarding information processing on the cloud side that consolidates information and on the edge side which installs sensors to generate information is required.

Specifically, the increase in electrical resistance due to the miniaturization of electrical wiring and the delay due to parasitic capacitance limit the speeding up and low power consumption on the cloud side. Competition for technological development to replace as much wiring in computers as possible with optical wiring is intensifying all over the world. However, even if optical wiring can be introduced, it is necessary to convert optical signals into electrical signals to perform calculation processing, and further speeding up of the optical-electrical conversion interface equipped with buffer memory, and lower power consumption are thought to largely contribute to the sophistication of information processing. On the other side, there is also a limit in securing power source in a moving object such as a living body monitor or self-driving vehicle, and if further reduction of power consumption cannot be achieved, the information processing required on the edge side will not be complete.

The JST-Mirai program started R&D of innovative thermoelectric conversion technology as the power source for driving sensors from FY2019. In this fiscal year, it plans to start R&D of innovative information processing hardware technology using various technologies that realize ultra-high level information processing in the era of Trillion (1 trillion) sensors, such as technologies far exceeding conventional photonics and spintronics, and technologies combining them. The synergistic effect with the innovative thermoelectric conversion technology on the edge side is expected to increase contribution to the realization of Society 5.0.

(3) Goal

The goal is to establish an innovative information processing hardware technology that realizes ultra-high-level information processing in the era of the Trillion sensors by dramatically reducing power consumption and achieving ultra-high-speed processing. R&D will be conducted straight up to a stage (proof of concept: POC) to determine the possibility of practical application based on consideration of its technological superiority and market competitiveness over conventional technologies, while assuming actual situations where the technology will be implemented in society (biological information monitors or self-driving vehicles). Moreover, when conducting R&D, it is desirable to clearly set specific milestones for social implementation for each elemental technology. For example, the path to social implementation may be planned like this: proofing the principle of photoelectric interfaces and edge information processing devices equipped with non-volatile memory in five years, and exceeding limits of conventional power consumption and processing speed and realizing photoelectric interfaces and edge information processing devices with cooperation of both sides assumed in 10 years. Then, it is desired that both devices have a cheap and simple structure as much as possible in consideration of productivity of both devices. In addition, an academia-industry cooperation R&D organization involving not only manufacturers but also potential users must be taken in account in view of the practical application after the completion of projects.

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

The management of the R&D project is believed to lead to the realization of a future society, as described below:

- A society where everyone can live safely as biological information acquired by wearable devices in real time can be processed by grownup as well as children, allowing not only early detection of diseases by individuals and optimization of biological rhythms, but also early detection of infections by processing of the same information on a large scale
- A society ensuring safe and comfortable movement with sensors installed on self-driving vehicles to realize zero traffic accident through real-time detection of rushing out people and animals into traffic from picture information, and zero traffic congestion with the suitable control of the entire flow of vehicles from position information
- A society that achieves ultra-high-level information processing by dramatically reducing power consumption and implementing ultra-fast operation on the cloud side that consolidates information from a large number of sensors as mentioned above, and produces totally new values

(5) Specific research examples

Specific research examples may include the following:

- Search and development of efficient materials with less toxic and free of rare elements, and available for stable reading and writing, storage and control at room temperature, and verification of device operation principle using those materials.
- Development of photoelectric interfaces and edge information processing devices using the verified materials; specifications are set based on the reality of future technology transfer while considering the latest technological development status (e.g. power consumption: Approx. 10 μW/Gbps, optical writing speed: Approx. 1 ns/bit)
- Simplified device structure according to the required size and form with integration and mass productivity in mind

(6) R&D trends

A remarkable progress of information processing speed has been reached by miniaturization of semiconductor devices. Research and development of photonics technology that replaces electrical wiring with optical wiring for higher speed and lower power consumption has exceeded the limit of delay caused by increases in electrical wiring resistance and parasitic capacitance between wiring due to miniaturization is being worked on (e.g. IOWN Initiative, an international enterprise consortium composed of 65 organizations with NTT, Intel, and SONY as the core). However, a high-speed, low-power consumption non-volatile optical memory has not been realized yet, and there is a problem that information processing using light is difficult to integrate. Therefore, fusion technology of spintronics technology and photonics technology, which uses the degree of freedom of electron spin, is drawing attention. For example, basic research is progressing on various methods such as spin photonics technology for controlling electron spin by light by utilizing the correlation between light and electron spin. The defects that serve as photon sources and spin sources have been discovered in two-dimensional materials, which are attracting attention as conductors of electron spin currents, and the number of related papers is rapidly increasing in each country. Non-Neumann type computing devices are also being actively including the development of neuromorphic chips in the postmoor era led by the US IEEE "Rebooting Computing Initiative" and brain research and brain-mimicking computing devices by the Human Brain Project in Europe.