The 4th Strategic Basic Research Programs
International Review

[Appendix]
Materials for review

October 8, 2020

Japan Science and Technology Agency

Table of Contents

1. Structure and Operations of Strategic Basic Research Programs

1.1. S&T Policies of Different Nations

1.1.1 Overview of Japan's S&T Policy

(1) Science and Technology Basic Plan

The Science and Technology Basic Law was established in 1995 with the ideal of "achieving a higher standard of science and technology (hereinafter referred to as "S&T"), to contribute to the development of the economy and society in Japan and to the improvement of the welfare of the nation, as well as to contribute to the progress of S&T in the world and the sustainable development of human society.[1]

This law was established against the backdrop of economic stagnation in Japan and exports that had been hurt by the steady increase in the value of the JPY, as well as predictions of the aging of society and increasingly fierce international competition in the future. Amidst these trends, there was an active debate about the need for "the founding of a nation based on the creation of S&T" that could use Japan's intellectual resources to create new industries and ensure the long-term growth of the nation, as well as helping to resolve the many problems facing humanity.[2]

Based on the Science and Technology Basic Law, a four-term, 20-year plan called the Science and Technology Basic Plan ("Basic Plan") was formulated. Through the execution of this plan, Japan's investment in research and development has been expanded despite the difficult financial situation. Japan has also scored numerous achievements and produced some of the world's leading research findings.

---

[1] The 4th Science and Technology Basic Plan

[2] CRDS-FY2013-FR-07_Overview Report of Research and Development

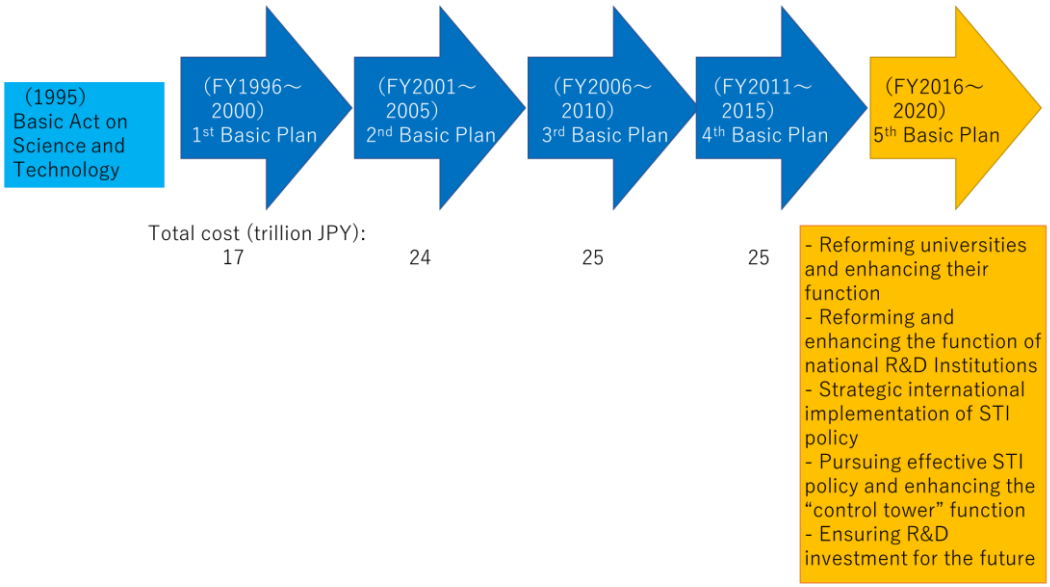


Figure A2-1. History of Science and Technology Basic Plan[3]

The 1st Science and Technology Basic Plan was limited largely to research and development systems. The 2nd Basic Plan incorporated a clear awareness of the relationship of S&T to society and indicated three goals that Japan should achieve (creation of wisdom, vitality from wisdom, and sophisticated society by wisdom), in addition to the reform of S&T systems that included returning the achievements of research to society. The relationship of S&T to society and the people was further emphasized in the 3rd Basic Plan, and the basic principle of "S&T to be supported by the public and to benefit society" was clearly identified. The innovations that would become important for this purpose were clearly identified as well. The 4th Basic Plan considers the role of S&T policy to be not only the advancement of S&T but also finding solutions to the various issues facing human society.

In 2016, the 5th Science and Technology Basic Plan was formulated. Based on the 5th Basic Plan, the Council for Science, Technology and Innovation (CSTI) is taking the lead under a basic policy that emphasizes the ability to look ahead and take strategic action (foreseeability and strategy) and the ability to accurately respond to any change (diversity and flexibility), and realizing the PDCA cycle directly linked to the budget, conducting initiatives to resolve critical issues, the establishment of the Strategic Innovation Program (SIP), a cross-ministry program from basic research to commercialization, the Impulsing Paradigm Change through Disruptive Technologies Program (ImPACT), which aims to create high-risk, high-impact innovations, and the Moonshot Research and Development, a bold new R&D program aiming to create disruptive innovation.

[3] https://www8.cao.go.jp/cstp/kihonkeikaku/ 5gaiyo.pdf

(2) National Budget for S&T

To ensure that the overall government budget relating to S&T is concentrated on promising areas and policies and is used effectively, the Council for Science, Technology and Innovation (CSTI) takes a broad view of STI policy and formulates “Principles for the Allocation of Budget and Other Resources Relating to S&T (“Resource Allocation Policy”) and plays a leading role in the efforts by relevant ministries and agencies. Under the “Promotion of Society 5.0 and the Achievement of the Government R&D Investment Objective” (Decided by CSTI in April 2017), CSTI identifies S&T innovation-related programs that are newly registered based on the budget requests of the ministries and agencies and are expected to contribute to STI (including those that aim to realize Society 5.0 by introducing STI elements into existing programs), and are cooperating with the Ministry of Finance to place emphasis on the identified programs in the budget process. By doing so, the CSTI is aiming at the "Target of Government R&D Investment (1% of GDP)" as stipulated in the Basic Plan.

Society 5.0:

The Internet of Things (IoT), which connects people and objects, sharing a variety of knowledge and information to create new value; artificial intelligence (AI), which provides necessary information when needed; and technologies such as robots and automated vehicles, will help resolve the issues of a low birthrate and aging population, depopulation of rural areas, and the gap between the rich and the poor. These social reforms (innovation) in Society 5.0 will achieve a forward-looking society that breaks down the existing sense of stagnation, a society whose members have mutual respect for each other, transcending the generations, and a society in which each and every person can lead an active and enjoyable life.

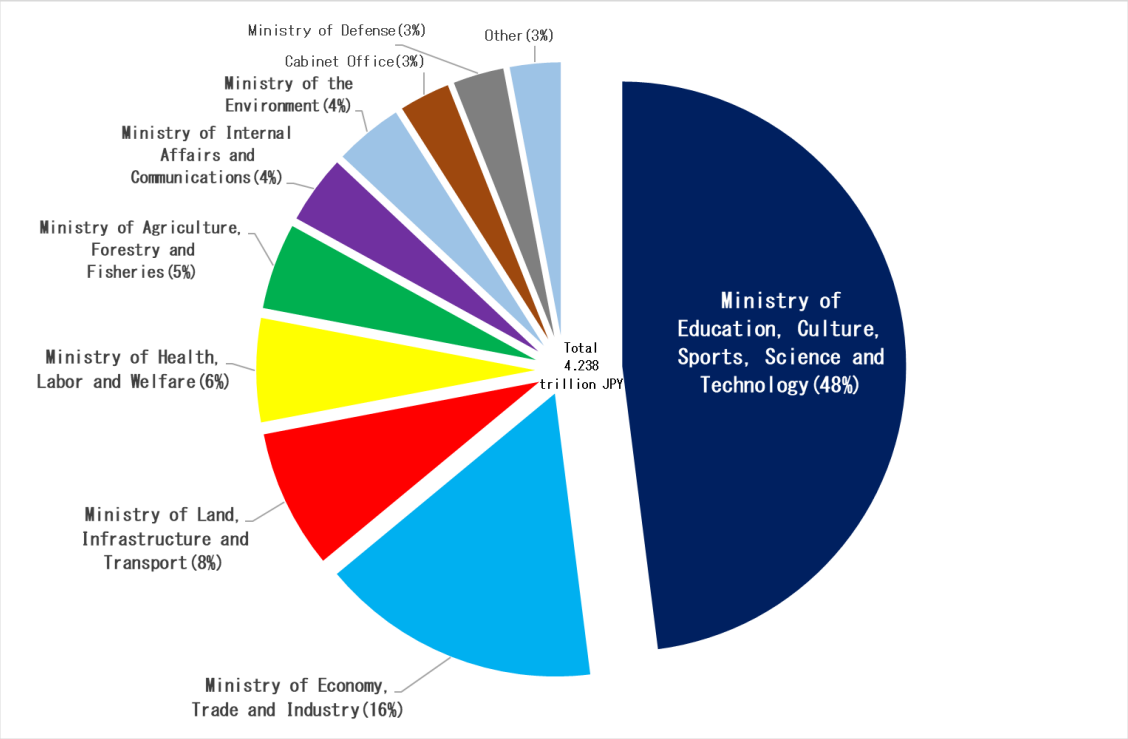


Figure A1-2. Budget relating to S&T (FY2020)[4]

As shown in Figure A1-2, the budget relating to S&T in the initial budget for FY2020 in Japan is 4.237 trillion JPY. Of this amount, the expenses for the advancement of S&T, the core expenses of the Special Coordination Funds for the promotion of S&T, amount to 1.3639 trillion JPY.[4]

(3) Competitive Funds

Competitive funds are defined in the Phase 3 S&T Basic Plan as "R&D funds distributed to researchers; the entities of resource allocation are diverse, and an expert team selects appropriate projects to be funded from research projects gathered and proposed, mainly based on the scientific or technological evaluation." The Plan also calls for the government to work to expand Competitive Research Funds, stating that "the government will continue to strive to increase competitive funds such as Grants-in-Aid for Scientific Research, which contribute to creating a competitive R&D environment, by expanding the breadth and freedom of the selection of researchers' research grants."

On the other hand, based on the "Expansion of Strategic Funding and Promotion of Institutional Innovation" (June 14, 2007, Expert Panel on Basic Policy, Council for S&T Policy), etc., the government is working to promote institutional reforms that include ensuring the diversity and continuity of basic research, building seamless mechanisms, creating an attractive research environment for young researchers and female researchers, intensifying high-risk, high-impact

[4] https://www8.cao.go.jp/cstp/budget/r2yosan.pdf

research and creative research, and establishing systems for fair, transparent allocation and use.[5].

As shown in Figure A1-3, the FY2020 competitive funds total approximately 441.6 billion JPY, and the budget for Strategic Basic Research Programs accounts for approximately 12% of competitive funds. As will be shown later, the Strategic Basic Research Programs that are the target of the 4th International Review include CREST、PRESTO、ERATO, ACCEL, ACT-C, ACT-I, and ACT-X.

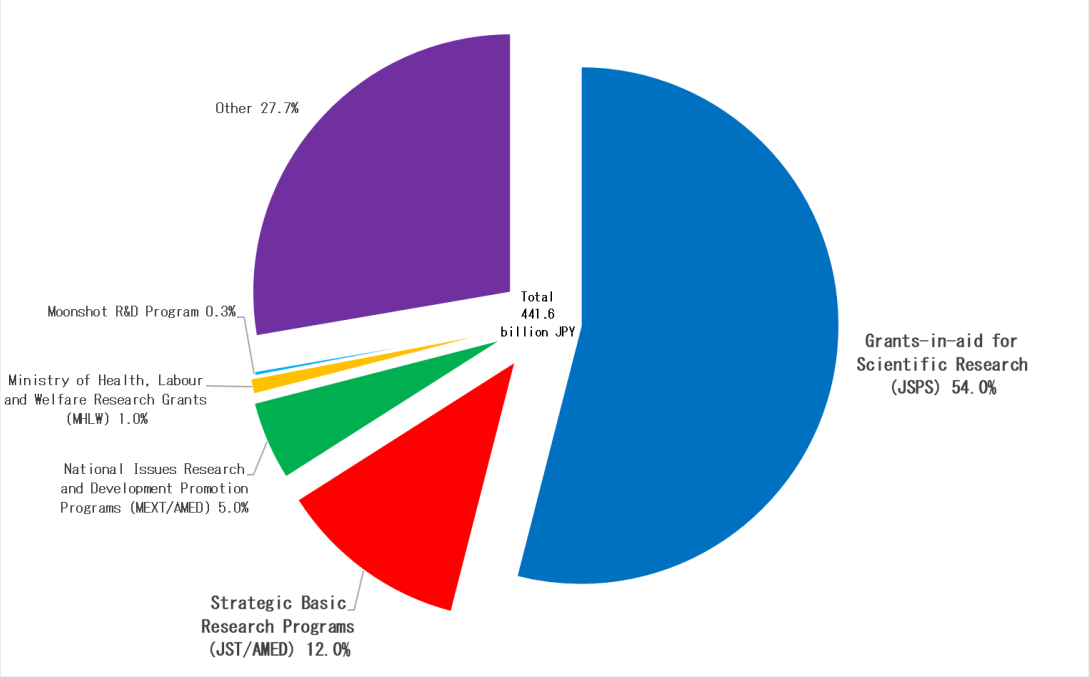


Figure A1-3. Competitive funds in FY2020[6]

1.1.2 Overview of Other Funding Agency etc. in Japan

(1) Japan Society for the Promotion of Science (JSPS): Grants-in-aid for Scientific Research (KAKENHI)

KAKENHI are grants provided for research proposals that are based on the free-thinking of individual researchers to encourage creative, pioneering, academically outstanding research in order to promote diverse learning through research activities. (FY2020 budget: 269.2 billion JPY, of which 139.4 billion JPY is for KAKENHI).

Strategic Basic Research Programs differ from Grants-in-aid for Scientific Research in that they are top-down projects. The JST receives the policy objectives of the national government (strategic

[5] http://www8.cao.go.jp/cstp/compefund/

[6] https://www8.cao.go.jp/cstp/compefund/kyoukin_r12.pdf

objectives), establishes research areas and appoints research supervisors, and pursues research aimed at achieving the strategic objectives, with the goal of creating the technological seeds that will help to create innovation.

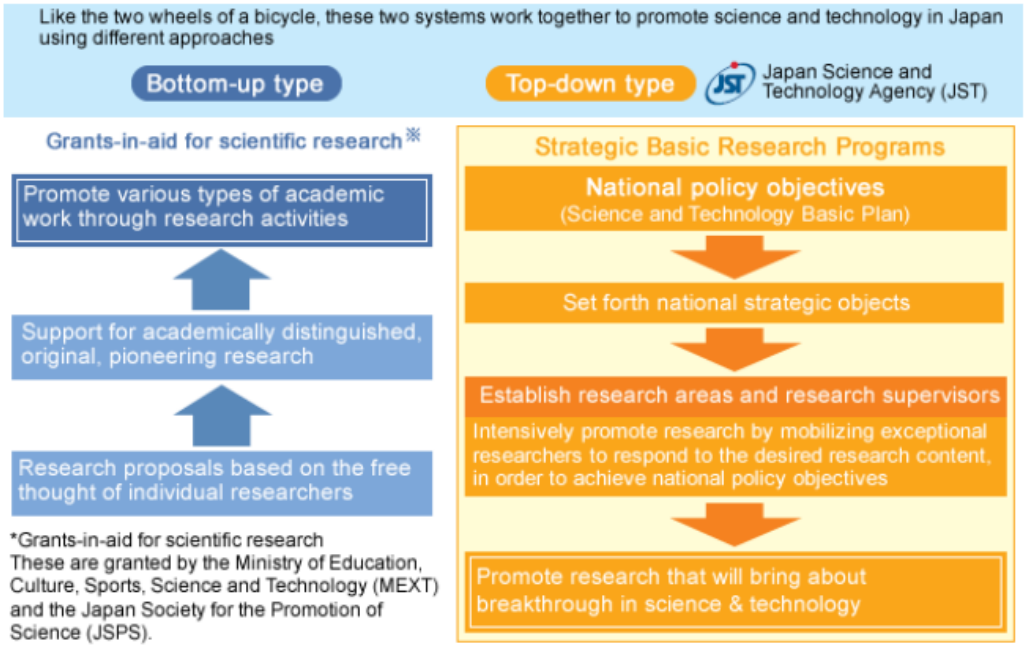


Figure A1-4. Differences between Strategic Basic Research Programs and Grants-in-aid for Scientific Research (KAKENHI)[7]

(2) New Energy and Industrial Technology Development Organization (NEDO)[8]: National Projects

The NEDO is one of the largest public research and development management agencies in Japan. As one part of the government's economic and industrial administration, its two missions are to address energy and global environmental problems and enhance industrial technology.

1) Addressing energy and global environmental problems

NEDO aims for the development of new energy (e.g., photovoltaic, wind power, biomass and waste, geothermal power, thermal utilization, and fuel cells) and energy conservation technologies. It also conducts research to verify technical results. Through these efforts, NEDO promotes greater utilization of new energy and improved energy conservation. NEDO also aims for a stable energy supply and the resolution of global environmental problems by promoting the demonstration of new energy, energy conservation, and environmental technologies abroad based

[7] http://www.jst.go.jp/kisoken/about/index.html

[8] http://www.nedo.go.jp/introducing/index.html

on knowledge obtained from domestic projects.

2) Enhancing industrial technology

With the aim of raising the level of industrial technology, NEDO pursues research and development of advanced new technology. Drawing on its considerable management know-how, NEDO carries out projects to explore future technology seeds as well as mid- to long-term projects that form the basis of industrial development. It also supports research related to practical application (FY2020 budget: 158.9 billion JPY).

NEDO projects are aimed primarily at strengthening Japanese technological capabilities and resolving energy issues. NEDO develops development-oriented projects with the aim of providing support up through the development of practical applications. In this respect, it is different from Strategic Basic Research Programs, which emphasize basic research. These programs are coordinated with NEDO projects in that NEDO develops practical applications for the research achievements of Strategic Basic Research Programs.

(3) AMED (Japan Agency for Medical Research and Development)[9]

The AMED was established in April 2015 as a new agency to play a central role in research and development and environmental improvement in the medical field. AMED conducts integrated management of medical research and development from the stage of basic research to application. Previously, this was handled by three different ministries (Ministry of Education, Culture, Sports, Science and Technology, Ministry of Health, Labour and Welfare and Ministry of Economy, Trade and Industry). (FY2020 budget: 127.2 billion JPY).

Of the projects implemented by the JST, some medical-related projects have been transferred to AMED. In the future, the JST will pursue research into areas such as plants and agriculture for which AMED does not provide support, as well as basic and foundational research in the life science field that is expected to contribute to a wide range of fields. In this way, a collaborative relationship will be established to enable JST research achievements to be turned over to AMED.

(4) Council for Science, Technology and Innovation (CSTI)[10]: ImPACT, SIP, PRISM, Moonshot.

CSTI is one of the "Councils on Important Policies," whose purpose is to plan and coordinate comprehensive and basic science, technology and innovation policies from a higher level than that of each ministry, under the leadership of the Prime Minister and the Minister of State for Science and Technology Policy. CSTI has created and promoted a new funding policy since FY2014.

---

[9] https://www.amed.go.jp/

[10] https://www8.cao.go.jp/cstp/

CSTI established new programs such as the Impulsing PAradigm Change through disruptive Technologies Program (ImPACT), the Cross-ministerial Strategic Innovation Promotion Program (SIP), Public/Private R&D Investment Strategic Expansion PrograM (PRISM) and Moonshot R&D Program to fund "concept-oriented research" (as opposed to the Strategic Basic Research Programs to fund measures for "problem-driven research").

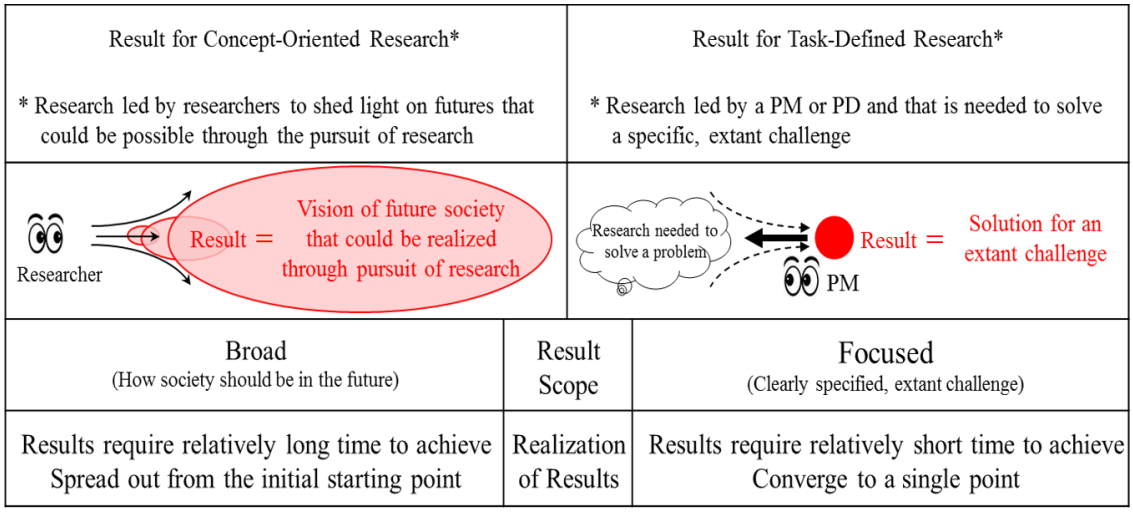


Figure A1-5. "Concept-Oriented research" and "Task-Defined research"

1) Impulsing Paradigm Change through Disruptive Technologies (ImPACT)

The ImPACT program is based on a recognition of the need for a new science and technology system in which universities and corporations can boldly tackle challenging research issues and open new areas of growth (innovation). The program was established to promote high-risk, high-impact research and development and achieve a sustainable system for innovation that can continue to grow. The program is characterized by the fact that Program Managers (PM) with outstanding ideas are given bold authority to pursue high-risk, high-impact strategic research and development aimed at creating groundbreaking scientific and technological innovation whose achievement will bring about profound changes in industry and society (budget: 55 billion JPY. [Fund through FY2018]); JST participated as the managing corporation, but the project ended in FY2018.

2) Cross-ministerial Strategic Innovation Promotion Program (SIP)

The SIP was founded in order to achieve scientific and technological innovation. Helmed by the Council for Science, Technology and Innovation (CSTI), it plays a leading role in providing management that goes beyond the boundaries between ministries and agencies and the boundaries between traditional fields. CSTI identifies important research projects and appoints a Program Director (PD) for each project, and pursues research with a view to everything from basic research to "exit" (practical and commercial application) as well as the use of regulatory reform, the special

zone system and so on. At present, thirteen issues have been set up as the second term of the Program, of which the JST is charged with two (Materials Integration" for Revolutionary Design System of Structural Materials and Energy Systems of an Internet of Energy (IoE) society) (FY2020 budget: 32.5 billion JPY, total SIP project).

3) Public/Private R&D Investment Strategic Expansion PrograM (PRISM)[11]

The Program was established in 2018 (budgeted: 10 billion JPY) to strengthen the command post function of the CSTI by guiding the policies of each government ministry and agency to areas that are highly effective in inducing private-sector R&D investment or that contribute to the effective fiscal spending. FY2019 designated areas are AI technology, Building/infrastructure maintenance/disaster mitigation technology, and biotechnology.

4) Moonshot R&D Program

This program is a national government initiative to develop ambitious goals and initiatives for social issues and other issues that are difficult to achieve but are expected to have a significant impact if realized. It was established in FY2019 with a maximum of 10 years' support (budget: 115 billion JPY). The Program has seven Moonshot goals[12] to achieve "human well-being" and to solve the social, environmental and economic issues that form the basis of the goals.

The JST is also one of the corporations in charge of the Program.

1.1.3 Financial Resource Distribution Institutions in Major Nations

The following shows the major programs of the financial resource distribution institutions in major nations.

(1) U.S. Funding Distribution Agencies

The United States uses a multi-funding system in which there are numerous research funds, each with a different purpose. Individual government agencies support basic, applied and developmental research within their respective areas. The major financial resource allocation institutions are the National Science Foundation (NSF) in the areas of science and engineering, the National Institute of Health (NIH) in the area of medicine, and the Department of Energy (DOE) in the area of energy. NSF is the only federal agency that supports basic research and engineering in all fields except medical science and also supports science, technology, engineering, and mathematics (STEM) education. NIH provides support for medical research. While 80% of its research funding goes to extramural research, the NIH allocates the remaining 20% to intramural research for research and development at 27 affiliated research institutes and research centers. The DOE is responsible for catalyzing the

[11] https://www8.cao.go.jp/cstp/prism/aboutprism.pdf.

[12] https://www.jst.go.jp/moonshot/en/outline.html

development of new clean energy technologies by promoting transformative progress in basic and applied research. Specifically, it allocates funds for advanced research and the development of innovative clean energy technologies through initiatives such as the Advanced Research Projects Agency-Energy (ARPA-E), the Department of Defense's Defense Advanced Research Projects Agency-Energy (DARPA-E). It promotes advanced energy research and development, modeled on the Defense Advanced Research Project Agency (DARPA).

(2) Financial Resource Distribution Institutions in the EU

The European Union (EU) has a principle (subsidiarity principle) that the EU does not execute projects that can be implemented by the member countries themselves, but the EU conducts various projects to assist policies implemented by member countries. This principle is also applied in the STI field, with Horizon 2020, which was launched in January 2014 and included investments in high-risk R&D, and Horizon Europe, a new science, technology and innovation policy, is the successor to this program. The project is scheduled to begin in 2021, with the three pillars of Open Science, Global Challenges and Industrial Competitiveness, and Open Innovation. In the EU, DG Research and Innovation (DGRI) is in charge of research and technology development, and DG Communication Networks, Content and Technology (DG Connect), which is responsible for the Future and Emerging Technologies Programme (FET), also allocate funds according to their missions. Until the 6th Framework Programme (FP6), which is a comprehensive R&D program, support for basic research was the role of the member countries and was mainly focused on supporting pre-competitive R&D. Since the 7th FP in 2007, however, support for basic research has been explicitly provided through the European Research Council (ERC). The European Research Council Executive Agency (ERCEA) is responsible for the allocation of funds and other practical matters.

In the UK, seven Sectoral Research Councils, Innovate UK, which supports innovation activity in industry and business, and the Higher Education Funding Council for England (HEFCE), which grants block grants to universities in England, was integrated as a corporate body named the UK Research and Innovation (UKRI) in 2018. UKRI allocates funds for research and development, including the industrial strategy of making the UK the largest innovation nation in the world.

In Germany, the German Research Foundation (DFG) supports basic research using a bottom-up approach and also gives various science-related awards and conducts researcher invitation programs, and so on. It is also commissioned by the federal government to conduct an Excellence Incentive that provides grants focusing on a select number of universities.

In France, the French National Research Agency (ANR), which has jurisdiction over national education and higher education as well as researchers, allocates competitive research funds in all sectors, from natural science and engineering to the humanities and social sciences, with the primary mission of promoting science and innovation as an all-round type of fund allocation agency.

In Sweden, VINNOVA provides funding for needs-driven research and encourages collaboration on the part of companies, universities, research institutions and public sector organizations. Its role also includes serving as the government's negotiating agency for the EU framework program.

(3) Financial Resource Distribution Institutions in Asia

In Singapore, the Agency for Science, Technology and Research (A*STAR) is an institution that allocates financial resources for the government ministries and agencies under its jurisdiction. It has eight engineering laboratories and 12 biomedical research centers and leads research and development with a strong emphasis on off-ramps for research through industry-academic collaboration.

In China, competitive financing from the central government is allocated primarily by the Ministry of Science and Technology and the National Natural Science Foundation of China (NSFC). The NSFC was set up in 1986 as the Chinese version of the NSF in the U. S., and it provides grants for basic research and some applied research projects.

1.2 Overview of JST

1.2.1 History of JST

The Japan Science and Technology Agency (JST) was established in October 1996 through the integration of the Japan Information Center of Science and Technology (JICST) and the Research Development Corporation of Japan (JRDC). The name of the agency at that time was Japan Science and Technology Corporation. Its mission was to conduct comprehensive and efficient construction of infrastructure to promote science and technology, and to vigorously promote the policies established in the Science and Technology Basic Act. In October 2003, the entity became an Independent Administrative Agency, and its name was changed to the current name (Japan Science and Technology Agency or JST). In April 2015, the agency was changed to a National Research and Development Corporation, but the English name remained the same.[13].

The Japan Information Center of Science and Technology (JICST) was set up in August 1957 to be the central institution for science and technology information in Japan, and to quickly and accurately provide information relating to science and technology from Japan and other countries. The Research Development Corporation of Japan (JRDC) was established in July 1961 to reduce Japan's dependence on overseas technology by disseminating the outstanding research achievements from Japanese universities, national laboratories, etc., and developing commercial applications for these achievements. The latter organization was subsequently tasked with additional responsibilities, and in 1989 the Japanese name was changed but the English name remained the Research Development Corporation of Japan.

1.2.2 Outline of Each System (Characteristics of Structure and Operation)

(1) CREST (Core Research Evolutionary Science and Technology)

[Overview]

CREST aims to promote unique, internationally high-level basic research to address the important problems facing our country and to produce creative, conspicuous, and innovative technology seeds based on new scientific knowledge that contributes to scientific and technological innovation that can transform the society and economy.

[Characteristics]

(i) To achieve the strategic objectives of each research area, the number of research project per research area, the size of the budget per research project, and the introduction of stage gates and team reorganization during the research period can be flexibly set at the discretion of the Research

[13] http://www.jst.go.jp/enkaku.html

Supervisor

(ii) Research Supervisors call for research proposals under the research area operation policy designed by him/herself and adopt 10-20 research projects per research area. The Research Supervisor builds the portfolio of the entire research area by looking at the balance between S&T fields and STI in multiple research projects. To this end, the call for proposals is divided into several rounds, and the adoption policy is clearly stated in the guidelines for each round. In the call for research proposals, the participation of researchers from industry or the humanities and social sciences may be required to promote concept-oriented research and interdisciplinary teams may be required to engage in more challenging research.

(iii) Adopt the best team led by a world-class Research Director. Supporting research funding of several hundred million JPY per research project so that top-level researchers can organize collaborative researchers to produce results.

(iv) The Research Supervisor will flexibly manage the research project to maximize the research results by directing changes, acceleration, and discontinuation of the research according to its progress. About ten advisors to support the management of the research area are assigned to the Research Supervisor. In addition to experts who provide advice and evaluation of S&T, industrial experts and experts who can provide legal advice, such as attorneys, are added as necessary to support concept-oriented research.

(v) In each research project, the mission is not only to achieve the proposed research objectives but also to develop the postdoctoral fellows and students who will join the team.

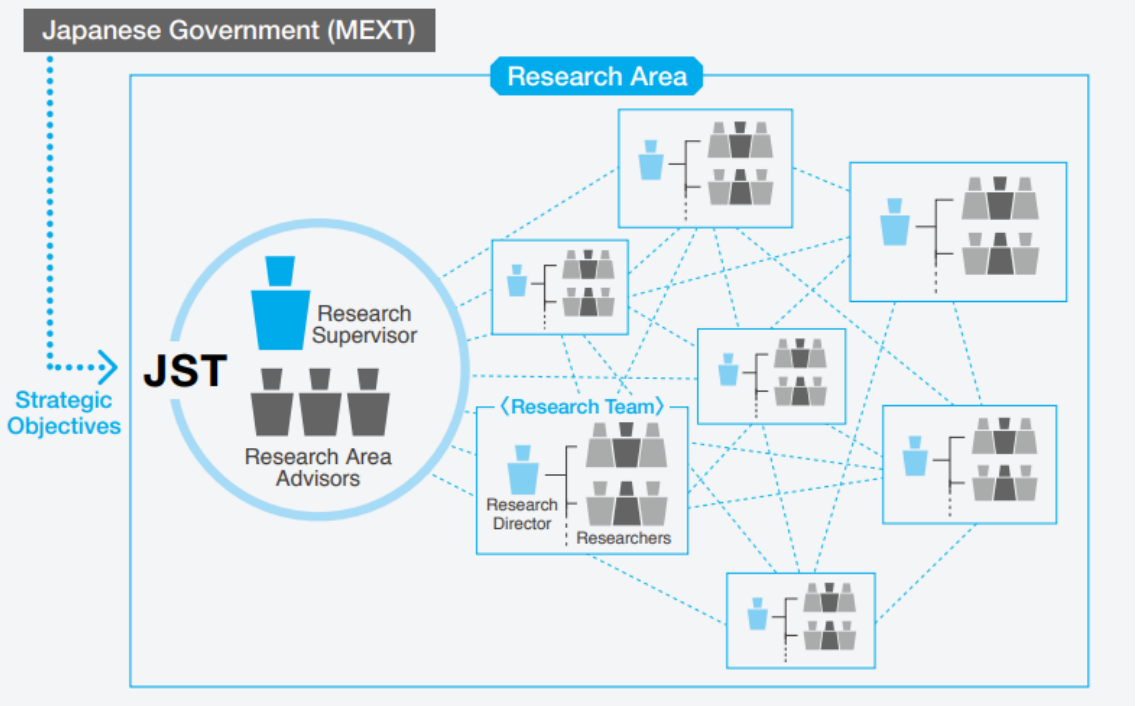


Figure A1-6. Research Framework of CREST[14]

(2) PRESTO (Precursory Research for Embryonic Science and Technology)

[Overview]

PRESTO aims to promote unique and challenging, internationally high-level basic research to address the important problems facing our country and to produce creative and innovative technology seeds (new technology seeds) based on new scientific knowledge as a source of scientific and technological innovation that can transform society and the economy.

[Characteristics]

(i) Research Supervisors call for research proposals based on the Research Areas they manage, adopting 30 to 40 research projects in each area. Research Supervisors consider the balance between science and scientific and technological innovation as they establish networks of researchers with different viewpoints in a Research Area or across Research Areas by accepting a variety of researchers and portfolios. For this purpose, we call for proposals several times separately and criteria for accepting proposals are clarified each time in the application requirements.

(ii) Approximately 40 million JPY has been allocated to support each research project, which is sufficient to enable young researchers to pursue/conduct their independent projects. Moreover, we give support to help young researchers become independent as well as organize the research environment.

(iii) We expect young researchers to not only produce results but also develop themselves as researchers. For this purpose, in PRESTO, Research Supervisors and Research Area Advisors give advice and guidance through area meetings held once or twice a year, and visits to the laboratories of PRESTO researchers. Furthermore, we provide a variety of support services to promote research, including exchanges with overseas researchers and opportunities that let young researchers review their research from the viewpoint of science in society depending on necessity.

(iv) In order to maximize achievements, our Research Supervisors adopt a flexible management approach by giving instructions to PRESTO researchers on changing, accelerating, or canceling research depending on their progress. We assign about ten Research Area Advisors to support Research Areas by giving advice and perform evaluations in terms of science and technology. In addition, we have experts who can give advice from a legal point of view such as lawyers and other experts from the industry when needed.

[14] https://www.jst.go.jp/kisoken/crest/en/about/index.html

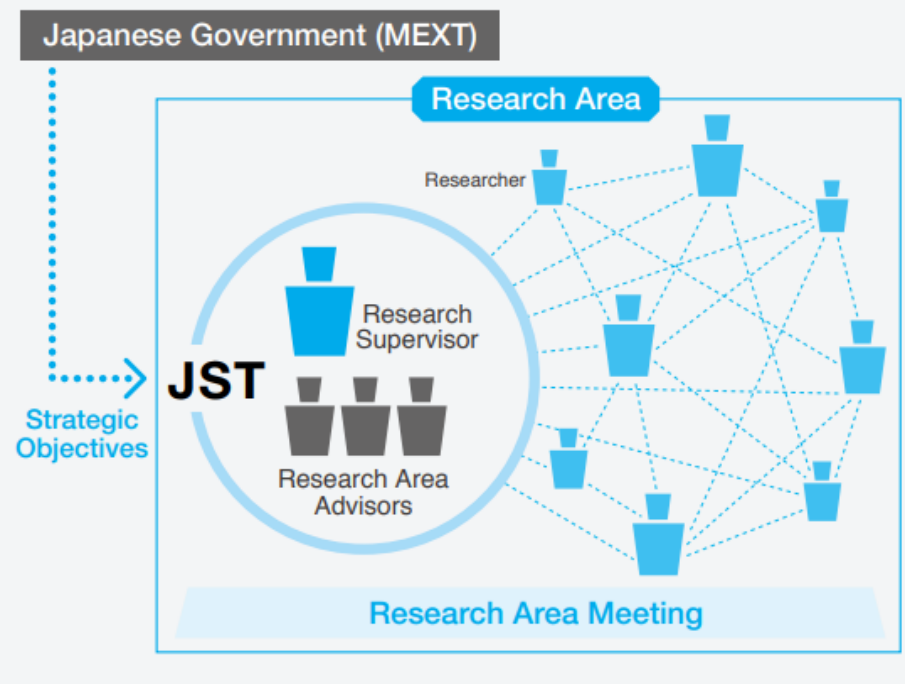


Figure A1-7. Research Framework of PRESTO[15]

(3) ERATO (Exploratory Research for Advanced Technology)

[Overview]

ERATO is a research funding program with a long history, first launched in 1981. The program aims to promote challenging basic research through the integration of different fields across existing research areas and/or on new approaches with a large size of research funds, and thus promote the formation of the new tides of science and technology that lead to scientific and technological innovation in the future and contribute to the accomplishment of Strategic Objectives. For this purpose, there are characteristics that enable Research Directors, as the managers in all aspects, to design Research Areas (projects) based on unique concepts and organize three to four research groups comprising different fields and/or functions by gathering researchers with different specialties and/or research projects to develop new fields.

[Characteristics]

(i) ERATO is a research system with "human" cores, in which the uniqueness and leadership of Research Directors are significant, while the young researchers involved are encouraged to exercise a certain amount of discretion.

(ii) The Research Directors design Research Areas (projects) based on unique concepts and deal with the development of new fields.

[15] https://www.jst.go.jp/kisoken/presto/en/about/index.html

(iii) The efforts to bring together excellent researchers from various fields, backgrounds, organizations, and nationalities are significant. Each project establishes three to four research groups in different fields and/or functions with the Research Director at the core. The projects contribute not only to the development of new fields but also to the development of young researchers. Those who participated in the past projects are active in various fields.

(iv) JST, in cooperation with the organizations to which the Research Directors belong, along with its dedicated staff, supports the establishment of new research organizations and the management of research bases that are independent of existing organizations.

(v) ERATO allows a flexible management approach toward research projects, enabling changing budgets and plans depending on the progress of research.

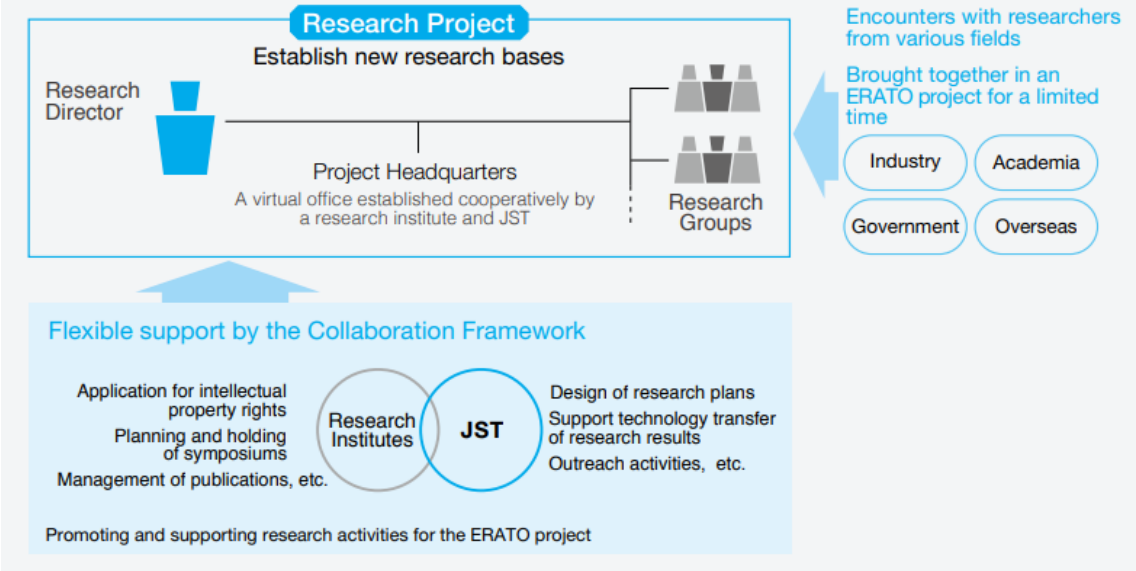


Figure A1-8. Research Framework of ERATO[16]

(4) ACCEL (Accelerated Innovation Research Initiative Turning Top Science and Ideas into High-Impact Values)

[Overview]

ACCEL aims to set a path to the next phase, such as company R&D, startup business and other public funding, based on the outputs of the Strategic Basic Research Programs (CREST, PRESTO, ERATO, etc.) that have the potential to be world-leading but cannot be continued by companies and other organizations due to their perceived risks. The Program Manager (PM) leads research and development with the innovation requirements and goals, demonstrating Proof of Concept (POC) and promoting the appropriate rights arrangements.

[16] https://www.jst.go.jp/erato/en/about/index.html

[Characteristics]

(i) Management structure led by the PM

(ii) Development and provision of Proof of Concept (POC)

(iii) Appropriate rights arrangement

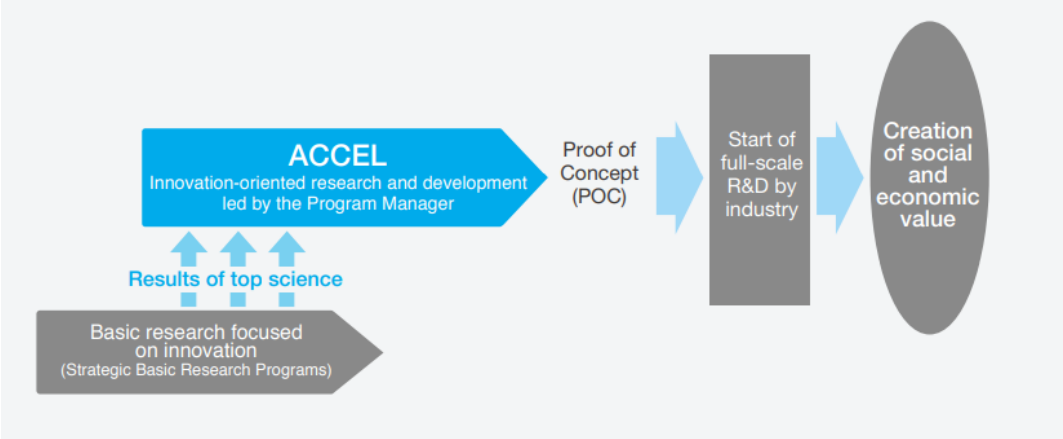


Figure A1-9. Mechanism of ACCEL[17]

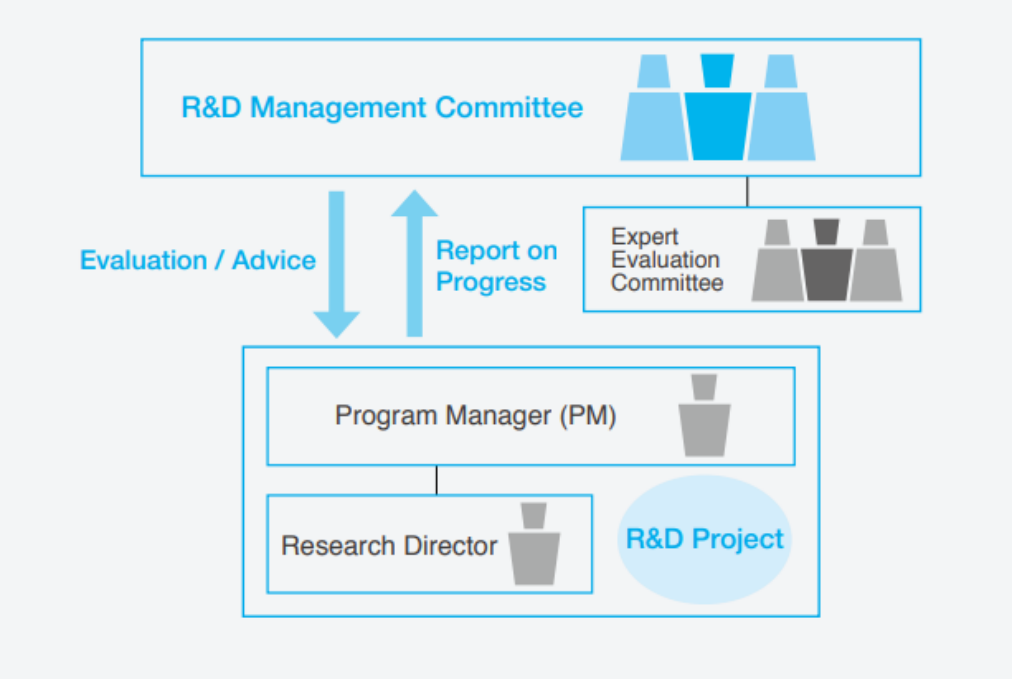


Figure A1-10. Research Framework of ACCEL[17]

[17] https://www.jst.go.jp/kisoken/accel/en/about/index.html

(5) ACT-C (Advanced Catalytic Transformation program for Carbon utilization)

: Creation of advanced materials conversion technologies for sustainable manufacturing with low energy and environmental impact

[Overview]

ACT-C aims to create catalytic materials conversion technologies that can contribute to addressing problems facing Japan and the rest of the world, including the realization of a low-carbon society and the sustainable and expansive production of pharmaceuticals and functional materials.

[Characteristics]

(i) Detailed follow-up for research activities

The Program Officer and Area Advisors will share research projects and provide various pieces of advice on research activities. Depending on the progress of the research, the research system and resources will be reviewed flexibly.

(ii) Presentation of research results and networking at the research area meetings

We will present our research results through the biannual research presentation sessions (research area meetings). In addition, we will build a cross-cutting research network through exchanges with researchers in different fields, including the Program Officer, Principal Program Director and Advisors.

(iii) Creation of synergies within the domain

We aim to promote joint research and create synergistic effects by sharing the background of each research topic in the field with other researchers.

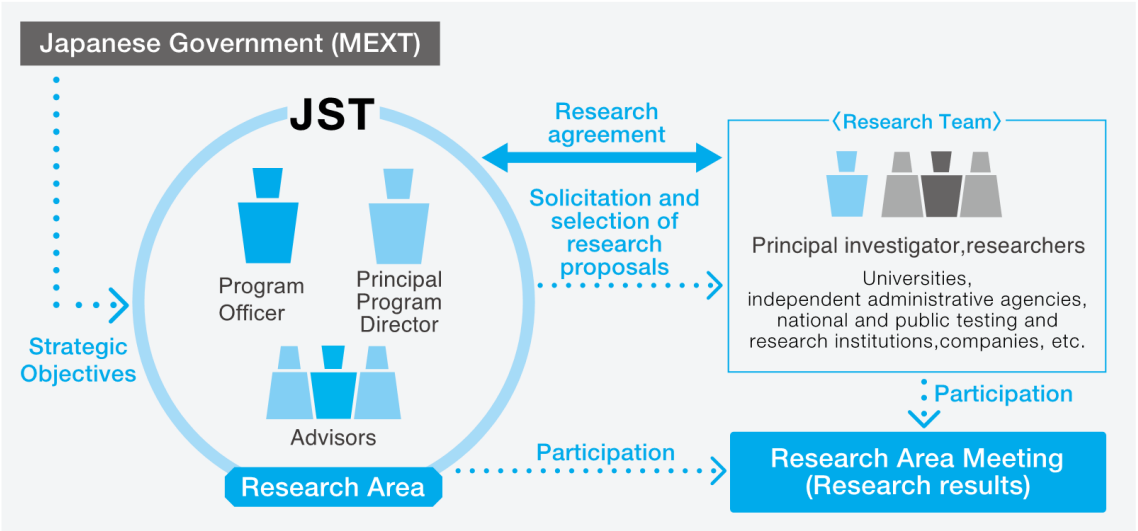


Figure A1-11. The structure of ACT-C[7]

(6) ACT-I (Advanced information and Communication Technology for Innovation)

[Overview]

ACT-I aims to find and develop superior young researchers to address important problems facing our country. Under the management principles of the Research Area defined by the Research Supervisor, we find researchers who have challenging ideas and support their researches aimed at creating new values that lead to scientific and technological innovation.

[Characteristics]

(i) ACT-I tries to find out and foster creative young researchers who are willing to provide solutions, through innovative imagination, for various challenges that people are facing today or will face tomorrow, and to establish the individuality of researchers. This solicitation is limited to people who are under the age of 35 on April 1 in the year of application. We are also looking forward to exciting proposals from graduate students and younger researchers affiliated with companies.

(ii) About 3 million JPY has been allocated to support each research project, which is sufficient to enable young researchers to pursue their independent research projects.

(iii) ACT-I researchers take responsibility for advancing projects which he or she has proposed within a Research Area led by a Research Supervisor. In advancing the research project, the researcher can gain various types of advice and guidance from the Research Supervisor and Research Area Advisors in Research Area Meetings (Meeting for research report presentation), and in addition, researchers will be strongly supported with Advisor Assignment System.

(iv) Research Area meetings are held twice yearly, researchers can interact with their Research Supervisor, Area Advisors, and researchers working in other fields of the same Research Area, and form networks that will continue beyond the end of their participation in the ACT-I program.

(v) After a regular research period, research subjects that can be expected to achieve even greater results will be eligible for a research extension of up to 10 million JPY per year for up to two years as the acceleration phase.

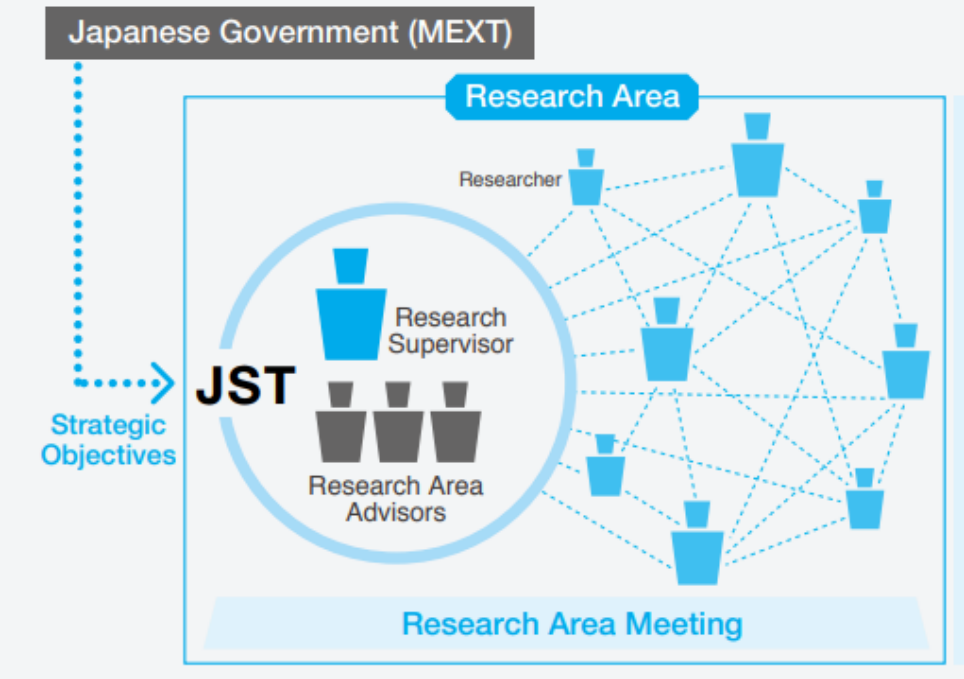


Figure A1-12. Research Framework of ACT-I[18]

(7) ACT-X

[Overview]

ACT-X aims to find and develop superior young researchers to address important problems facing our country. Under the management principles of the Research Area defined by the Research Supervisor, we find researchers who have challenging ideas. We give aid to research aimed at creating new values that lead to scientific and technological innovation.

[Characteristics]

(i) We support young researchers (including graduate school students) who have had their doctorate for less than 8 years (or researchers who are bachelor's degree holders for less than 13 years; excluding periods of maternity leave and parental leave.

(ii) Research Supervisors call for research proposals based on the Research Areas they manage, adopting 60 to 90 research projects in each area. We consider the balance between science and technology fields when accepting a variety of researchers. Thus, we give them support by forming networks of researchers with different viewpoints in a Research Area or across Research Areas. For this purpose, we call for proposals several times separately. Our criteria for accepting proposals are clarified each time in the application requirements.

(iii) Several million JPY has been allocated to support each research project, which is sufficient

[18] https://www.jst.go.jp/kisoken/act-i/en/about/index.html

to enable young researchers to begin working on their unique and challenging ideas, and pursue their independent research projects.

(iv) In order to maximize achievements, our Research Supervisors adopt a flexible management approach by giving instructions to ACT-X researchers on changing, accelerating, or canceling research depending on their progress. We assign about ten Research Area Advisors to support Research Areas. We also have experts who give advice and perform evaluations in terms of science and technology. In addition, we have experts from the industry who can give advice from a variety of viewpoints. To help young researchers establish themselves as independent entities, we assign each ACT-X researcher to a Research Area advisor who also plays the role of a mentor. Furthermore, Research Supervisors and Research Area Advisors give advice and guidance through area meetings held once or twice a year, and by visiting the laboratories of ACT-X researchers.

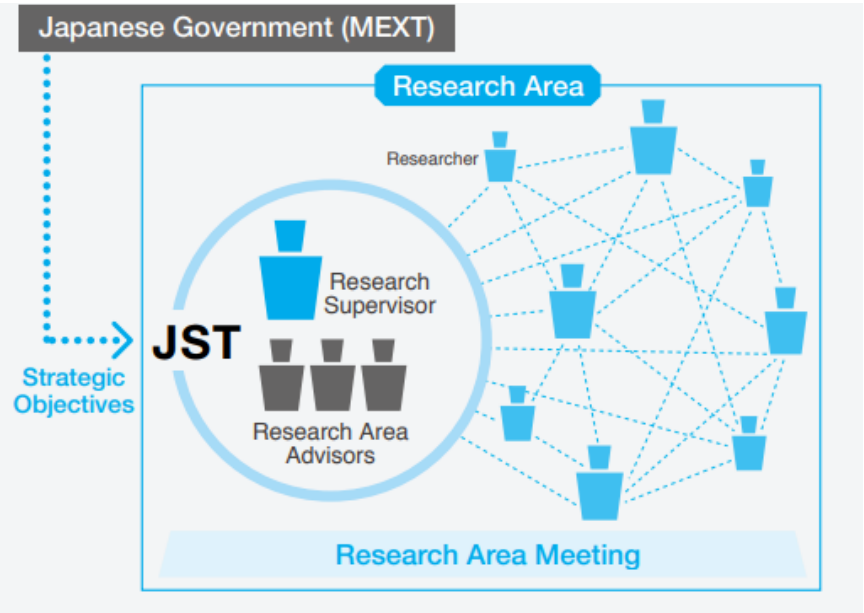


Figure A1-13. Research framework of ACT-X[19]

[19] https://www.jst.go.jp/kisoken/act-x/en/about/index.html

1.2.3 Program Operation

(1) CREST, PRESTO, ACT-I, ACT-X

1) Determination of Research Area and Program Officer (Ex-ante evaluation of Research Area)

The Program Director Committee conducts an Ex-ante evaluation based on JST implementation regulations, and the decision is finalized at a meeting of the JST Board of Directors.

[Evaluation Standards]

(i) Research areas

- A Research Area that is appropriate for achieving the strategic objectives
- A Research Area that is appropriate based on the current state of research in Japan, one in which many outstanding research proposals are anticipated

(ii) Research Supervisor

- A person who has vision and discernment with regard to the Research Area Possesses foresight and insight into the research field
- A person who has the experience and capacity to manage research in an appropriate manner to make effective and efficient progress in the research project
- A person who has a record of outstanding research achievements and who has the confidence of researchers in related areas
- A person who conducts fair and impartial evaluations experience and the ability to conduct appropriate research management to promote effective and efficient research projects.

[Process used to determine Research Area and Research Supervisor/Research Director]

(i) Ex-ante survey by JST based on status of study of the strategic objective-

JST conducts an Ex-ante survey in order to determine the Research Area and Research Supervisor, based on information provided by the MEXT starting from the stage of study of the strategic objectives.

- JST ex-ante survey is conducted using the following methods.

* JST references reports, etc. from various review boards (which are also referenced during studies conducted by the Ministry of Education, Culture, Sports, Science and Technology), as well as strategic proposals and other reports from the JST Center for Research and Development Strategy (CRDS). JST also collects and analyzes information on research trends and technological trends in relevant fields, the situation at related academic societies and so on.
* Interviews with experts in related fields will be conducted.

- The progress of the aforementioned Ex-ante survey is reported to the relevant Program Director appointed for each strategic objective and in-depth discussions are held.
- After formal notification of the strategic objectives is received from the MEXT (area survey).

(ii) Ex-ante evaluation and finalization of Research Area and Research Supervisor

- The Program Director Council conducts an Ex-ante evaluation of the Research Area and Research

Supervisor.

- Upon receipt of the results of the Ex-ante evaluation, the Research Area and Research Supervisor are finalized at a meeting of the JST Board of Directors.

2) Research Project selection (Ex-ante Evaluation of Research Project)

The Research Supervisor selects the research project with the assistance of the area advisors, etc., based on the implementation regulations and the decision is finalized at a meeting of the JST Board of Directors.

[Evaluation Standards (CREST)]

- A project that contributes to the achievement of strategic objective.
- A project that is consistent with the Research Area intent
- Basic research that is unique, highly appreciated internationally, and expected to produce outstanding results that contribute greatly to science and technology innovation. Projects must meet all of the following conditions.

Project must meet all of the following conditions.

- The research project applicant has produced research results for accomplishing research objectives.
- Promising preliminary results have been obtained for pursuing the research initiative.
- The research proposals must separately and clearly specify: (i) the background to the research initiative (its necessity and importance); (ii) the actual research record of the research project applicants; and (iii) the research initiative and plan.
- An optimal research organization is in place.
- The research project applicant will exercise strong leadership and bear responsibility for the entire research team, and, if there will be Lead Joint Researchers, they are essential for pursuing the research project applicant's research initiatives, and a collaboration framework sufficient for enabling significant contributions toward the achievement of research objectives will be constructed.
- Research budget planning necessary and sufficient for pursuing the research project applicant's research initiatives has been performed.
- The research institutions with which the research project applicant and Lead Joint Researchers are affiliated have R&D capabilities and other technical foundations in the subject research field.

[Evaluation Standards (PRESTO)]

- A project that contributes to the achievement of Strategic Objectives.
- A project that is consistent with the Research Area intent.
- Basic research that is unique, challenging, internationally expected to develop at an advanced level, and can be expected to produce groundbreaking results that lead to science and technology innovation.
- The research project applicant can be expected to contribute to the development of the subject overall PRESTO Research Area and to the ongoing development of related research fields through

the content of the proposed research the applicant's research approach and the applicant’s efforts to engage with other researchers in discussions and activities that mutually inspire.

Project must meet all of the following conditions.

- The uniqueness of the research project application is based on the original ideas of the research project applicant.
- Promising preliminary results have been obtained for pursuing the research initiative.
- The proposed research project is of a scale appropriate for pursuit by an individual researcher.

[Evaluation Standards (ACT-I)]

- A project that contributes to the achievement of Strategic Objectives.
- A project that is consistent with the Research Area intent.
- An R&D proposal that is based on a unique and challenging idea and internationally expected to develop at an advanced level, and can be expected to create new values that lead to science and technology innovation.
- The research project applicant can be expected to contribute to the development of the subject overall ACT-I Research Area and to the ongoing development of related research fields through the content of the proposed research, the applicant's research approach, and the applicant’s efforts to engage with other researchers in discussions and activities that mutually inspire.

Project must meet all of the following conditions.

- The uniqueness of the research project application is based on the original ideas of the research project applicant.
- The proposed research project is of a scale appropriate for pursuit by an individual researcher.

[Evaluation Standards (ACT-X)]

- A project that contributes to the achievement of Strategic Objectives.
- A project that is consistent with the Research Area intent.
- An R&D proposal that is based on a unique and challenging idea and internationally expected to develop at an advanced level, and can be expected to create new values that lead to science and technology innovation.
- The research project applicant can be expected to contribute to the development of the subject overall ACT-X Research Area and to the ongoing development of related research fields through the content of the proposed research the applicant's research approach and the applicant’s efforts to engage with other researchers in discussions and activities that mutually inspire.

Project must meet all of the following conditions.

- The uniqueness of the research project application is based on the original ideas of the research project applicant.
- The proposed research project is of a scale appropriate for pursuit by an individual researcher.

[Evaluation Process]

- The basic approach to selection is studied by the Program Officer with the assistance of the area advisors, etc. in order to achieve consensus between the Research Supervisor and area advisors, etc. (Selection policy meeting)
- The area advisors review the research proposals.
- Based on the results of the document review, the Research Supervisor conducts document selection with the assistance of the area advisors, etc. to determine the interview candidates. (Document screening)
- The Research Supervisor conducts the interview screening for the interview candidates with the assistance of the area advisors, etc., and the Research Supervisor selects the final candidates and additional final candidates. (Interview screening)
- The final candidate projects are reported to the Program Director Council.
- The final projects are finalized at a meeting of the JST Board of Directors.

3) Project Evaluations: Midterm and Ex-post Evaluations

(i) Midterm Evaluation

The Midterm Evaluation is conducted by the Research Supervisor with the assistance of Area Advisors, etc. The progress and research outcome is determined and based on the results, appropriate resources are allocated, research plans are reviewed and so on with the aim of helping to promote research more effectively in order to achieve the objectives of the research project, etc. Midterm evaluations are performed approximately three years after the start of research projects that are, as a general rule, scheduled to continue for five years or more.

[Evaluation Standards]

- Research progress and future prospects for the achievement of Research Project objectives
- Structure for research execution and status of research fund disbursement for the achievement of Research Project objectives

(ii) Ex-post Evaluation

The Ex-post Evaluation is conducted by the Research Supervisor with the assistance of area advisors, etc. The status of achievement of the research project, etc. and other research objectives, status of research implementation, impact and so on are determined, in order to develop research achievements in the future and help to improve project administration. Ex-post Evaluations are conducted as soon as possible after the conclusion of research or at an appropriate time prior to the conclusion of research, in accordance with the characteristics and stage of development of the research.

[Evaluation Standards]

- Status of achievement of research objectives
- Structure for research execution and status of research fund disbursement
- Impact of research achievements on science and technology as well as society and the economy

4) Research Area Evaluations: Midterm and Ex-post Evaluations

(i)Midterm Evaluation

The Midterm evaluation is conducted by an outside specialist selected by the JST. The status with a view to achievement of strategic objectives and the status of research management is determined and, based on the results, appropriate resources are allocated and so on with the aim of helping to improve Research Area administration and the JST-SBRPs coordination and support system. The Midterm evaluation is conducted approximately three to four years after the start of research in a Research Area in which research projects are expected to continue for five years or more.

[Evaluation Standards]

- Status with a view to achievement of strategic objectives as a research area
- Status of research management as a research area

(ii) Ex-post Evaluation

The Ex-post Evaluation is conducted by an outside specialist selected by the JST. The status of achievement of the strategic objectives and the status of research management are determined with the aim of helping to improve future project administration. Ex-post Evaluations are conducted as quickly as possible after the conclusion of research in the Research Area or at an appropriate time prior to the conclusion of research.

[Evaluation Standards]

- Status with a view to achievement of strategic objectives as a research area
- Status of research management as a research area

5) Follow-up Evaluations

The follow-up evaluation is conducted by an outside specialist selected by the JST. The status of development (including secondary effects) and status of use of research achievements, the impact of the research, and so on are determined, with the aim of helping to improve the project and project administration and so on. Follow-up evaluations are conducted after a certain period of time has elapsed following the end of the research.

[Evaluation Standards]

- Status of development and status of use of research achievements
- Impact of research achievements on science and technology as well as society and the economy

(2) ERATO

1) Determination of Research Project and Research Director (Ex-ante Evaluation)

The selection of the Research Area and Research Director is evaluated by the Panel Officer with the assistance of the panel members.

[Evaluation Standards]

- Novel, unique and transformative research, which could change the direction of thought in a discipline or make a substantial discovery to break new ground in science and technology

- Appropriate from the standpoint of the strategic objectives
- In the case of research that will be conducted jointly with a foreign research institution or the like, a project in which the combination of research capabilities with those of the joint research partner institution can be expected to create the seeds of innovative science and technology and contribute to international research exchanges

Projects must meet all of the following conditions.

- An outstanding and competent scientist who is qualified to lead an ERATO Project.
- Capable of leadership and be a person who can inspire young scientists.
- Appropriate research execution organization and scale of execution

2) Ex-post Evaluation (preliminary evaluation) and Ex-post Evaluation (final evaluation)

(i) Ex-post Evaluation (preliminary evaluation)

The Ex-post Evaluation (preliminary evaluation) is conducted by an outside specialist selected by the JST, taking into account the views of the Panel Officer as needed. The progress and status of execution of research in each Research Area are determined and, based on the results, appropriate resources are allocated, research plans are reviewed, and so on, in order to help promote research in a more effective manner in order to achieve the objectives of the Research Area and so on. The evaluation is generally conducted four years after the start of research.

[Evaluation Standards]

- Status of achievement of research objectives in the research area
- Structure for research execution and status of research fund disbursement
- The impact of the research results on S&T, society and the economy

(ii) Ex-post Evaluation (final evaluation)

The Ex-post Evaluation (final evaluation) is conducted for each Research Area by an outside specialist selected by the JST. The status of achievement of the research objectives, status of research execution, impact and so on is determined in order to develop research achievements in the future and help improve project administration. The evaluation is conducted as soon as possible after the conclusion of research in the Research Area or at an appropriate time prior to the conclusion of the research.

[Evaluation Standards]

- Status of achievement of research objectives in the research area
- Structure for research execution and status of research fund disbursement
- The impact of the research results on S&T, society and the economy

3) Follow-up Evaluations

The follow-up evaluation is conducted by an outside specialist selected by the JST. The status of development (including secondary effects) and status of use of research achievements, impact of the research, and so on are determined, with the aim of helping to improve the project and project

administration and so on. Follow-up evaluations are conducted after a certain period of time has elapsed following the end of the research.

[Evaluation Standards]

- Status of development and status of use of research achievements
- Impact of research achievements on science and technology as well as society and the economy

(3) ACCEL

1) Selection (Ex-ante Evaluation)

The selection of R&D Projects, Program Managers and Research Directors is conducted by the R&D Management Committee with the assistance of the Expert Evaluation Committee.

[Evaluation Standards]

(i) R&D Project

- Significant, world-leading research achievements must be produced as a result of the promotion of research in Strategic Basic Research Programs.
- It must be possible to create scenarios in which the achievements of research derived through Strategic Basic Research Programs, etc. are developed to strength industrial competitiveness and leads to a transformation of society, in a way that meets the expectations of society.
- Research and development by companies, etc. must be expected to continue even after the research period has ended.
- The research plan must be appropriate in terms of specific Proof of Concept for companies, etc.
- Efforts must be planned to train personnel who will enable ongoing research and development, as well as corporate collaboration, startup business, and other practical applications and the incorporation of personnel with a global outlook, even after the conclusion of the ACCEL program.

(ii) PM

- A person who possesses the experience and specialist knowledge relating to research and development, product development, the acquisition of rights, and so on
- A person with experience and a proven track record in technology transfer, company startup, product development etc.
- A person with project management experience in business administration or a thorough education in that area
- A person with the practical experience, specialist knowledge etc. deemed to be necessary for each Research Area

(iii) Research Director

- A researcher with outstanding research achievements who is capable of directing overall research in the Research Area as the leader of the research team

2) Midterm/Ex-post Evaluation/Follow-up Evaluations

(i) Midterm Evaluation

The Midterm Evaluation is conducted for each research and development project by the R&D Management Committee with the assistance of the Expert Evaluation Committee. The progress and achievements of research are determined and, based on the results, allocation of an appropriate budget, review of research plans, suspension of research and so on are conducted in order to help improve research administration and so on. As a rule, the evaluation is conducted approximately three years after the start of research (The timing of the evaluation may change depending on the judgment of the R&D Management Committee).

[Evaluation Standards]

- Current progress of research and prospects when research period ends
- Current status of research achievements and prospects when research period ends

(ii) Ex-post Evaluation

The Ex-post Evaluation is conducted by R&D Management Committee with the cooperation of the Specialist Council. The status of research execution and research achievements, etc. are determined in order to ensure the development of achievements in the future and help improve project administration. The evaluation is conducted as quickly as possible after the conclusion of the research or at an appropriate time prior to the conclusion of the research.

[Evaluation Standards]

- Status of execution of Proof of Concept and related corporate collaboration
- Status of acquisition of industrial property rights and other rights

(iii) Follow-up Evaluations

The follow-up evaluation is conducted by an outside specialist selected by the JST. The status of development (including secondary effects) and status of use of research achievements, impact of the research and so on are determined with the aim of helping to improve the project and project administration and so on. Follow-up evaluations are conducted after a certain period of time has elapsed following the end of research.

[Evaluation Standards]

- Status of development and status of use of research achievements
- Impact of research achievements on science and technology as well as society and the economy

(4) ACT-C

1) Determination of Research Area and Program Officer (Ex-ante evaluation of Research Area)

The Program Director Committee conducts an Ex-ante evaluation based on JST implementation regulations, and the decision is finalized at a meeting of the JST Board of Directors.

[Evaluation Standards]

(i) Research areas

- A Research Area that is appropriate for achieving the strategic objectives
- A Research Area that is appropriate based on the current state of research in Japan, one in which many outstanding research proposals are anticipated

(ii) Program Officer

- A person who has vision and discernment with regard to the Research Area Possesses foresight and insight into the research field.
- A person who has the experience and capacity to manage research in an appropriate manner to make effective and efficient progress in the research project
- A person who has a record of outstanding research achievements and who has the confidence of researchers in related areas
- A person who conducts fair and impartial evaluations

[Process used to determine Research Area and Program Officer]

(i) Ex-ante Survey by JST Based on Status of Study of the Strategic Objective

- The JST conducts an Ex-ante survey in order to determine the Research Area and Program Officer, based on information provided by the Ministry of Education, Culture, Sports, Science and Technology starting from the stage of study of the strategic objectives.
- The JST Ex-ante survey is conducted using the following methods.
  * The JST references reports, etc., from various review boards (which are also referenced during studies conducted by the Ministry of Education, Culture, Sports, Science and Technology), as well as strategic proposals and other reports from the JST Center for Research and Development Strategy (CRDS). The JST also collects and analyzes information on research trends and technological trends in relevant fields, the situation at related academic societies, and so on.
  * Interviews are conducted with leading figures in related fields.
- The progress of the aforementioned Ex-ante survey is reported to the relevant Program Director appointed for each strategic objective, and in-depth discussions are held.
- After formal notification of the strategic objectives is received from the Ministry of Education, Culture, Sports, Science and Technology, the JST conducts a further survey (area survey).

(ii) Ex-ante Evaluation and Finalization of Research Area and Program Officer

- The Program Director Council conducts an Ex-ante evaluation of the Research Area and Program Officer.
- Upon receipt of the results of the Ex-ante evaluation, the Research Area and Program Officer are finalized at a meeting of the JST Board of Directors.

2) Research Project Selection (Ex-ante Evaluation of Research Project)

In order to contribute to the selection of research projects and research representatives, the Program Officer selects the research project with the assistance of the area advisors, etc., based on the

implementation regulations and the decision is finalized at a meeting of the JST Board of Directors.

[Evaluation Standards]

- A project that contributes to the achievement of strategic objective.
- A project that is consistent with the Research Area intent
- A basic research that is pioneering, unique, and highly appreciated internationally and expected to have a significant impact on the future of science and technology.
- Contributing to the creation of innovative technological seeds and providing a clue to the creation of scientific and technological innovation.
- The research project applicant has produced research results for accomplishing research objectives and the ability to take responsibility for the research team as a whole.
- The research will be conducted on an appropriate scale.
- The research will be conducted for an appropriate period of time.
- An optimal research organization is in place. If there will be Lead Joint Researchers, they are essential for achieving the research project applicant's research initiatives.
- The research institutions with which the research project applicant and Lead Joint Researchers are affiliated have R&D capabilities and other technical foundations in the subject research field.
- Research budget planning necessary and sufficient for pursuing the research project applicant's research initiatives has been performed. Consideration of the cost performance of research is fully given.

3) Project Evaluations: Midterm and Ex-post Evaluations

(i) Midterm Evaluation

The Midterm Evaluation is conducted by the Program Officer with the assistance of Area Advisors, etc. The progress and research outcome is determined and based on the results, appropriate resources are allocated, research plans are reviewed, and so on with the aim of helping to promote research more effectively in order to achieve the objectives of the research project, etc. In general, midterm evaluations are performed approximately three years after the start of research projects.

[Evaluation Standards]

- Research progress and future prospects
- Structure for research execution and status of research fund disbursement

(ii) Ex-post Evaluation

The Ex-post Evaluation is conducted by the Program Officer with the assistance of area advisors, etc. The status of achievement of the research project, etc. and other research objectives, status of research implementation, impact and so on are determined, in order to develop research achievements in the future and help to improve project administration. Ex-post Evaluations are conducted as soon as possible after the conclusion of research or at an appropriate time prior to the conclusion of research, in accordance with the characteristics and stage of development of the research.

[Evaluation Standards]

- Status of achievement of research objectives
- Structure for research execution and status of research fund disbursement
- Impact of research achievements on science and technology as well as society and the economy

4) Research Area Evaluations: Midterm and Ex-post Evaluations

(i) Midterm Evaluation

The Midterm evaluation is conducted by an outside specialist selected by the JST. The status with a view to achievement of strategic objectives and the status of research management are determined and, based on the results, appropriate resources are allocated and so on with the aim of helping to improve research administration and the JST support organization. The Midterm evaluation is conducted approximately three to four years after the start of research

[Evaluation Standards]

- Status with a view to achievement of strategic objectives
- Status of research management

(ii) Ex-post Evaluation

The Ex-post Evaluation is conducted by an outside specialist selected by the JST. The status of achievement of the strategic objectives and the status of research management is determined with the aim of helping to improve future project administration. Ex-post Evaluations are conducted as quickly as possible after the conclusion of the research in the Research Area or at an appropriate time prior to the conclusion of the research.

[Evaluation Standards]

- Status of achievement of strategic objectives
- Status of research management

5) Follow-up Evaluation

The follow-up evaluation is conducted by an outside specialist selected by the JST. The status of development (including secondary effects) and status of use of research achievements, the impact of the research, and so on are determined, with the aim of helping to improve the project and project administration and so on. Follow-up evaluations are conducted after a certain period of time has elapsed following the end of the research.

[Evaluation Standards]

- Status of development and status of use of research achievements
- Impact of research achievements on science and technology as well as society and the economy

2. Strategic Basic Research Programs Research Results and Impacts

2.1 Strategic Basic Research Programs Research Results (Outstanding Results in Each Field)

2.1.1 Initiatives in Research Areas and the Creation of Outstanding Research Results That Contribute to the Achievement of Strategic Objectives

CREST "Molecular Technology" Research Area (2011-2019), Research Supervisor: Hisashi Yamamoto

To achieve the strategic objectives of “establishment of molecular technology, which is the free control of molecules to bring innovation to environmental and energy materials, electronic materials, and health and medical materials,” Research Supervisor has established a new scientific principle of "molecular technology -- a series of technologies that enable us to qualitatively change existing science and technology through purposefully designing and synthesizing molecules and creating the physical, chemical, and biological functions of materials at a molecular level. This was highly evaluated by the ex-post evaluation committee (an external panel set up by JST) for its contribution to the achievement of strategic objectives. The following is an overview of the initiatives to achieve the strategic objectives and research results.

(Efforts to create results)

- Establishment of the "Rising Star Award": The Research Supervisor actively supported collaborative research between young CREST researchers and PRESTO researchers with the aim of fostering young people who will be responsible for molecular technologies in the next 10 to 20 years. Some of the researchers have been promoted from Assistant Professor (at the time of receiving the award) to Professor (as of March 2020).
- Clarification and sharing of the status of goal achievement: The structure of the presentation materials at the Research Area meetings was unified so that the progress and results of the research and the status of strategic goal achievement could be understood at a glance. This led to more active discussions and accelerated the research in the research area as a whole to achieve the strategic goals.
- Enhancement of collaboration activities as a network-based research institute: In addition to the joint symposium with PRESTO, The Research Supervisor held public symposium in Paris. CREST, PRESTO, and Strategic International Collaborative Research Program (SICORP) (a Japan-France joint research project in the field of "Molecular Technology" under the JST SICORP; the Research Supervisor is also the Program Officer of SICORP) worked together to establish a system to promote research beyond the framework of the project in an integrated manner.

(Case Study)

- Itaru Hamachi (Professor, Kyoto University) has developed zinc-responsive molecules that can tag proteins around zinc ions and has developed a completely novel molecular technology to identify and analyze proteins involved in zinc homeostasis using these molecules. The results of this research are expected to elucidate the physiological phenomena and diseases related to changes in zinc ion concentration, such as brain ischemia and Alzheimer's disease. He was selected as an ERATO Research Director.

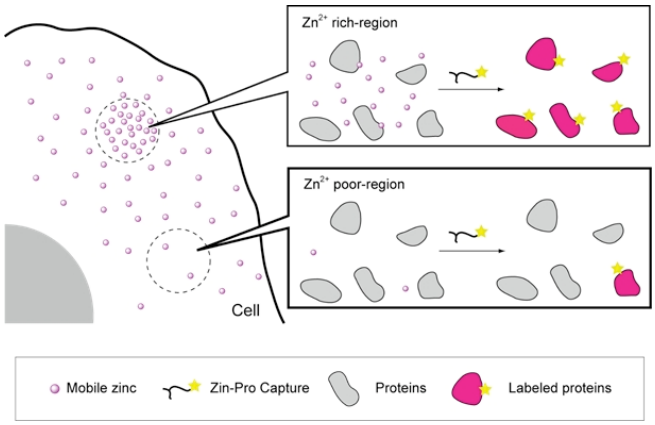


Figure A2-1. Protein labeling in cells by Zin-Pro capture[20]

- Satoshi Maeda (Professor, Hokkaido University) extended the Artificial Force Induced Reaction (AFIR) method, which is a method to explore the reaction process quickly by forcing reactants against each other, and succeeded in generalizing it for various chemical reactions (e.g., catalytic and surface reactions). The research results are expected to significantly speed up the development of materials and drug discovery through the discovery of unknown reaction routes and optimal chemical reactions for the formation of target substances. The Institute for Chemical Reaction Design and Discovery (ICReDD), which he proposed, was selected as one of the World Premier International Research Center Initiative (WPI), and he serves as the director of the center. In addition, he was selected as an ERATO Research Director.

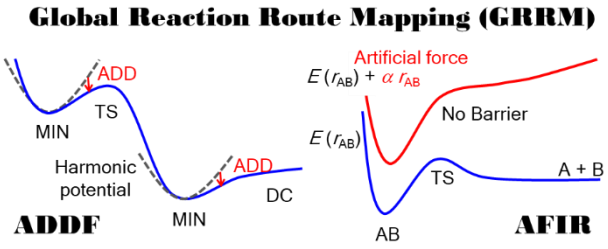


Figure A2-2. Conceptual diagram of GRRM

[20] https://www.funakoshi.co.jp/contents/80823

- Hiroaki Suga (Professor, The University of Tokyo) is conducting joint research on the results of basic research with PeptiDream Corporation, a university-launched bio-venture established by the Research Director with capital participation from pharmaceutical manufacturers. In order to license and commercialize basic patents, he is promoting joint research with many pharmaceutical manufacturers.

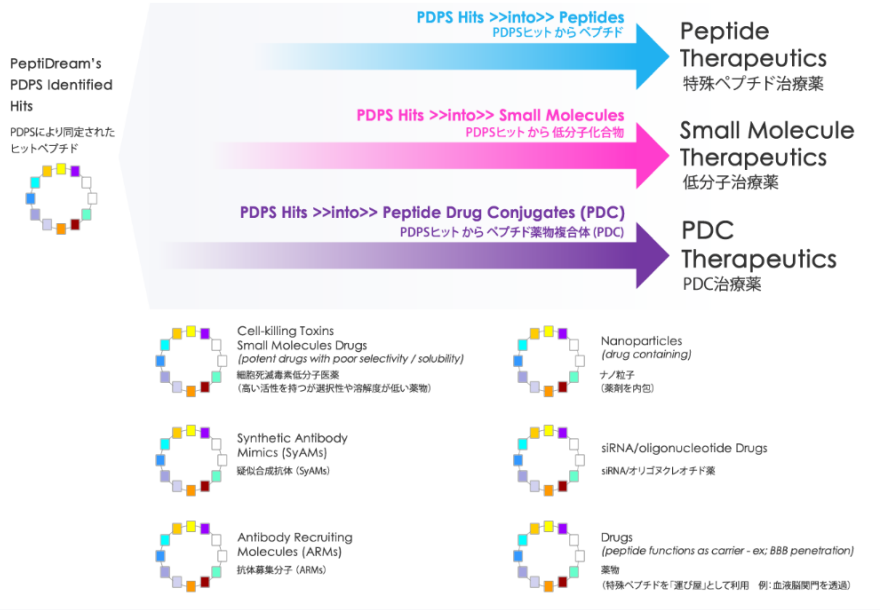
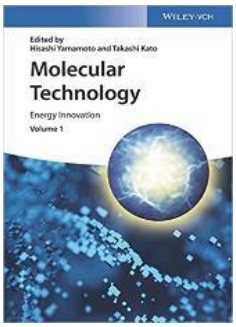


Figure A2-3. PeptiDream's drug discovery and development platform system[21]

(Construction and dissemination of new scientific field)

- The Research Area has established the new scientific field of "molecular technology" originating in Japan through this strategic project. In addition, with the involvement of the CREST/PRESTO Japan-France joint research team, The Research Area published Molecular Technology in four volumes from Wiley, the world's leading scientific publisher, which could be the bible of the field, and disseminated “molecular technology” to the world.



[21] https://www.peptidream.com/discovery/#technology

Figure A2-4. *Molecular Technology* (Volume I), published by Wiley in 2018.

PRESTO "Design of Information Infrastructure Technologies Harmonized with Societies" Research Area (2013-2020), Research Supervisor: Hiroto Yasuura

The strategic objectives of the Research Area are the "development of intelligent information processing technology to realize creative collaboration between human and machines" and "creation, advancement, and systematization of innovative information technologies and their underlying mathematical methodologies for obtaining new knowledge and insight from use of big data across different fields." A new concept and research results that have not been extended in the past were generated among the rapid growth of data science and AI technologies in recent years. The ex-post evaluation committee highly evaluated the contribution to the achievement of the strategic objectives. The following is an overview of the initiatives to achieve the strategic objectives and research results.

(Efforts to create results)

- Short overseas visits: Short overseas visits have been conducted every year since the inception of the research area. By making young researchers visit startup capitalists and companies in the U.S., Singapore, and Taiwan, and giving them an opportunity to experience the fast pace of the field, the Research Supervisor provided young researchers with new insights and ideas. In addition, study sessions on entrepreneurship and workshops with experts of organizations visited were held. Some projects were adopted the JST-Mirai Program and some impacts were also seen.
- Panel sessions: As well as holding public talks, more than 20 researchers participated in the talk session at the National Museum of Emerging Science and Innovation (Miraikan), where they made presentations to the public, including children, in an easy-to-understand manner.
- Exchange of opinions with policymakers: The Research Supervisor held meetings with policymakers from the Cabinet Office and the Ministry of Internal Affairs and Communications (MIC). They were meaningful for both sides, as they led to widening research activities for researchers and served as a reference for officers in formulating policies.

(Case Study)

- Emi Tamaki (Associate Professor, Waseda University) has developed an AR/VR system that provides a highly immersive sensation by reproducing the sense of touch through electrical muscle stimulation (EMS), and launched an AR/VR product through the startup company (H2L Corporation), of which she is a co-founder. The system is expected to enable people who have difficulty in going out of their homes due to rehabilitation at home and other reasons to share the sensation of being out of the house by making physical senses transferred from or to other people and robots.

Figure A2-5. Two basic technologies for people with difficulty in going out to share their proprioceptive senses with others and robots remotely

- Shizuko Hiryu (Professor, Doshisha University) discovered that bats could avoid interference by changing the frequency of their ultrasonic waves with each other. It was shown that bats can be a new model animal for swarm behavior, and the application of bat ultrasonic is expected to lead to technological seeds for designing sensing systems that are resistant to interference and future swarm control for autonomous sensing robots. This is an original and unique achievement, a typical PRESTO program.

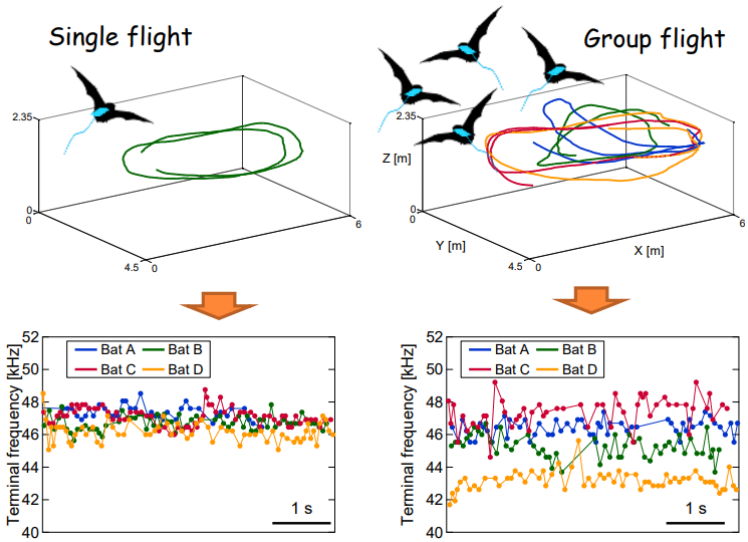


Figure A2-6. Top: Flight trajectory of bats in collective flight; Bottom: Change in terminal frequency (TF) over time(left): Using similar TF; (right): adjusted to avoid TF superimposition

PRESTO "Hyper-nano-space Design toward Innovative Functionality" Research Area (2013-2018), Research Supervisor: Kazuyuki Kuroda

The research results were highly evaluated by the ex-post evaluation committee as contributing to

the strategic objectives of "creation of new functional materials by means of technology for controlling spaces and gaps in advanced materials in order to realize selective material storage, transport, chemical separation, and conversion, etc." and "establishment of a technology system for technology for controlling spaces and gaps". The research results with no similarities seen in the world and efforts for practical applications were recognized.

(Case Study)

- Design and Development of next-generation chiral hyper-nano-space controlled on the molecular level

  Tomoki Ogoshi (Professor, Kyoto University), in collaboration with some PRESTO researchers, has succeeded in making a proprietary ring-shaped organic space material (pillar[n]arene) technology a new major scientific field. The material has the ability to change the size of the vacancy at will and to selectively incorporate molecules of suitable size into the material. With the research result, he was highly evaluated by the scientific community as a pioneer in this field, and his project was subsequently adopted by the PRESTO Network and CREST. It is expected to become a key material that will be useful in a wide range of industrial fields, including electrode materials and separation membranes.

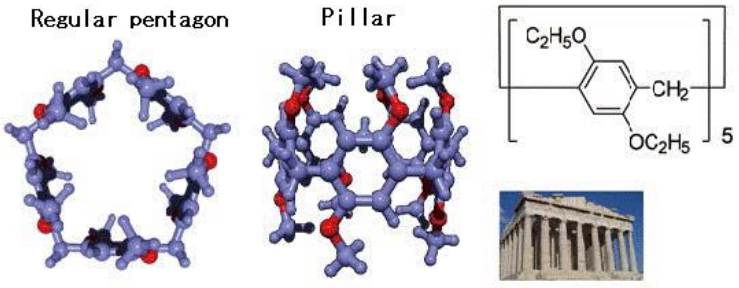


Figure A2-7. Pillar[n]arene

- Artificial hyper-nanospace for mechanism elucidation of cancer metastasis

  Takao Yasui (Associate Professor, Nagoya University) has developed a new technique for capturing exosomes in urine using nanowire structures. He further developed the technology and established a new technique to identify cancer (lung, pancreas, liver, bladder, and prostate) from 1mL of urine. Based on the research results, he established a startup company, Icaria Corporation (now Craif Corporation), which was funded by the JST's Support Program of Capital Contribution to Early-Stage Companies (SUCCESS). Although it has been considered difficult to develop a non-invasive and simple health diagnosis method, this technology is expected to enable non-invasive cancer diagnosis and identification using urine, such as detecting cancer in urine during medical check-ups. He was also honored with the 2019 Award for Academic Startups.

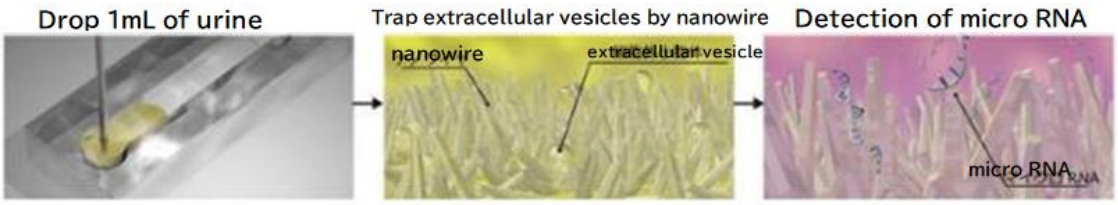


Figure A2-8. Capture of exosomes in urine using nanowire structures and microRNAs encapsulated therein

2.1.2 Producing Outstanding Research Results in Research Projects (Nanotechnology & Materials, Green Innovation, Life innovation, Information and Communication Technology)

[Nanotechnology & Materials]

Major innovation in sliding parts, starting with basic research

ACCEL "Reinforcement of Resiliency of Concentrated Polymer Brushes (CPBs) and Its Tribological Applications － Development of Novel 'Soft and Resilient Tribology (SRT)' System" (2015-2020), Research Director: Yoshinobu Tsujii (Director/Professor, Kyoto University), Program Manager: Kimihiro Matsukawa (JST)

The project promoted the practical applications of Concentrated Polymer Brushes (CPBs), a successfully developed technology to cover the surface of the material with long polymer strings in high density. When the material developed by this technology was applied to a sliding bearing, the friction was reduced to one-tenth of the torque with the minimum speed reduced by one digit. The research has progressed through appropriate management by the PM, such as the use of open innovation among the participating companies (assuming one application per company) and the establishment of a system of corporate cooperation for application.

The 1,000-hour operation period proposed as a criterion for judging the feasibility of the CPBs has been met. The prospect of using the CPBs in speakers and other applications has already been established, with the ultimate goal of applying them to automotive parts. By reducing friction with the CPBs, all kinds of machine parts can be made smaller and lighter, which is expected to contribute to reducing environmental impact with improved fuel efficiency and energy conservation. The project aims to create a material that controls friction and create innovation from basic research in a mature market where technological differentiation is difficult.

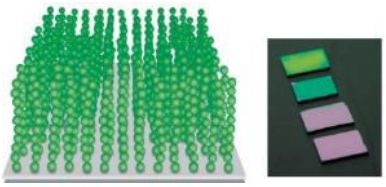


Figure A2-9. Image of the CPB

Realization of current-injection-type organic semiconductor laser diodes (OSLD)

ERATO "ADACHI Molecular Exciton Engineering" Project (2013-2019), Research Director: Chihaya Adachi (Director/Professor, Kyushu University)

The project succeeded in the oscillation of organic semiconductor laser diodes (OSLDs) by current injection for the first time in the world, by the introduction of optimal optical resonators, low-threshold current oscillation through the molecular design of the advanced laser molecule, optimization of the layered structure, and suppression of optical loss.

Any oscillation wavelengths (from visible light to infrared region) can be selected due to the molecular design of the organic materials. The relatively low cost and simple manufacturing process allow for a greater degree of mounting flexibility than inorganic semiconductor lasers. In addition, the organic thin-film laser oscillation provides a high degree of compatibility with organic devices in terms of mounting, which will lead to the development of new organic light-emitting devices, such as display devices that integrate organic EL and organic lasers.

For the purpose of the practical application of OSLDs, KOALA Tech (Kyushu Organic Laser Technology), a Kyushu University startup business, was established in 2019. The company aims to improve the characteristics and stability of OSLDs, raise their performance to a practical level, and develop and commercialize new applications such as information security, displays, biosensing, healthcare, and optical communications.

Figure A2-10. Image of OSLD (left) and oscillation (right)

Synthesis of a carbon nanobelt with potential applications in nanotechnology

ERATO "Itami Molecular Nanocarbon" Project (2013-2018), Research Director: Kenichiro Itami (Professor, Nagoya University)

The project team succeeded in the first organic synthesis of a carbon nanobelt, a dream molecule that chemists around the world have been trying to synthesize. The carbon nanobelts were successfully synthesized in 11 steps using *p*-xylene, an inexpensive petroleum component, as a carbon raw material by converting a strain-free cyclic molecule into a tubular structure. Various spectroscopic analyses were conducted, and it was confirmed that the synthesized carbon nanobelts

are very similar to carbon nanotubes in structure and properties. A new scientific field of "molecular nanocarbon science" is expected to be established, such as the synthesis of single-structure carbon nanotubes and the development of new functional materials.

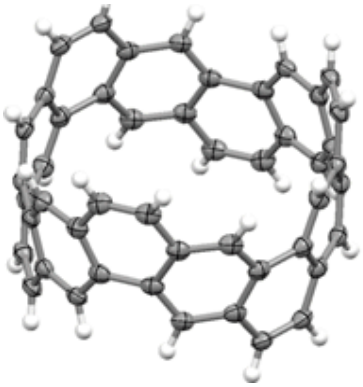


Figure A2-11. Structural analysis of carbon nanobelts

A solar cell you can put in the wash

PRESTO "Innovative Nano-electronics through Interdisciplinary Collaboration among Material, Device and System Layers" (2014-2017), Researcher: Kenjiro Fukuda (Research Fellow, RIKEN)

The project successfully developed ultra-thin photovoltaic cells that achieve three important factors at the same time: high energy conversion efficiency, stretchiness and water resistance. A new semiconducting polymer film is formed on an ultra-thin substrate, sandwiched between rubber, only 3 micrometers thick, and can be bent and crushed to work. It achieved a maximum energy conversion efficiency of 10%, with only a 5% reduction in conversion efficiency after being placed in water for 120 min. It is expected to be a power source to drive wearable sensors and other devices capable of continuous biological monitoring.

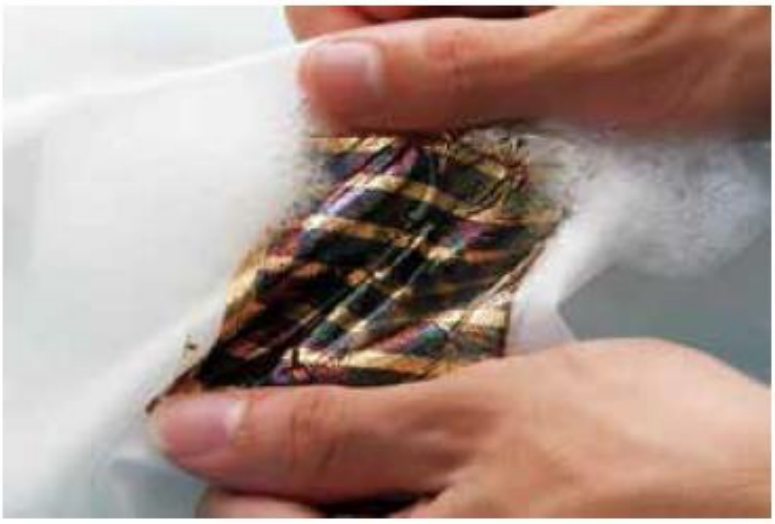


Figure A2-12. Washing of ultra-thin organic solar cells attached to clothes

An innovative method to control the crystal structure of nano-alloys

ACCEL "Creation of the Functional Materials on the Basis of the Inter-Element-Fusion Strategy and Their Innovative Applications" Research Area (2015-2020), Research Director: Hiroshi Kitagawa, (Professor, Kyoto University); Program Manager: Akihiro Okabe, JST)

The project succeeded in synthesizing solid solution nano-alloys and also in producing solid solution nano-alloys with the same composition but different crystal structures by utilizing the features of chemical reduction, a common method of synthesizing nano-alloys particles, for the combination of gold and ruthenium, which are not mixed in bulk. This method is expected to be an innovative method for controlling the crystal structure of nano-alloys and to improve the catalytic performance of nano-alloys materials such as catalysts and magnetic materials, which are widely used in the engineering field.

In this project, mass production technology for the continuous synthesis of solid solution alloys of a few nanometers, which had been difficult to be stably mass-produced, was jointly developed with a company. New solid-solution nano-alloy materials with unprecedented metal combinations can be developed and are being evaluated as exhaust gas purification catalysts and various chemical process catalysts. The solid-solution nano-alloy materials, for which there was no mass production technology, are expected to be put to practical use.

Figure A2-13. An innovative method to control the crystal structure of nano-alloys

[Green Innovation]

Innovating IoT devices with IoT devices with vertical transistors -- ultra-low leakage current and reduced chip area

ACCEL "Three-Dimensional Integrated Circuits Technology Based on Vertical BC-MOSFETs and Its Advanced Application Exploration" (2014-2018), Research Director: Tetsuro Endoh (Professor, Tohoku University); Program Manager: Toru Masaoka (JST)

A G-bit-class DRAM test chip with a vertical BC-MOSFET peripheral was fabricated and evaluated, and operation with a low power supply voltage of 0.8 V was successfully demonstrated while maintaining high speed. Using the vertical BC-MOSFET layout rule, it was demonstrated

that the area of the device could be reduced to almost half in SRAM. It was also confirmed that, due to the improvement of the device performance, the leakage current is reduced to about 1/10 of the leakage current of conventional planar devices. These considerable improvements in performance are expected to make a significant contribution to the energy-saving society of the future, including the realization of large-capacity, high-speed, lower power consumption working memory, and smaller, lower power consumption IT devices.

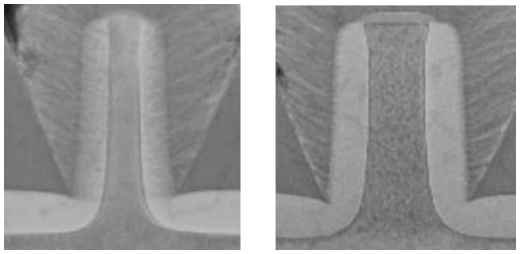


Figure A2-14. Cross-sectional TEM image of the Si pillar[22]

Highly efficient ammonia synthesis at lower temperatures and lower pressures

ACCEL "Materials Science and Application of Electrides" (2013-2017), Research Director: Hideo Hosono (Professor Emeritus, Tokyo Institute of Technology), Program Manager: Toshiharu Yokoyama (JST)

Utilizing electrides, which are chemical compounds in which electrons serve as anions, the project developed a catalyst that enables highly efficient ammonia synthesis at lower temperatures and lower pressures. Based on the results of this research, the project established Tsubame BHB Co., Ltd., a startup company from the Tokyo Institute of Technology, with Ajinomoto Co., Inc. and others, and began operations on April 25, 2017. With the aim of realizing the world's first on-site ammonia production, which will contribute to solving issues such as high energy load and high logistics costs, the company has completed a pilot plant capable of producing several tens of tons of ammonia per year and is currently conducting continuous test operations.

[22] e-J. Surf. Sci. Nanotech. Vol. 15 (2017) 127-134

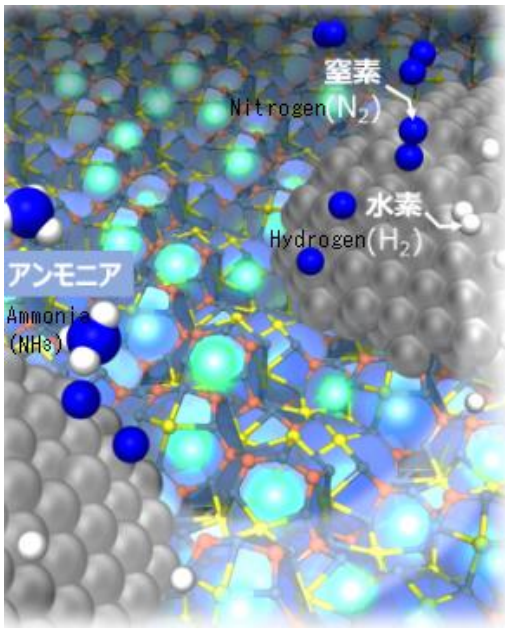


Figure A2-15. Schematic diagram of ammonia synthesis with electride catalyst[23]

[Life Innovation]

Database of drug action

ERATO "SATO Live Bio-Forecasting" Project (2013-2019), Research Director: Thomas N. Sato (Director, The Thomas N. Sato, BioMEC-X Laboratories, Advanced Telecommunications Research Institute International (ATR))

Karydo TherapeutiX Inc., a startup company, established as a development of research results, has launched a database on drug effects. The data on the body-wide effects of the world's leading drugs is expected to uncover unknown effects and hidden risks of side effects of drugs, thus promoting open science in the field of drug discovery.

[23] https://tsubame-bhb.co.jp/technologies/electride/

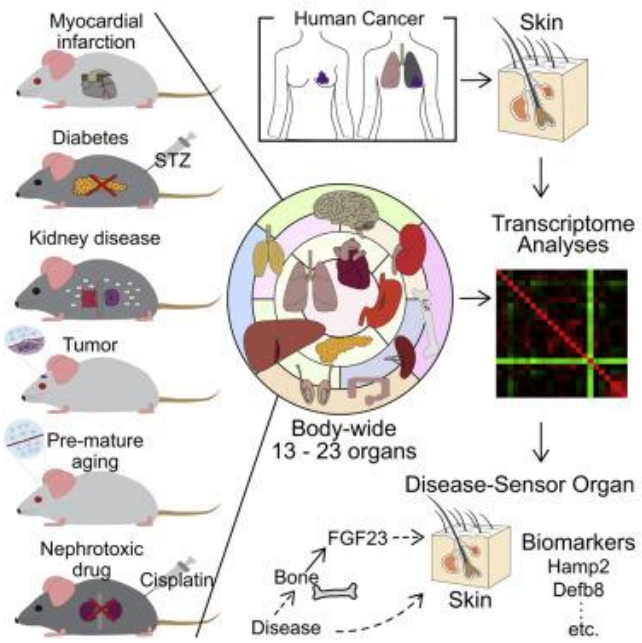


Figure A2-16. Database on body-wide drug effects[24]

The structure of DNA scissors that cut DNA

PRESTO "Structural Life Science and Advanced Core Technologies for Innovative Life Science Research", (2013-2016), Researcher: Hiroshi Nishimasu (Associate Professor, The University of Tokyo)

The crystal structure of a tripartite complex composed of CRISPR-Cas9 (SpCas9) derived from Streptococcus pyogenes, which is widely used for genome editing by Cas9[25], guide RNA, and target DNA was elucidated for the first time in the world. In addition, by introducing amino acid mutations into SpCas9, we developed a SpCas9 variant (SpCas9-NG) that recognizes the NG sequence NG (PAM sequence) instead of the NGG sequence and succeeded in extending and improving the accuracy of target regions for genome editing. In order to improve the efficiency of cell introduction, the project clarified the structure of the complex of Cas9 derived from Staphylococcus aureus (SaCas9), which is smaller than SpCas9 and has a higher efficiency of cell introduction, and developed Cas9, which has a function of activating targeted genes.

In collaboration with Tetsuyuki Furudera (Professor, Kanazawa University), who was also a PRESTO researcher in the same research area, the project conducted the single-molecule analysis

[24] https://karydo-tx.com/

[25] Cas9 binds to guide RNAs and has the ability to selectively break DNA that is complementary to a portion of the guide RNA (guide sequence).

using high-speed AFM[26], and in 2017 it succeeded in capturing a video of the entire process of DNA breakage by Cas9, and received a great response from across the world.

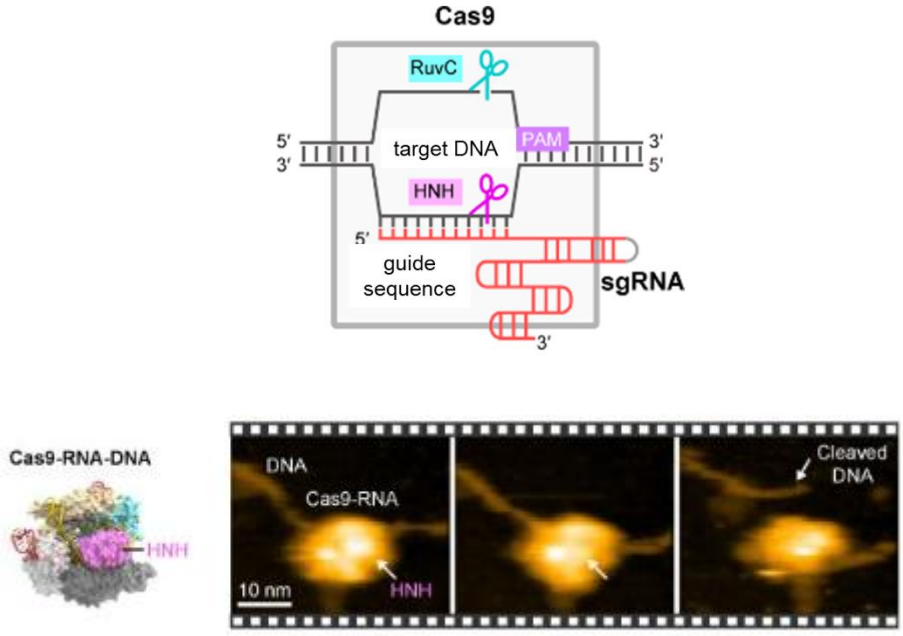


Figure A2-17. Mechanism of double-strand breakage (DSB) by Cas9-guide RNA complex (upper) and DNA breakage by Cas9-guide RNA complex (lower). The part indicated by the arrow acts as scissors

Mass production of egg cells from iPS cells in laboratory culture

PRESTO "Epigenetic Control and Biological Functions" (2011-2014), Researcher: Katsuhiko Hayashi (Professor, Kyushu University)

By examining a variety of culture conditions, the project developed the world's first egg cell production and culture system in which the entire process from pluripotent stem cells to egg cells is performed in a culture plate, and succeeded in generating egg cells from iPS cells derived from the tail tissue of adult mice. The project also obtained healthy mice from the egg cells produced by these systems. The ability to produce egg cells in culture using this culturing method will help to unravel the mystery of egg cell formation, which will lead to the clarification of the cause of infertility and the development of treatment methods.

This research result was featured as one of the 10 greatest achievements of 2016 by the American journal *Science* ("Mouse egg cells made entirely in the lab give rise to healthy offspring").

[26] High-speed atomic force microscope: real-time imaging of biomolecules in aqueous solution at the nanometer scale is possible.

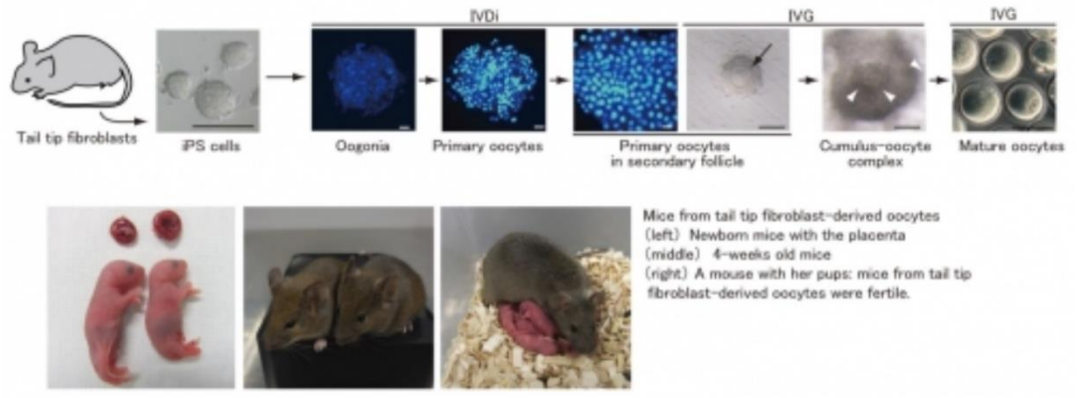


Figure A2-18. Egg cells made by the egg cell production and culture system and mice obtained by *in vitro* fertilization

[Information and Communication Technology]

Adopted for the Tsunami Inundation Forecast System, a partial function of the Cabinet Office's Comprehensive Disaster Prevention Information System

CREST "Advanced Application Technologies to Boost Big Data Utilization for Multiple-Field Scientific Discovery and Social Problem Solving" (2014-2019), Research Director: Shunichi Koshimura (Professor, Tohoku University)

The Real-time Tsunami Inundation Forecast System was put to practical use. This system predicts tsunami inundation damage in real-time immediately after a major earthquake by calculating and disseminating the propagation of tsunamis from the wave source area, their ascent to land, and damage to infrastructures and human beings based on the "forward “modeling approach. This system was adopted as the Tsunami Inundation Forecast System, a part of the Cabinet Office's Comprehensive Disaster Prevention Information System, and was put into full operation in April 2018. Based on this system, RTi-cast, a Tohoku University startup company, was established. In addition, the project received the Minister of Internal Affairs and Communications Award (2019) for the 1st Japan Open Innovation Prize.

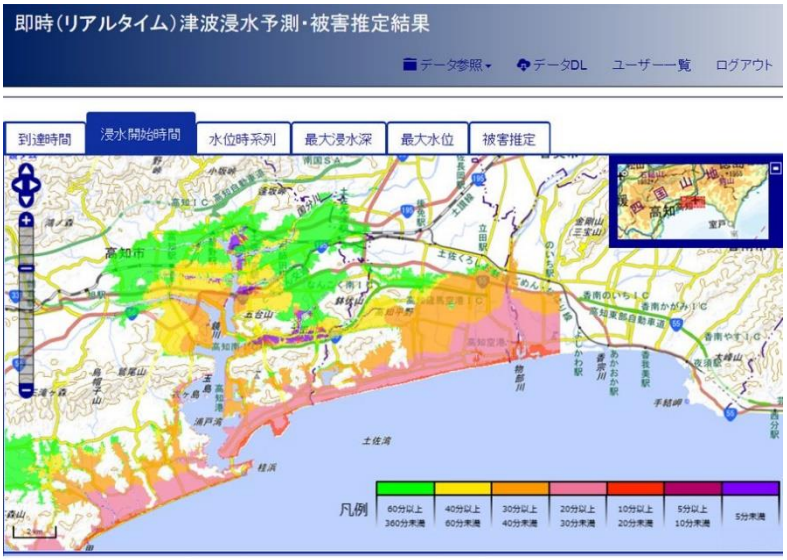


Figure A2-19. Output of the real-time tsunami damage forecast system (e.g., inundation start time)

Weather forecast updated every 10 minutes

CREST "Advanced Application Technologies to Boost Big Data Utilization for Multiple-Field Scientific Discovery and Social Problem Solving" (2013-2018), Research Director: Takemasa Miyoshi (Team Leader, RIKEN)

The project succeeded in directly using the infrared radiance data of the cloud area observed by Himawari 8 for numerical weather forecasting, and developed a weather forecasting method ("3D Nowcasting Method"), which updates the data every 10 minutes. This method is expected to lead to a significant reduction in the risk of disasters by floods and heavy rains, and to the realization of smart operations that can improve the productivity of hydroelectric power plants.

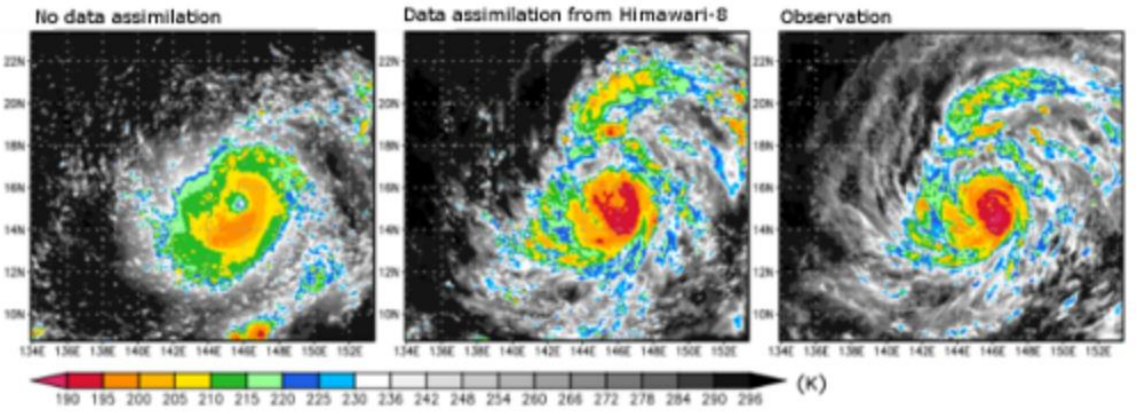


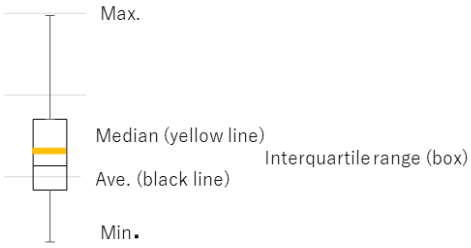
Figure A2-20. Image of data assimilation technology of Himawari-8's all-weather infrared radiance data, which is updated every 10 minutes

2 2 Research Results in Terms of Research Papers, etc. (Research Trends in Japan and Abroad, Influential Researchers, etc.)

2.2.1 Research Trends in Japan and Abroad

We compared the Strategic Basic Research Programs (19 research areas/projects of CREST, PRESTO and ERATO in the fields of Green Innovation and Nanotechnology/Life Innovation/ICT, see Table AN2-1 and 2 in Note)[27] with the Grant-in-Aid for Scientific Research (Grant-in-Aid for Scientific Research on Innovative Areas (Research in a Proposed Research Area), Grant-in-Aid for Young Scientists(A), Grant-in-Aid for Scientific Research(S)/(A)/(B) and Grant-in-Aid for Specially Promoted Research, MEXT, with similar grants in similar fields and at similar scale at the same period; hereinafter collectively referred to as "KAKENHI")[28][29].

The legend of the box-and-whisker diagram is as follows.



In terms of the comparison of the number of papers per researcher during the research period, the values of CREST and ERATO were higher than that of KAKENHI.

[27] Considering the time lag between publication and citation of research results, research areas/projects that completed their research period in 2017 or earlier were included in the survey and analysis.

[28] July 2019 Survey.

[29] JST analysis based on data from Web of Science

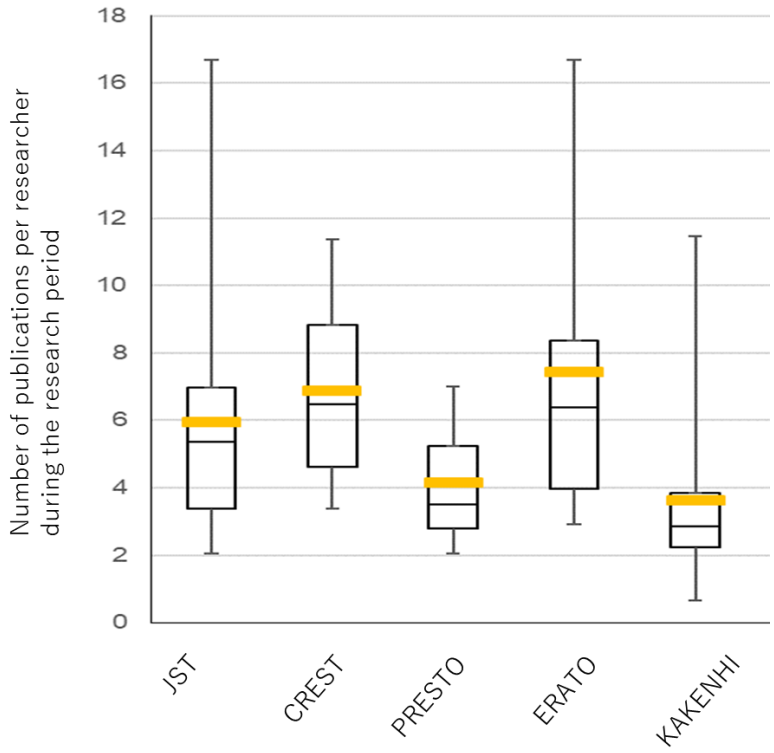


Figure A2-21. Number of papers per researcher during the research period

The number of the top 10% literature per researcher during the period is generally high for CREST, PRESTO, and ERATO. The high value of the box section of the box-and-whisker diagram indicates that the number is high in all research areas, regardless of the specific research area. Here, the top 10% are calculated within the same type, year of publication and research field, so the influence of the type of literature, the field, and the number of citations due to years passed is eliminated.

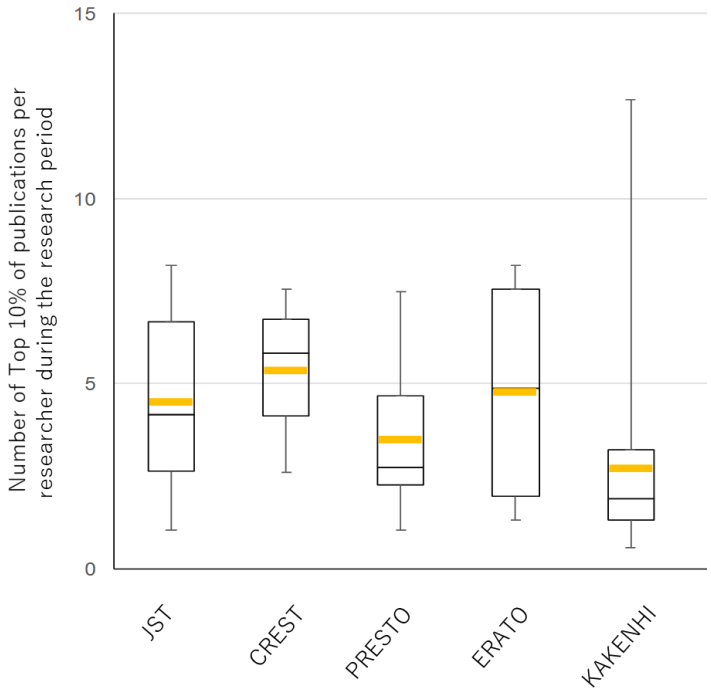


Figure A2-22. Number of top 10% literature per researcher during the period

We also compared Strategic Basic Research Programs (19 research areas/projects of CREST, PRESTO and ERATO with universities and research institutes in Japan and abroad (see Table AN2-1 and 2 in Note)[30] in terms of the average FWCI[31] per researcher (research representative) and the percentage of top 10% papers.[32]

[30] https://www.ruconsortium.jp/site/tf/248.html (period of publication of articles covered: 2011-2015, as of February 1, 2017) and JST analysis based on Scopus data (as of November 2019)

[31] Field Weighted Citation Impact (FWCI): A measure of the number of citations in a given article divided by the global average of the number of citations in the same year of publication, in the same field, and in the same type of literature. The FWCI is a measure of the number of citations compared to similar publications. A paper with an FWCI value greater than 1 means that it is cited more than the average.

[32] December 2019 Survey.

- Comparison with CREST and PRESTO

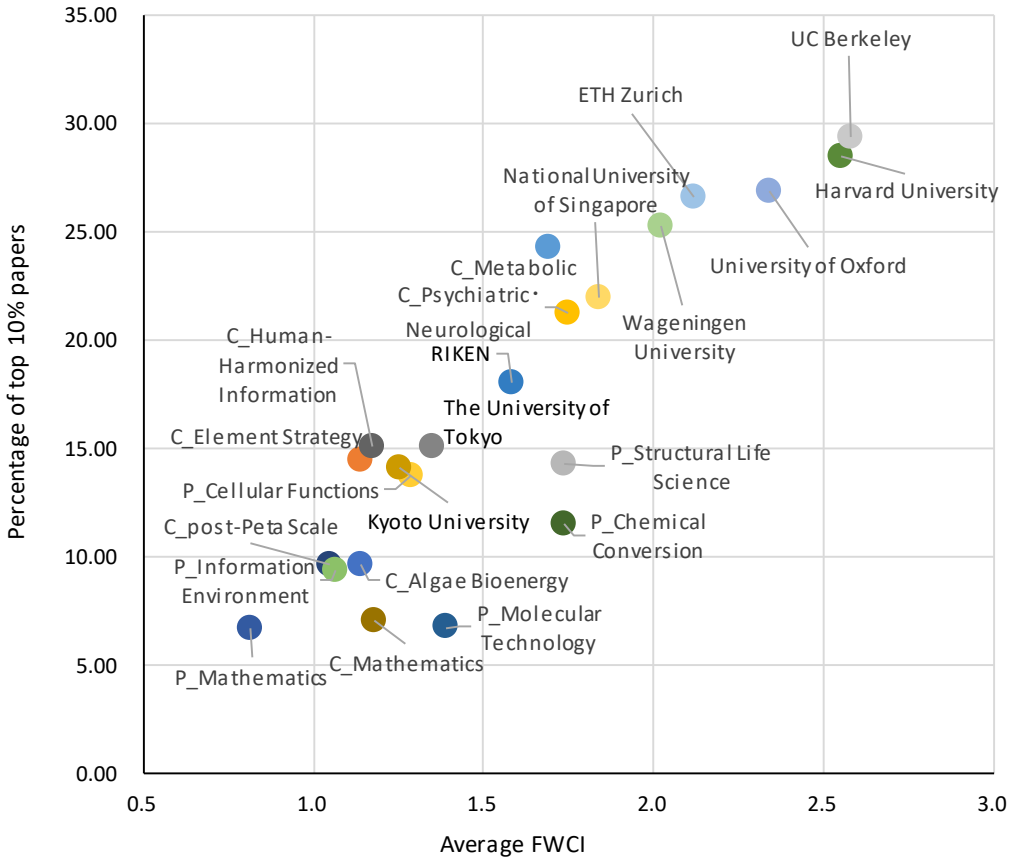


Figure A2-23. Average FWCI per researcher (research representative) and the percentage of top10% papers in the SBRPs (CREST and PRESTO) and universities and research institutes in Japan and abroad (C in the data label is CREST, P for PRESTO)

In CREST, the average FWCI and the percentage of the top 10 % papers were similar to or higher than those of the University of Tokyo and Kyoto University in many fields. In PRESTO, the average FWCI was relatively high in some research areas.

On the other hand, universities and research institutions abroad have a higher average FWCI and a higher percentage of the top 10% papers.

It should be noted that the characteristics and impact of individual research field should be taken into consideration, as some fields such as ICT tend not to be actively involved in publishing papers.

- Comparison with ERATO

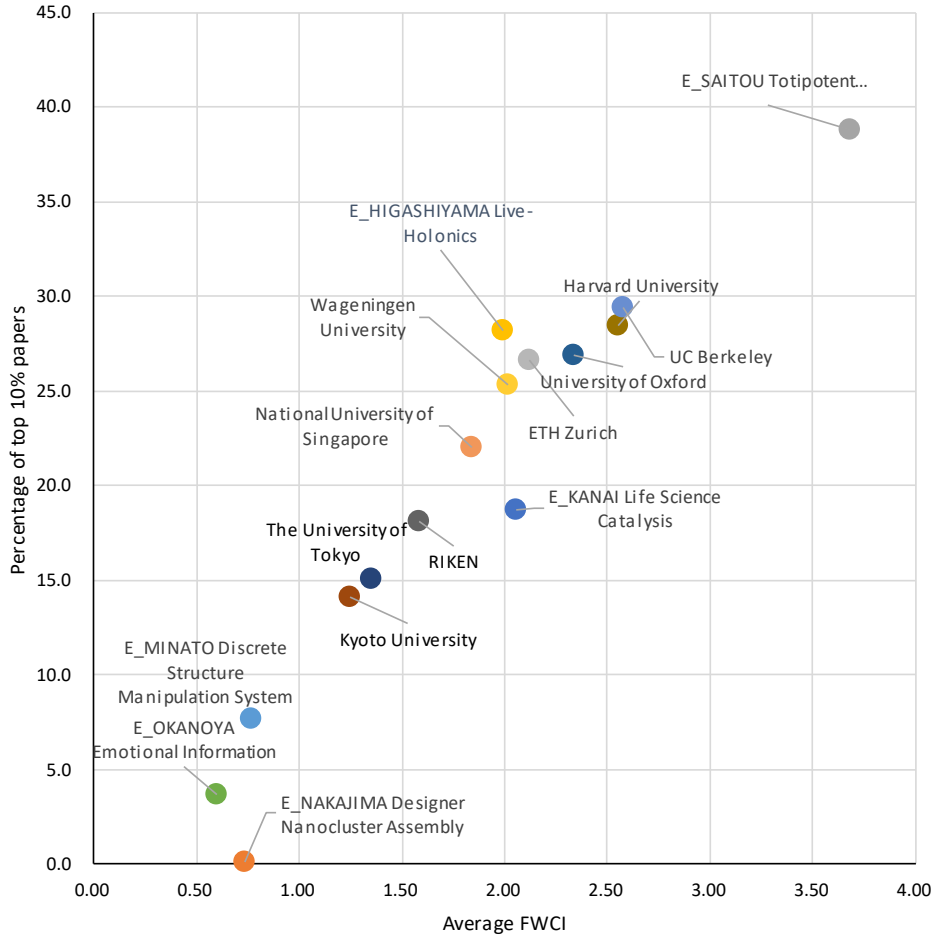


Figure A2-24. Average FWCI per researcher (research representative) and the percentage of top10% papers in the SBRPs (ERATO) and universities and research institutes in Japan and abroad (E in the data label is ERATO)

In ERATO, the average FWCI and the percentage of the top 10% papers were higher than those of universities and research institutes in Japan. In addition, when compared with universities and research institutes, these figures are almost the same or even higher in some projects.

2.2.2 Examples of Influential Researchers in Scientific and Technological Impacts

A few examples of scientific and technological impacts from metrics related to the papers are as follows.[33]

Development of "optical lattice clocks"

Hidetoshi Katori (Professor, the University of Tokyo and Chief Scientist, RIKEN), continuously produced unique, advanced research results regarding optical lattice clocks in the PRESTO, CREST and ERATO projects. He created a new scientific field of "optical lattice clocks" and contributed to improving the accuracy of precision measurement. Since the publication of the paper titled "An optical lattice clock" (Takamoto, M., Hong, F.-L. Higashi, R., Katori, H.) in *Nature* (2005, 435, 321-324), an increase in the number of papers including the keyword “optical lattice clocks) suggests the new scientific field has been created and established.

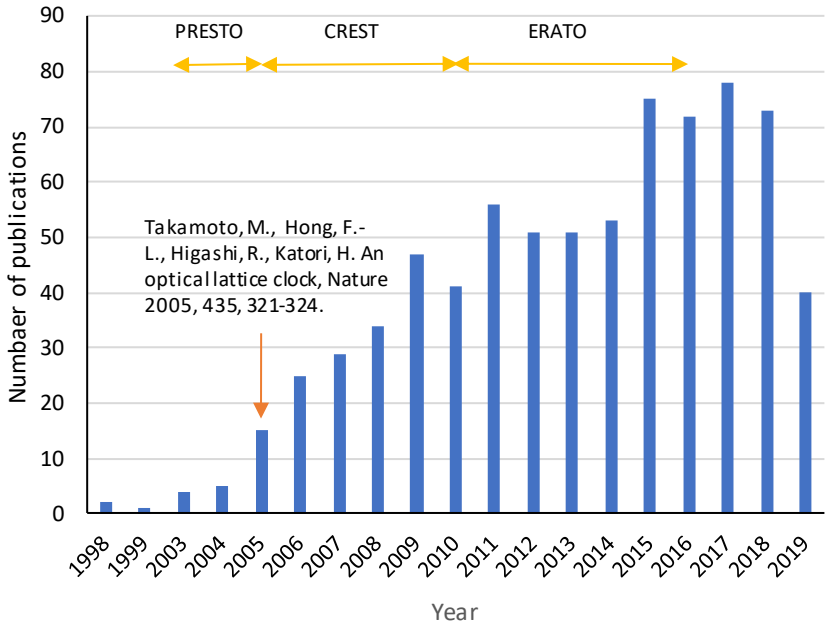


Figure A2-25. Change over time in the number of papers including "optical lattice clocks”

A novel fusion gene, EML4-ALK, which causes lung cancer

Hiroyuki Mano (Director, National Cancer Center Research Institute) discovered a novel fusion gene (EML4-ALK) that is a cause of lung cancer and published a paper titled "Identification of the transforming EML4-ALK fusion gene in non-small-cell lung cancer" in *Nature* (2207, 448, 561-U3). The change over time in the number of citations is shown below. The total number of citations

[33] July 2020 survey

is 3135, which is 0.01 as top%.

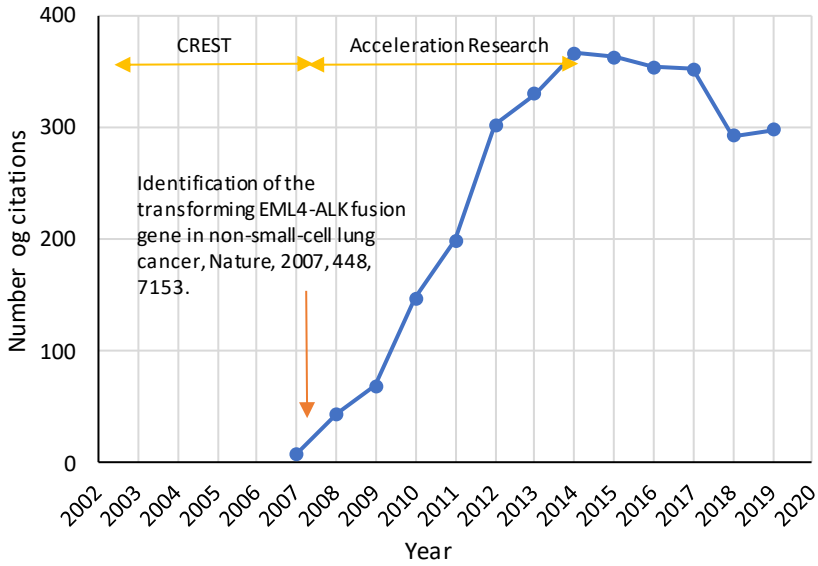


Figure A2-26. Change over time in the number of citations of the paper "Identification of the transforming EML4-ALK fusion gene in non-small-cell lung cancer" (*Nature*, 2207, 448, 561-U3)

Transcription factor Nrf2 in detoxification and antioxidant

Masayuki Yamamoto (Professor, Tohoku University Graduate School of Medicine) identified the involvement of the transcription factor Nrf2 in detoxification and antioxidation, and he was the first to discover a regulatory protein of Nrf2 (Keap1). Since then, the number of papers with the keyword "transcription factor Nrf" has increased, suggesting that the research field of biological responses to environmental stress has developed.

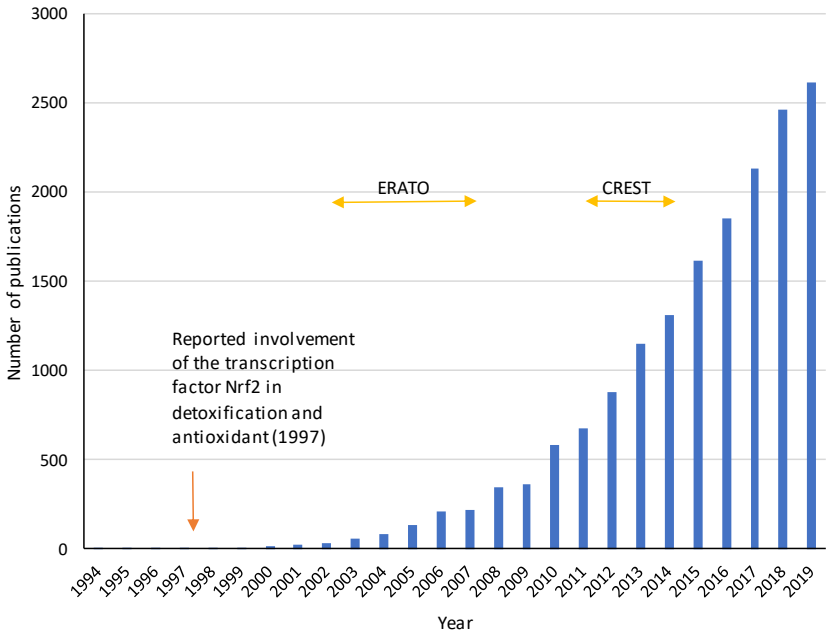


Figure A2-27. Change over time in the number of papers with the keyword "transcription factor Nrf2

Note

Table AN 2-1. 19 Research Areas/Projects of SBRPs

Program	Field	Research area	Project period	
			Start year	End year
CREST	Green Innovation, Nanotechnology	Creation of Basic Technology for Improved Bioenergy Production through Functional Analysis and Regulation of Algae and Other Aquatic Microorganisms	2010	2017
	Green Innovation, Nanotechnology	Creation of Innovative Functions of Intelligent Materials on the Basis of Element Strategy	2010	2017
	Life Innovation	Creation of a new technology towards diagnosis and treatment based on understanding of molecular pathogenesis of psychiatric and neurological disorders	2007	2014
	Life Innovation	Basic Technologies for Controlling Cell Functions Based on Metabolic Regulation Mechanism Analysis	2005	2012
	Information and Communication Technology, Mathematical and Computer Sciences	System Software for Post Petascale Data Intensive Science	2010	2017
	Information and Communication Technology, Mathematical and Computer Sciences	Creation of Human-Harmonized Information Technology for Convivial Society	2009	2016
	Information and Communication Technology, Mathematical and Computer Sciences	Alliance for Breakthrough between Mathematics and Sciences (ABMS)	2007	2015
PRESTO	Green Innovation, Nanotechnology	Molecular Technology and Creation of New Functions	2012	2017
	Green Innovation, Nanotechnology	Chemical Conversion of Light Energy	2009	2016
	Life Innovation	Structural Life Science and Advanced Core Technologies for Innovative Life Science Research	2012	2017
	Life Innovation	Design and Control of Cellular Functions	2011	2017

Program	Field	Research area	Project period	
			Start year	End year
	Information and Communication Technology, Mathematical and Computer Sciences	Information Environment and Humans	2009	2016
	Information and Communication Technology, Mathematical and Computer Sciences	Alliance for Breakthrough between Mathematics and Sciences (ABMS)	2007	2012
ERATO	Green Innovation, Nanotechnology	KANAI Life Science Catalysis	2011	2017
	Green Innovation, Nanotechnology	NAKAJIMA Designer Nanocluster Assembly	2009	2015
	Life Innovation	SAITOU Totipotent Epigenome	2011	2017
	Life Innovation	HIGASHIYAMA Live-Holonics	2010	2016
	Information and Communication Technology, Mathematical and Computer Sciences	MINATO Discrete Structure Manipulation System	2009	2015
	Information and Communication Technology, Mathematical and Computer Sciences	OKANOYA Emotional Information	2008	2014

Table AN2-2. Universities and research institutions in Japan and abroad

The University of Tokyo

Kyoto University

RIKEN

Harvard University

University of Oxford

University of California at Berkeley

National University of Singapore

ETH Zurich

Wageningen University and Research Center

2.3 Impacts of the Project (Results for Creation of Science, Technology and Innovation (STI), Researchers Produced by the Project, etc.)

Researchers who are contributing to STI are selected from among the researchers (research representatives) of the Strategic Basic Research Programs through research area evaluation, results from development survey, follow-up survey, and ad-hoc impacts, and their specific scientific and technological, social, and economic impacts were also evaluated. We conducted interviews with researchers and a database search of literature and patents.

2.3.1 Scientific and Technological Impacts

Development of innovative methods for ammonia production and related reactions by using transition metal catalysts

CREST "Creation of Innovative Core Technology for Manufacture and Use of Energy Carriers from Renewable Energy" (2015-2020), Research Director: Yoshiaki Nishibayashi (Professor, The University of Tokyo)

The synthesis of ammonia, a raw material for fertilizer and other products, consumes several percent or more of the energy consumed by human beings on earth, and it also generates a large amount of CO_2. In particular, the energy consumed in the production of hydrogen gas from fossil fuels accounts for 80% of the total energy for producing ammonia, and there is a need to convert to a hydrogen source that can replace hydrogen gas.

In this project, a synthesis method has been developed to synthesize ammonia by simply mixing nitrogen gas as a nitrogen source and water as a hydrogen source in a flask with a catalyst under normal temperature and pressure reaction conditions.

The results of this research have been featured in TV news programs, more than 10 newspapers including several national newspapers, and *Nature*. As a new synthesis method that will bring about a breakthrough in a process that has been used for more than 100 years (Haber-Bosch process), it is expected to make a significant contribution to solving environmental and energy problems and has the potential to cause a paradigm shift in energy resources.

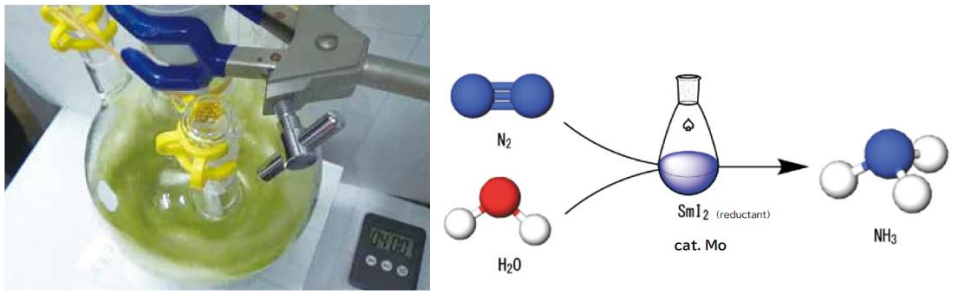


Figure A2-28. Synthesis of ammonia by mixing nitrogen and water in a flask with a catalyst containing

molybdenum and a reductant (samarium iodide) (Left: photo of the reaction, right: schematic diagram of the reaction equation)

Development of optical lattice clocks that change the concept of a clock

PRESTO “Light and Control” Research Area (2002-2005); CREST "Creation of New Technology Aiming for the Realization of Quantum Information Processing Systems" (2005-2010), ERATO "KATORI Innovative Space-Time" Project (2010-2016), Researcher/Research Director: Hidetoshi Katori (Professor, the University of Tokyo and Chief Scientist, RIKEN)

The projects created a new scientific field of "optical lattice clocks" and contributed to improving the accuracy of precision measurements as the next generation frequency standard. The current clock accuracy of the second is about 10-15-digit precision (uncertainty of one second for 30 million years), which is shared by all over the world. By comparison of two optical lattice locks working at low temperature, 18-digit precision (making an error less than one second after 13.8 billion years) was achieved during the ERATO project, and relativistic geodetic measurements were made with an accuracy of a few centimeters in height difference. The research has been adopted by the JST (JST) Mirai Program (Large-scale type) since 2018, and further development has been achieved. It is expected to make a significant contribution to the “Redefinition of the Second,” which is scheduled to take place in 2026.

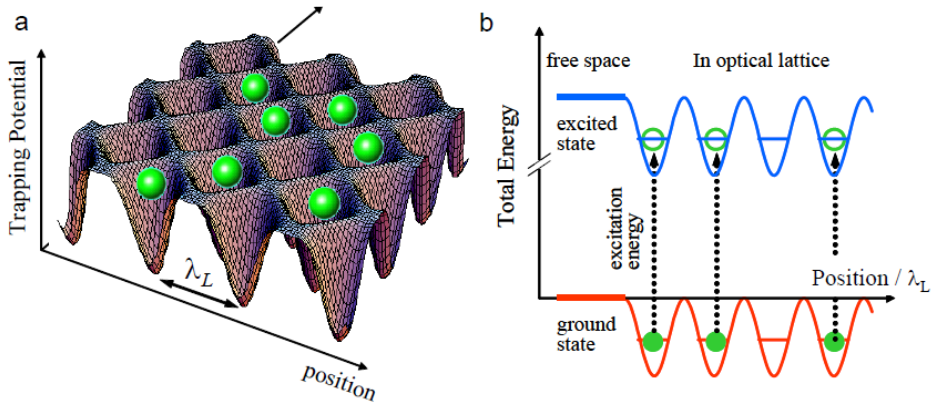


Figure A2-29. Conceptual diagram of the optical lattice clock

Development of operating systems for embedded systems that can be used in a wide range of applications and basic technology for building dependable information systems as a whole area

CREST "Dependable Operating Systems for Embedded Systems Aiming at Practical Applications" (2006-2013), Research Supervisor: Mario Tokoro

In 2013, the Dependability Engineering Society (DEOS Association) was established to promote international standardization as part of the activities to contribute to improving the dependability of the world's systems through the widespread use of the research results developed in the project.

In 2018, The IEC 62853 OSD (Open systems dependability[34]) was established. An example of its application to actual systems is small satellites, which are one of the most complex systems, and it is expected to be an effective approach to “issues difficult to solve,” such as improving satellite reliability.

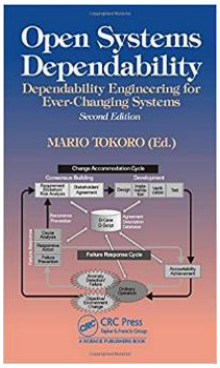


Figure A2-30. A book describing how to achieve reliability in information systems, an outcome of the DEOS project (published in 2015 by CRC Press)

2.3.2 Social and Economic Impacts

[Nanotechnology & Materials]

Development of TMR elements

PRESTO "Nanostructure and Material Property" (2002-2006), Researcher: Shinji Yuasa (Director, Spintronics Research Center, AIST)

The project worked on elucidating the mechanism of the magnetoresistive effect of tunnel magnetoresistance (TMR) elements and increasing their output power, which led to higher accuracy of TMR elements in HDD heads and magnetic sensors and higher integration of MRAMs. This technology was put to practical use in 2007, and in 2017 In FY2019, TMR elements have a 100% share of the global HDD magnetic head market.

[34] Open Systems Dependability: the ability of a computer system to cope with the problems that arise from providing services over a long period of time (various changes in user expectations, environment, unknown obstacles that constantly arise).

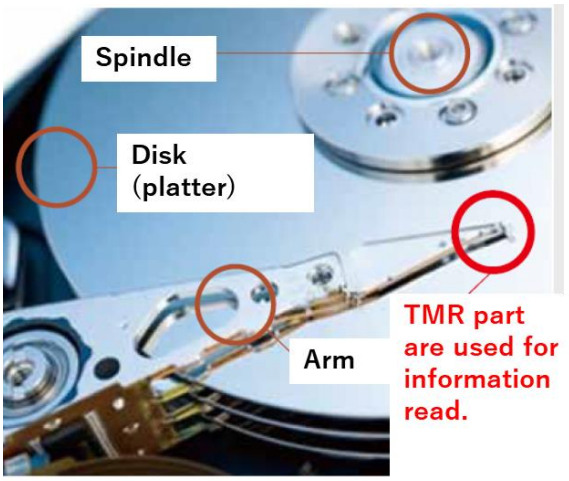


Figure A2-31. Internal structure of a hard disk

Development of transparent oxide semiconductors (IGZO)

ERATO "HOSONO Transparent Electro Active Materials" Project, Research Director: Hideo Hosono (Professor Emeritus, Tokyo Institute of Technology) (1999-2004)

Using transparent oxide semiconductors, the project developed transparent field effect transistors (transparent FETs) with properties comparable to those of poly-Si, which are used as thin film transistors (TFTs). The amorphous In-Ga-Zn-O material system (IGZO) we developed has been commercialized as liquid crystal panels and organic light emitting diode (OLED) panels by domestic and overseas panel manufacturers.

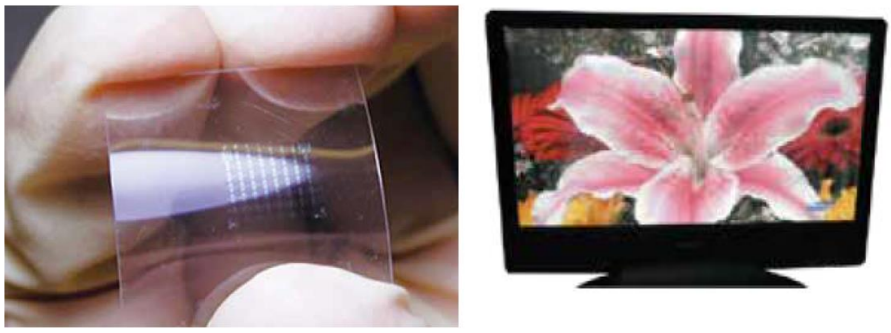


Figure A2-32. Transparent oxide semiconductor IGZO-TFT

[Green Innovation]

Development of real-time OS technology for low energy multi/many-core system

CREST "Technology Innovation and Integration for Information Systems with Ultra Low Power" (2005-2010), Research Director: Hiroaki Takada (Professor, Nagoya University)

In 2015, APTJ Corporation, a startup company to develop a software platform for in-vehicle

control (SPF, in the broadest sense of the word, an operating system) based on the AUTOSAR in-vehicle software standard specification, was established. In 2018, the company officially launched an AUTOSAR-compliant SPF. By the end of 2020, more than one million vehicles equipped with electronic control units (ECUs) using SPF are expected to be available on the market.

There have been concerns that the oligopoly of SPF by overseas companies would lead to a decline in the international competitiveness of the domestic auto industry and a contraction of the in-vehicle embedded software industry, but the development and release of a domestic SPF is expected to halt the contraction of the industry. It is also designed to improve memory efficiency and processing speed. This technology was highly evaluated by external experts at the research area evaluation and has contributed to the competitiveness of the entire auto industry.

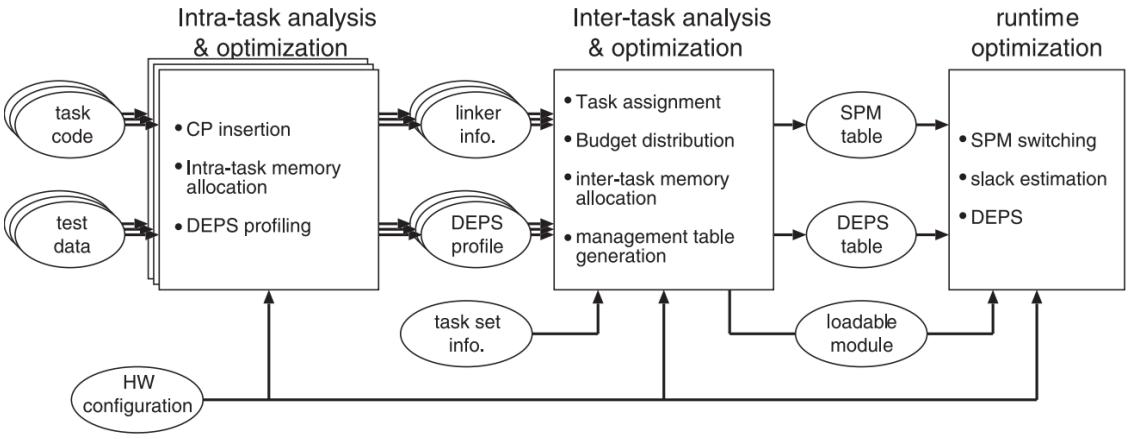


Figure A2-33. Overview of ULP software development environment

Development and commercialization of biodegradable plastics

CREST "Social Systems for Better Environment Performance" (1995-2000), Solution Oriented Research for Science and Technology (SORST) (2000-2004), Risk-taking Fund for Technology Development (2008-2013), Research Director: Yoshiharu Doi (President, Japan Synchrotron Radiation Research Institute)

Based on the basic technology to produce bioplastics from vegetable oil and other materials with high efficiency (80 wt%) using genetically modified microorganisms, the projects have developed a process to produce polyester with excellent tensile strength and suitable for stretch processing.

In 2019, in collaboration with Kaneka Corporation, the projects worked to commercialize the process and established a production system for 1,000 t of biodegradable plastic per year, and in fiscal 2019, Kaneka PHBH® biodegradable polymer became available for use in all food contact applications in the EU and PHBH straws were introduced in approximately 10,000 convenience stores in Japan. Future global development of this technology is greatly expected.

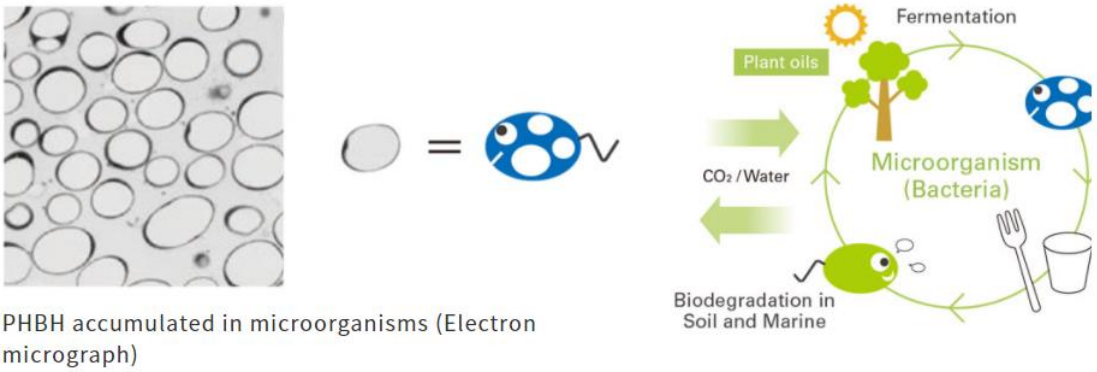


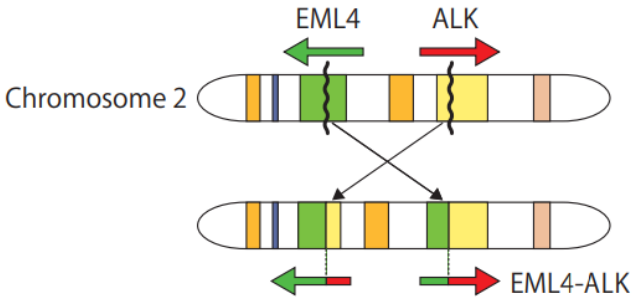
Figure A2-34. Characteristics and life cycle of plastics PHBH[35]

[Life Innovation]

Discovery of fusion oncogenes and development of cancer diagnostics and therapeutics

CREST "Basic Technology to Establishing Tailor-Made Medicine by Utilizing Genome Information", "Personalized Diagnosis of Diseases through Comprehensive Analysis of Gene Expression Regulation" (2002-2007) and the Accelerated Research Project "Identification of New Oncogenes" Project (2008-2014), Research Director: Hiroyuki Mano (Director, National Cancer Center Research Institute)

The project discovered a novel fusion oncogene, EML4-ALK, which causes lung cancer. Noticing this, Pfizer enrolled new patients with ALK-positive lung cancer in a clinical trial for the anticancer drug Crizotinib, which was under development, and launched the drug in the U.S. in 2011, just four years after the announcement of the discovery. Global sales of the drug in FY2017 were $594 million. This research has led to the launch of several next-generation ALK inhibitors. Of these, Alectinib, which was launched in 2014, is estimated to have peak sales of $1751 million (2024). In addition, anticancer drugs targeting the ROS1 and RET fusion oncogenes have been approved or are in development. The project's research results have generated one of the major trends in anticancer drug targeting, namely fusion oncogenes.



[35] https://www.kaneka.co.jp/en/esg/feature/case1/

Figure A2-35. EML4-ALK fusion oncogene

The mechanism of action of the Keap1-Nrf2 system and the development of Nrf2 activators and other drugs.

ERATO "YAMAMOTO Environmental Response" Project (2002-2007) and CREST "Protective mechanisms against environmental stresses leading to therapeutic strategies for chronic inflammation" (2011-2014), which was transferred to AMED from 2015, under CREST "Creation of Basic Medical Technologies to Clarify and Control the Mechanisms Underlying Chronic Inflammation", Research Director: Masayuki Yamamoto (Professor, Tohoku University)

The project identified the involvement of the transcription factor Nrf2 in detoxification and antioxidation, and was the first to discover a regulatory protein of Nrf2 (Keap1). In addition, it proposed a new theory that the Keap1-Nrf2 system plays a central role in the oxidative stress response and created a new frontier in the research field of biological responses to environmental stress. Nrf2 activators have received a lot of attention in terms of drug discovery, and dimethyl fumarate, developed by Biogen Idec Inc. in the US, was launched in 2013 as a first-line oral treatment for patients with relapsing-remitting multiple sclerosis. The sales of Dimethyl fumarate (brand name: Tecfidera) were $4214 million in 2017. In addition, bardoxolone methyl, an Nrf2-activating compound studied during ERATO project, is currently undergoing Phase 3 trials by Kyowa Kirin Co., Ltd. and others for the treatment of diabetic kidney disease. Once the drug is launched, the peak sales in 2024 will be $781 million.

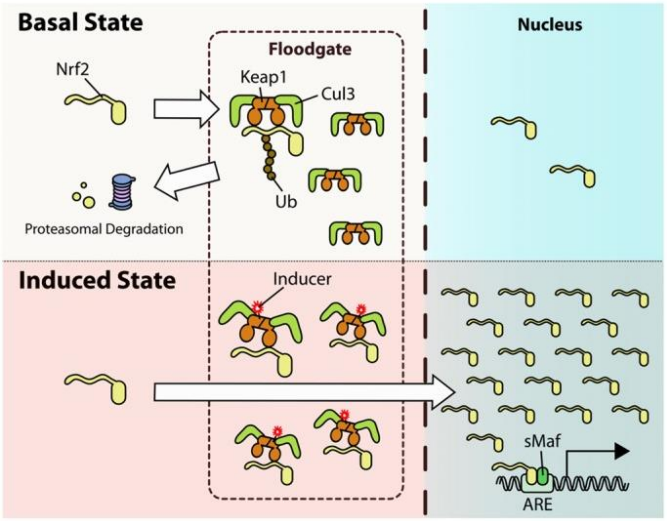


Figure A2-36. Regulation of the Nrf2-Keap1-Cul3 complex in stress response

Discovery of orexin, a neurotransmitter that controls sleep arousal, and launch of suboxanthine

ERATO "YANAGISAWA Orphan Receptor" Project (2001-2006) and Integrated Analysis of Sleep

Function and Control Mechanism Using Light" Research Project under the CREST "Development and application of optical technology for spatiotemporal control of biological functions" (2016-2021), Research Director: Masashi Yanagisawa (Director, the International Research Institute for Integrative Sleep Sciences, Professor, University of Tsukuba)

The project discovered orexin, a ligand for G protein-coupled receptors (GPCRs), and analyzed its function, revealing for the first time that orexin is deeply involved in central inhibition of sleep and wakefulness as well as feeding. These findings revealed that orexin is deeply involved in both feeding and central inhibition of sleep and wakefulness, and led to the creation of a new treatment for insomnia. The first drug to be launched for this mechanism of action, suvorexant, was developed by Merck and launched in 2014. Its peak sales will be $675 million (in 2024). At the same time, Yanagisawa and his colleagues are also conducting research and development on the orexin receptor (agonists), which have the potential to treat hypersomnia. Yanagisawa is the director of the International Research Institute for Integrative Sleep Sciences at the University of Tsukuba, which was selected by the World Premier International Research Institute (WPI) of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 2013. He advocates a world-class research center for sleep medicine, from basic research to clinical research, with the aim of clarifying the mechanisms of sleep/wakefulness research.

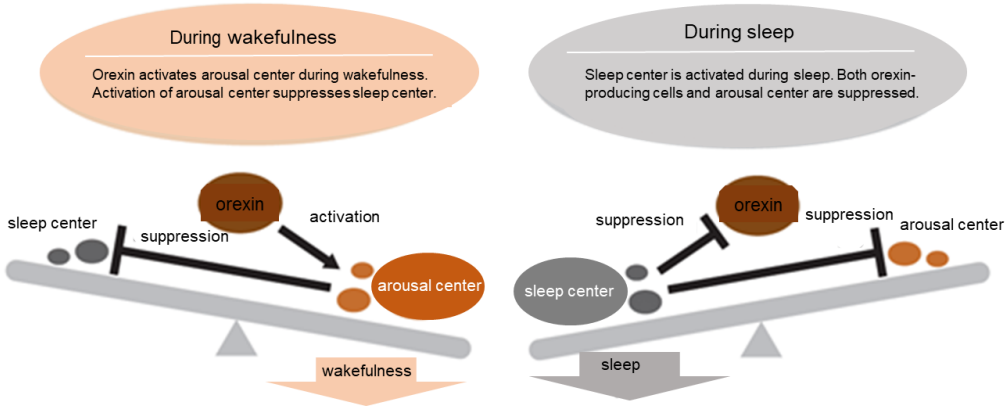


Figure A2-37. Switching between wakefulness and sleep and the function of orexin

[Information and Communication Technology]

Development of a telexistence system that conveys a sense of touch

CREST "Creation of Human-Harmonized Information Technology for Convivial Society" (2009-2014) and ACCEL "Embodied Media Technology based on Haptic Primary Colors" (2014-2019), Research Director: Susumu Tachi (Professor Emeritus, The University of Tokyo, Program Manager: Junji Nomura (JST))

The project developed the telexistence system TELESAR V, an avatar robot that integrates virtual reality and robotics technologies to promote pioneering research into the realization of the concept of telexistence (invented in 1980), which aims to enable humans to act freely in locations different from their current location. By transmitting the robot's contact sensor information as "haptic primary colors," Tachi was the first to demonstrate that fine tactile sensations such as the sensation of grasping an object, hot and cold, and the touch of cloth can be transmitted to the operator as if they were his/her own. He launched a startup company, TELEXISTENCE Inc., which was later founded by JST under the Support Program of Capital Contribution to Early-Stage Companies (SUCCESS) in 2017. The system continues to evolve, and recently the latency between the robot's camera and the operator's display, which can be a problem when operating the system remotely, has been reduced. As a result, the system is expected to reduce VR sickness of the operator and enable him/her to operate the robot remotely for a longer period of time, and also to facilitate accurate control of fast-moving objects.

The XPRIZE Foundation, a US non-profit organization, asked Tachi to demonstrate the world's most advanced avatar, TELESAR V, at the Visioneers Summit in October 2016, and he made a presentation at the Summit. In addition, ANA AVATAR XPRIZE, proposed by the ANA team, has been selected as the next theme of XPRIZE, an incentivized prize competition that is intended to encourage technological development to benefit humanity.

In the summer of 2020, TELEXISTENCE, in collaboration with two major convenience store operators, has announced the introduction of a remote-controlled humanoid robot to display products on shelves in convenience stores.

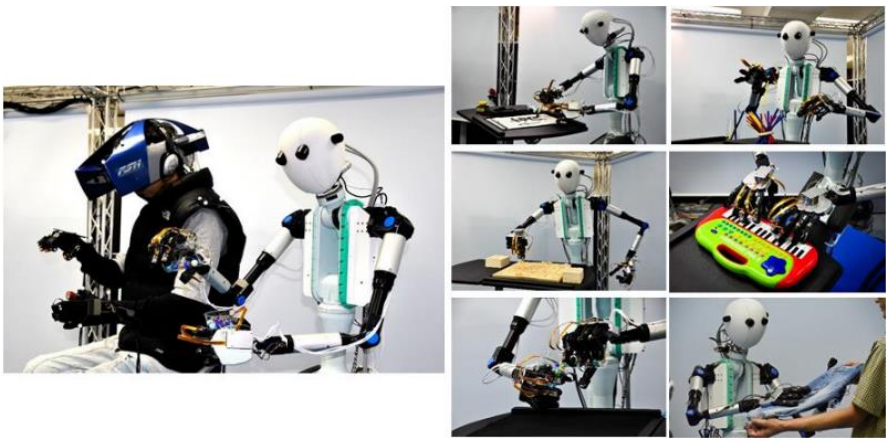


Figure A2-38. The altered body robot – telexistence system TELESAR V

Development and sales of a muscle suit to support human behavior

PRESTO "Interaction and Intelligence" (2000-2005), Researcher: Hiroshi Kobayashi (Professor, Tokyo University of Science)

Kobayashi proposed the concept of muscle suit in the PRESTO project in 2013, and he established the Tokyo University of Science venture Innoffis, Inc. and the following year launched a muscle suit for waist support. In 2019, the company began selling the "Muscle Suit Every", which succeeded in reducing costs and mass production by changing the material of the suit. The price is less than one-third that of existing models (in the 100,000-200,000 JPY range), and the company aired TV commercials at the same time as the product launch.

In 2020, the Muscle Suit Every acquired ISO13482[36] certification, and the total number of units sold exceeded 10,000.

There is great promise for solving social issues, from manual labor to home care and support for working sites.

Figure A2-39. Muscle suit Every

[Other: COVID-19]

Development of a water monitoring system with rapid, accurate and comprehensive detection of pathogenic microorganisms

CREST "Innovative Technologies and Systems for Sustainable Water Use" (2011-2016), Research Director: Tatsuo Omura (Professor, Tohoku University)

The project developed a comprehensive identification and absolute quantification technique for pathogenic microorganisms and showed that a sewage monitoring system might detect an outbreak of infectious gastroenteritis earlier than the current monitoring system based on reports from medical institutions. In addition, a comparison with genotypes detected in patients with a community outbreak of infectious gastroenteritis showed that the sewage contained the same strains and genotypes as the patients, which changed over time. In addition to the quantitative information of virus concentration in the sewage, qualitative information of strains and genotypes was obtained, suggesting that this information may be useful in understanding the prevalence of infectious gastroenteritis outbreaks in the water treatment area.

[36] The only international standard for the safety of personal assistive robots

This method has been used for the early detection of a novel coronavirus infection, which has recently become a problem, under the leadership of the COVID-19 Task Force of the Japan Society for Water Environment, and has been reported by the media as contributing to the monitoring of the spread of COVID-19 in the event of a secondary or tertiary infection. It has been widely covered and has aroused great public interest and expectations.

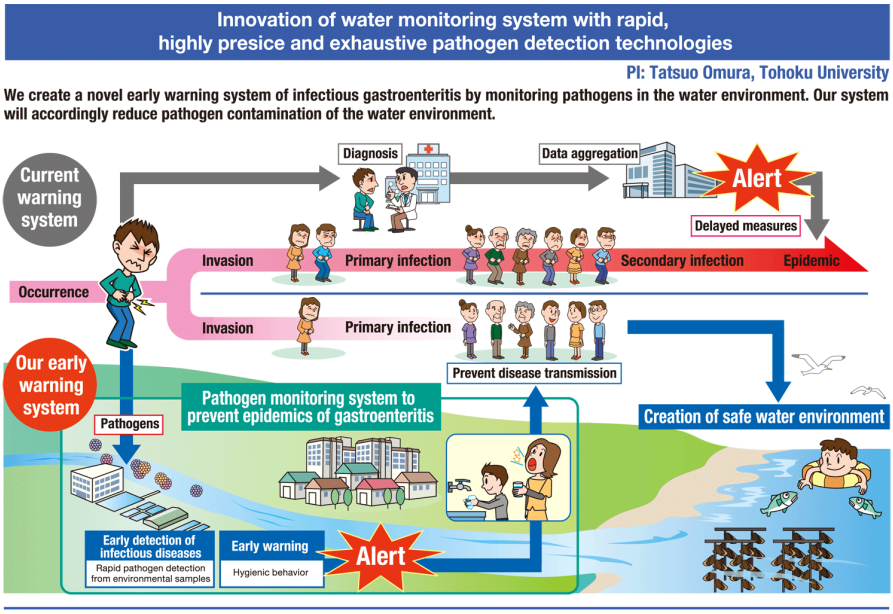


Figure A2-40. Infectious disease monitoring system

Prediction of infectious diseases using mathematical models

CREST "Advanced Application Technologies to Boost Big Data Utilization for Multiple-Field Scientific Discovery and Social Problem Solving" (2014-2019), Research Supervisor: Hiroshi Nishiura (Professor, Hokkaido University)

The project has adopted a mathematical model of infectious diseases that uses mathematical equations to describe the process from infection to disease onset and severity of illness for detection of signs and real-time forecasting of the pandemic. It also assimilated epidemiological data and genetic data using real-time epidemic status and machine learning methods to predict the prevalence of rubella, measles, Ebola hemorrhagic fever, Zika fever, and the Middle East Respiratory Syndrome (MERS). This mathematical model of infectious diseases was also applied to the recent measures against the novel coronavirus (COVID-19), and Nishiura provided various scientific data as a member of the Cluster Task Force of the Ministry of Health, Labour and Welfare (MHLW). The data was used as a reference for the government's policy of "reducing human contact by 80%".

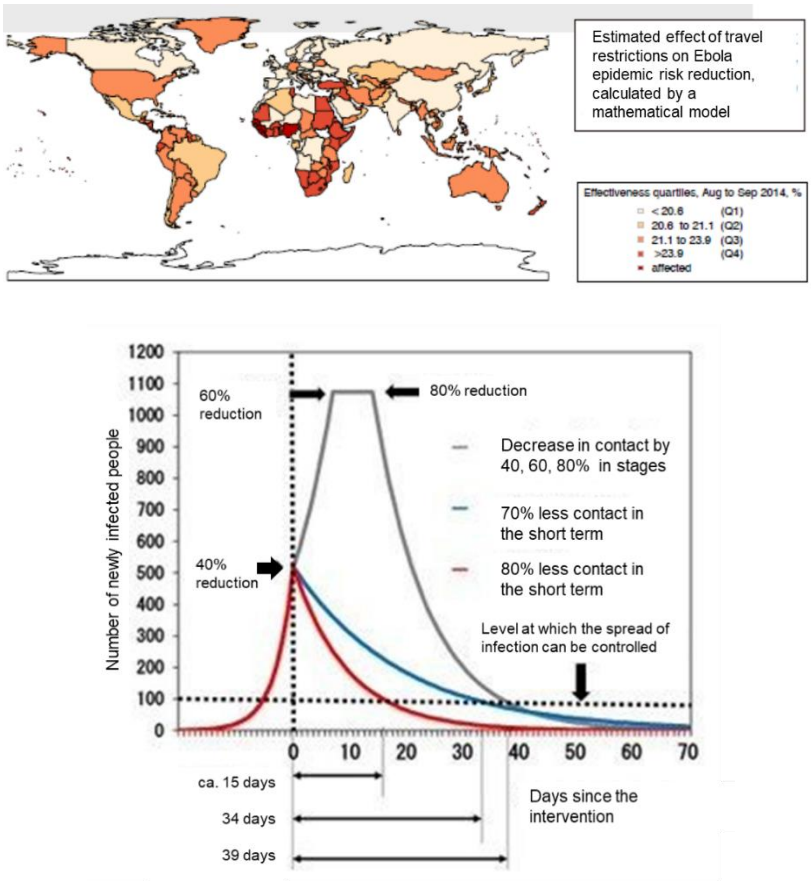


Figure A2-41. Estimated effect of travel suppression on reducing the risk of the Ebola epidemic calculated by the mathematical model (top), and graphs showing the degree of reduction in contact opportunities and the number of new infections in the COVID-19 control measures (bottom).[37]

[37] From Twitter, Ministry of Health, Labor and Welfare (Translated by JST)

2.4 Impacts of Strategic Basic Research Programs (Results from Social and Economic Perspectives, Development to Social Implementation, etc.)

The following is a summary of the development status of each program based on the results of the "research results development survey" conducted for each researcher one year after the completion of the research project.

2.4.1 Handing Over to Other Funding Programs

Table A2-1 shows the results by the program at the time of the survey (one year after the completion of the research project). In the case of ERATO, 100% of the research results were handed over to other funding sources in FY2017 and 80% in FY2018; in the case of CREST, the rate was about 80% in FY2017 and about 50% in FY2018 and FY2019. For PRESTO, about 70% in FY2017 and about 40% in FY2018 and FY2019.

Table A2-1. Expansion to other funding programs

Survey year, FY	Program name	No. of other funds acquired	No. of researchers who acquired other funds (%)	Total no. of researchers
2017	CREST	96	39 (79.6%)	49
	ERATO	20	5 (100%)	5
	PRESTO	436	170 (74.9%)	227
	subtotal	552	214 (76.2%)	281
2018	CREST	16	10 (34.5%)	29
	ERATO	9	4 (80.0%)	5
	PRESTO	53	33 (33.0%)	100
	ACT-C	46	27 people (54.0%)	50
	ACT-I	14	11 (36.7%)	30
	subtotal	138	85 (39/7%)	214
2019	CREST	25	21 (46.7%)	45
	ERATO	1	1 (50.0%)	2
	PRESTO	68	55 (44.0%)	125
	CT-C	0	0 (0%)	1
	ACT-I	8	8 (27.6%)	29
	subtotal	102	85 (42.1%)	202
Total		792	384 (55.1%)	697

About half of the total number of respondent programs were funded by JSPS, and about 20% were funded by JST, as shown in Figure A2-42.

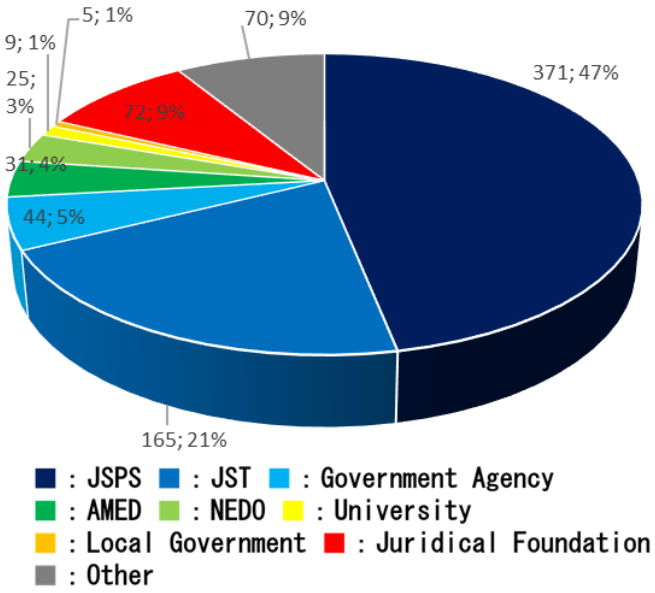


Figure A2-42. Number of responses by funding

2.4.2 Joint Research, Contract Research and Technology Transfer

Table A2-2 shows the results of the number of cases where researchers were involved in joint research and contract research with corporations by the program. Figure A2-42 shows the percentage of researchers involved in joint research and contract research.

This percentage was high at ERATO, where all five members were involved in joint or contract research in FY2017 and FY2018; at CREST and PRESTO, the percentage was around 70-85% in FY2017, but only 50% in FY2018 and 40% in FY2019.

As it often takes time for results like this one to become noticeable as an index after the project is completed, the year-by-year comparisons are included as a reference only.

Table A2-2. Development to joint research and contract research

Survey year, FY	Program name	No. of researchers involved (%)	Total no. of researchers
2017	CREST	36 (73.5%)	49
	ERATO	5 (100%)	5
	PRESTO	179 (78.9%)	227

	subtotal	251 (89.3%)	281
2018	CREST	16 (55.2%)	29
	ERATO	5 (100%)	5
	PRESTO	47 (47.0%)	100
	ACT-C	39 (78.0%)	50
	ACT-I	20 (66.7%)	30
	subtotal	178 (83.2%)	214
2019	CREST	19 (42.2%)	45
	ERATO	1 (50.0%)	2
	PRESTO	49 (39.2%)	125
	ACT-C	0 (0%)	1
	ACT-I	7 (24.1%)	29
	subtotal	76 (37.6%)	202
Total		505 (72.5%)	697

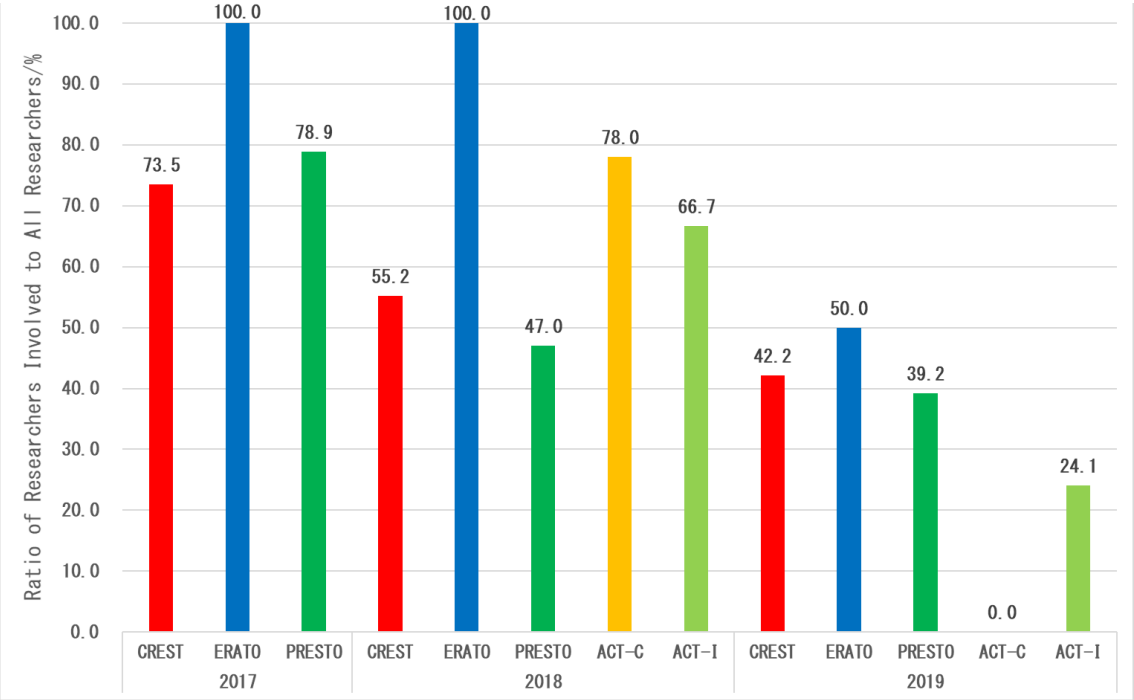


Figure A2-43. Percentage of researchers involved in joint research and contract research

Next, the number of technology transfer by the program was tabulated as shown in Table A2-3. Figure 2-44 also shows the percentage of researchers involved in technology transfer.

This percentage was also relatively high in ERATO, with all five of the researchers involved in technology transfer of research results in FY2017 and three of the five in FY2018. However, there was no technology transfer in FY2019. Compared to joint and contract research, the number of cases that led to technology transfer tended to be lower for all programs.

Table A2-3. Technology transfer

Survey year, FY	Program name	No. of researchers involved (%)	Total no. of researchers
2017	CREST	28 (57.1%)	49
	ERATO	5 (100%)	5
	PRESTO	78 (34.4%)	227
	subtotal	111 (39.5%)	281
2018	CREST	8 (27.6%)	29
	ERATO	3 (60.0%)	5
	PRESTO	19 (19.0%)	100
	ACT-C	11 (22.0%)	50
	ACT-I	6 (20.0%)	30
	subtotal	47 (22.0%)	214
2019	CREST	4 (8.9%)	45
	ERATO	0 (0%)	2.
	PRESTO	10 (8.0%)	125
	ACT-C	0 (0%)	1
	ACT-I	2 (6.9%)	29
	subtotal	16 (7.9%)	202
Total		174 (25.0%)	697

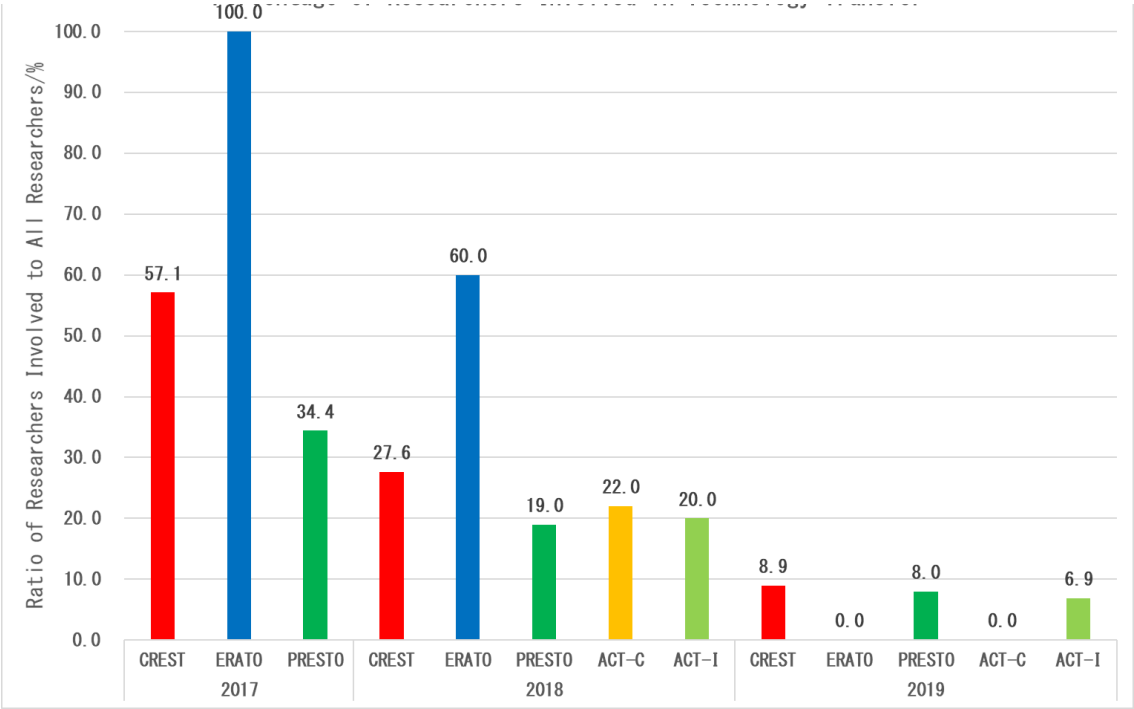


Figure A2-44. Percentage of researchers involved in technology transfer

2.4.3 Startup Business Establishment

Table A2-4 summarizes the results by the program at the time of the survey (one year after the completion of the research project). The percentage of researchers involved in the establishment of a startup company was high at ERATO, with two out of five researchers (Masaharu Takeuchi and Tetsuya Higashiyama) being involved in the establishment of a startup company in 2017 and two out of five researchers (Takao Someya and Kazunari Akiyoshi) in 2018.

Table A2-4. Involvement in the establishment of startup firms

Survey year, FY	Program name	No. of companies started	No. of researchers involved in startups (%)	Total no. of researchers
2017	CREST	8	7 (14.3%)	49
	ERATO	2	2 (40.0%)	5
	PRESTO	4	4 (1.8%)	227
	subtotal	14	13 (4.6%)	281
2018	CREST	2	2 (6.9%)	29
	ERATO	3	2 (40.0%)	5
	PRESTO	1	1 (1.0%)	100
	ACT-C	0	0 (0%)	50
	ACT-I	0	0 (0%)	30
	subtotal	6	5 (2.3%)	214

2019	CREST	2	2 (4.4%)	45
	ERATO	0	0 (40.0%)	2
	PRESTO	3	3 (2.4%)	125
	ACT-C	0	0 (0%)	1
	ACT-I	0	0 (0%)	29
	subtotal	5	5 (2.5%)	202
Total		25	23 (3.3%)	697

Table A2-5 summarizes the startup companies that the researchers were involved in establishing. Among them, Nokagaku Koryo (Brain Science Aroma) Inc., in which Takashi Kobayakawa was involved, is reported to have had sales of several tens of millions of JPY[38]. For example, Xenoma Inc., of which Takao Someya was substantially involved in the establishment, has succeeded in raising more than 200 million JPY in funding.

Table A2-5. List of startup companies

Name (Affiliation)	Name of the strategic project (research area)	Startup Company Name	Year of establishment	Relationships with the researcher(s)	Business Overview	Capital stock	No. of employees
Yasuharu Koike (Solutions Research Laboratory, Tokyo Institute of Technology,)	CREST (Creation of Human-Harmonized Information Technology for Convivial Society)	Riverfield Inc.	2014	Founder	Research, development and sale of medical equipment such as surgical support robots	100,000 thousand JPY	23
Kazuya Takeda (Graduate School of Information Sciences, Nagoya University)	CREST (Creation of Human-Harmonized Information Technology for Convivial Society)	Tier IV, Inc.	2015	President and Representative Director	Automatic driving technology consulting, workshops, public road testing, ride-sharing solutions, etc.	100,000 thousand JPY	160

[38] Nihon Keizai Shimbun, "Nokagaku Koryo (Brain Science Aroma) Inc." (October 12, 2019) https://www.nikkei.com/article/DGKKZO50913620R11C19A0LKB000/ (viewed March 17, 2020)

Name (Affiliation)	Name of the strategic project (research area)	Startup Company Name	Year of establishment	Relationships with the researcher(s)	Business Overview	Capital stock	No. of employees
2222-22 (Graduate School of Media Design, Keio University)	CREST (Creation of Human-Harmonized Information Technology for Convivial Society)	Teleiexistence Inc.	2017	Chairman	Design, manufacture and operate robots in all areas where they can be utilized.	Unknown	21
Kiyoharu Aizawa (The University of Tokyo III)	CREST (Creation of Human-Harmonized Information Technology for Convivial Society)	foo.log, Inc.	2005	Unknown	Provision, customization and development of FoodLog, and development, customization and provision of health management information systems	32,000 thousand JPY	About 15
Hiroshi Ishiguro (Social Media Research Laboratory, Advanced Telecommunications Research Institute International (ATR))	CREST (Creation of Human-Harmonized Information Technology for Convivial Society)	Telenoid Planning (current Telenoid Healthcare Company)	2015	Unknown	Provision of "Telenoid Care," a training program for nursing care facilities to develop human resources using the communication robot Telenoid™, and development of system operation applications.	32,250 thousand JPY	2
Hiroshi Ishiguro (Social Media Research Laboratory, ATR)	CREST (Creation of Human-Harmonized Information Technology for Convivial Society)	Vstone Co., Ltd.	2000	Unknown	Development, manufacturing and sales of robotics-related products Planning and implementation of robot-related events Development,	100,000 thousand JPY	Unknown

Name (Affiliation)	Name of the strategic project (research area)	Startup Company Name	Year of establishment	Relationships with the researcher(s)	Business Overview	Capital stock	No. of employees
					manufacturing and sales of omnidirectional sensor-related products Development, manufacturing and sales of sensor network products		
Shiro Ise (Department of Architecture and Architectural Engineering, Kyoto University)	CREST (Creation of Human-Harmonized Information Technology for Convivial Society)	Cask Acoustics	2016	Unknown	Unknown	1,000 thousand JPY	Unknown
Toshinori Tsuru (Graduate School of Engineering, Hiroshima University)	CREST (Innovative Technologies and Systems for Sustainable Water Use)	Established as a branch of eSEP Inc. in the incubation office of Hiroshima University.	2018	Unknown	Unknown	Unknown	Unknown
Shigeru Shigeoka (Faculty of Agriculture, Kinki University)	CREST (Creation of essential technologies to utilize carbon dioxide as a resource through the enhancement of plant productivity and the exploitation of plant products)	MeDream Inc.	2019	Director	(1) R&D of effective use of biological resources (2) R&D, production, sales, and import/export of biofuels (3) Bioenergy supply business and the design, manufacture, installation and sale of related equipment and plants (iv) Manufacturing, sales, import/export, distribution	20,000 thousand JPY	Unknown

Name (Affiliation)	Name of the strategic project (research area)	Startup Company Name	Year of establishment	Relationships with the researcher(s)	Business Overview	Capital stock	No. of employees
					and consulting of health foods		
Teruhisa Komatsu (Department of Commerce, Yokohama University of Commerce)	CREST (Establishment of core technology for the preservation and regeneration of marine biodiversity and ecosystems)	Deep Sensing Initiatives Co. Ltd.	2017	Founder	(1) Development, design, manufacture, import/export, rental and sales of bioinformation measuring instruments (2) Development, design, manufacture, import/export, rental and sales of electronic measuring instruments (3) Consultancy and contract research in sensors, deep learning and data processing (4) Collaboration with Tokyo Tech faculty and Tokyo Tech venture (5) Application research in the fields of medical imaging and brain measurement	Unknown	Unknown
Minoru Ko (School of Medicine, Keio University)	CREST (Creation of Fundamental Technologies for Understanding and Control of Biosystem Dynamics)	Elixirgen Scientific, Inc.	Unknown	Founder, Chief Scientific Officer (CSO), and Interim Chief Executive Officer (interim CEO)	Unknown	Unknown	Unknown
Takanori Yokota	CREST (Establishment of	Renatherapeutics , Co., Ltd.	2015	Unknown	Creation of new nucleic acid drugs using third	100,000 thousand JPY	11

Name (Affiliation)	Name of the strategic project (research area)	Startup Company Name	Year of establishment	Relationships with the researcher(s)	Business Overview	Capital stock	No. of employees
(Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University)	molecular technology towards the creation of new functions)				platform Technology		
Shoji Takeuchi (Institute of Industrial Science, The University of Tokyo)	ERATO (Takeuchi Biohybrid Innovation project)	CellFiber Co., Ltd.	2015	Founder	Research, development, production and sales of biomaterials and soft materials including cells	11,000 thousand JPY	Unknown
Tetsuya Higashiyama (Institute of Transformative Bio-Molecules (ITbM), Nagoya University)	ERATO (Higashiyama Live Horonics project)	GRA&GREEN Inc.	2017	Technical Advisor	Development of an automatic grafting device using a microchip	Unknown	Unknown
Takao Someya (Graduate School of Engineering, The University of Tokyo)	ERATO (Someya Bio-Harmonized Electronics project)	Signtle Inc.	2018	Unknown	Development, manufacturing and sales of measuring instruments, such as biometric information, and provision of information services using the measured information.	10,000 thousand JPY	Unknown

Name (Affiliation)	Name of the strategic project (research area)	Startup Company Name	Year of establishment	Relationships with the researcher(s)	Business Overview	Capital stock	No. of employees
Takao Someya (Graduate School of Engineering, The University of Tokyo)	ERATO (Someya Bio-Harmonized Electronics project)	Xenoma Inc.	2015	Unknown	Development and sales of “e-skin,” a smart apparel product	292,650 thousand JPY	28
Kazunari Akiyoshi (Kyoto University)	ERATO (Akiyoshi Bio-nanotransporter project)	United Immunity, Co., Ltd.	2017	Unknown	Research, development, manufacturing, marketing and strategy of cancer immunotherapy and other pharmaceutical products	Unknown	Unknown
Yoshinobu Kano (Informatics Course, Graduate School of Informatics, Shizuoka University)	PRESTO (Information Environment and Humans)	Araya Inc.	2013	Unknown	AI algorithm and product development (deep learning business, edge AI business, autonomous AI business)	Unknown	41
Kenzo Fujiwara (Institute for Materials Research, Tohoku University)	PRESTO (Photoenergy conversion systems and materials for the next generation solar cells)	Pan Solution Technologies, Co., Ltd.	2017	Unknown	Manufacturing and sales of materials for solar cells and semiconductor inspection equipment Consulting and licensing of materials and technologies for solar cells and semiconductors Manufacture and sale of materials for solar cells and semiconductors	67,750 thousand JPY	Unknown

Name (Affiliation)	Name of the strategic project (research area)	Startup Company Name	Year of establishment	Relationships with the researcher(s)	Business Overview	Capital stock	No. of employees
Atsushi Wakamiya (Institute for Chemical Research, Kyoto University)	PRESTO (Photoenergy conversion systems and materials for the next generation solar cells)	EneCoat Technologies Co., Ltd.	2018	Co-founder Director Chief Technology Officer	Manufacture and sale of perovskite solar cells (PSCs) and related materials	90,000 thousand JPY	Fifteen.
Takashi Kobayakawa (Department of Functional Neurology, Osaka Bioscience Institute)	PRESTO (Development and Fdunction of Neural Networks)	Nokagaku Koryo (Brain Science Aroma) Inc.	2010	Founder	Unknown	13,000 thousand JPY	Four.
Kazunori Sakamoto (National Institute of Informatics)	PRESTO (Design of Information Infrastructure Technologies Harmonized with Societies)	WillBooster Inc.	2018	President and Representative Director	Development and provision of educational and healthcare services Consulting in Education and Healthcare Planning and management of various events	500 thousand JPY	one person
Emi Tamaki (Graduate School of Creative Science and Engineering, Waseda University)	PRESTO (Design of Information Infrastructure Technologies Harmonized with Societies)	H2L Inc.	2012	Co-founder Chief Engineer	Planning, research, design, development, manufacturing, sales, licensing, export and support of support tools to help people reach their full potential (including hardware, software and services) Business for services that provide experiences by	326,950 thousand JPY	8

Name (Affiliation)	Name of the strategic project (research area)	Startup Company Name	Year of establishment	Relationships with the researcher(s)	Business Overview	Capital stock	No. of employees
					means of a physical motion transfer device		
Masato Hosokawa (Waseda University, Faculty of Science and Engineering)	PRESTO (Innovative Technology Platforms for Integrated Single Cell Analysis)	bitBiome, Inc.	2018	Founder Director CSO	Genome analysis of microorganisms using single cell technology	100,000 thousand JPY	6
Takao Yasui (Graduate School of Engineering, Nagoya University)	PRESTO (Creation of Innovative Functional Materials with Advanced Properties by Hyper-nano-space Design)	Icaria Inc. (Now Craif Inc.)	2018	Technical Advisor and Co-founder	Early Detection of Cancer with High Precision and Painlessness	500,000 thousand JPY	10

2.4.4 Filing and Exploiting Patents

The number of patent applications filed by researchers is summarized in Figures A2-45 to A2-47; in the case of ERATO (Fig. A2-45), the number of applications per research area fluctuated significantly from year to year, reaching 33.3 in FY2017, compared to 2.5 in FY2018. Differences in research fields and patent strategies had a significant impact on the number of patent applications: in the case of CREST (Fig. A2-46), the number of applications per research project ranged from roughly two to five, while in the case of PRESTO (Fig. A2-47), the number was around one in each year.

Kobayakawa Takashi, as mentioned in section 3, was granted three patents with a startup company (Brain Science Fragrances, Inc.) as the rights holder, which generated tens of millions of JPY in sales. In addition, PRESTO researcher Shinji Yuasa co-petitioned and obtained 6 patents related to magnetoresistive devices and magnetic memory with a co-researcher company. Hideo Hosono (ERATO) has licensed patents on amorphous transparent oxide transistors to nine companies,

including three major Japanese and Korean display manufacturers.

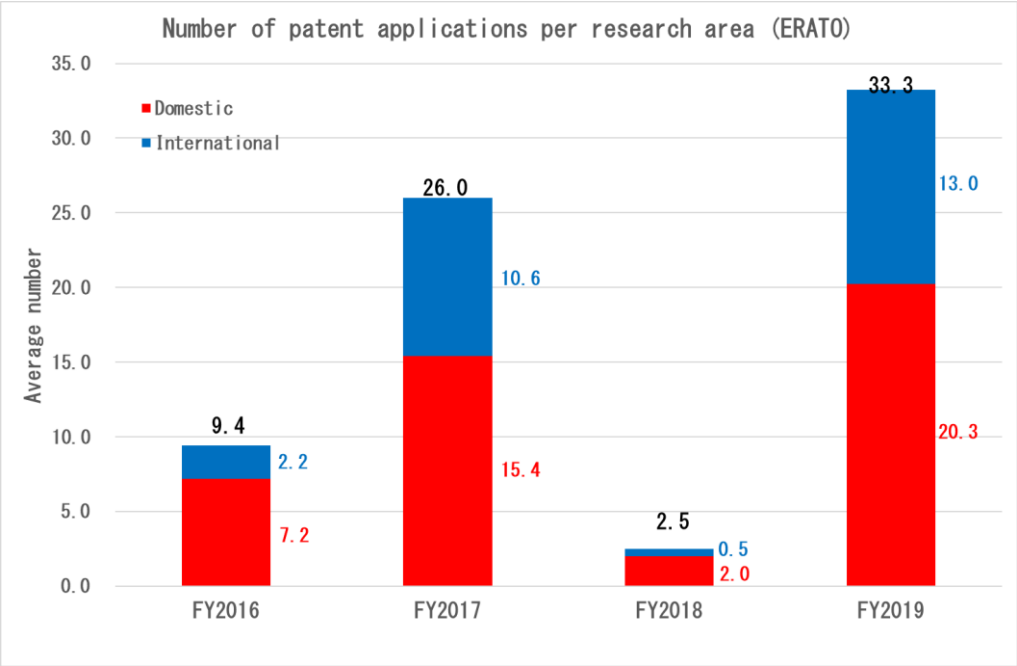


Figure A2-45. Number of patent applications per research area at ERATO

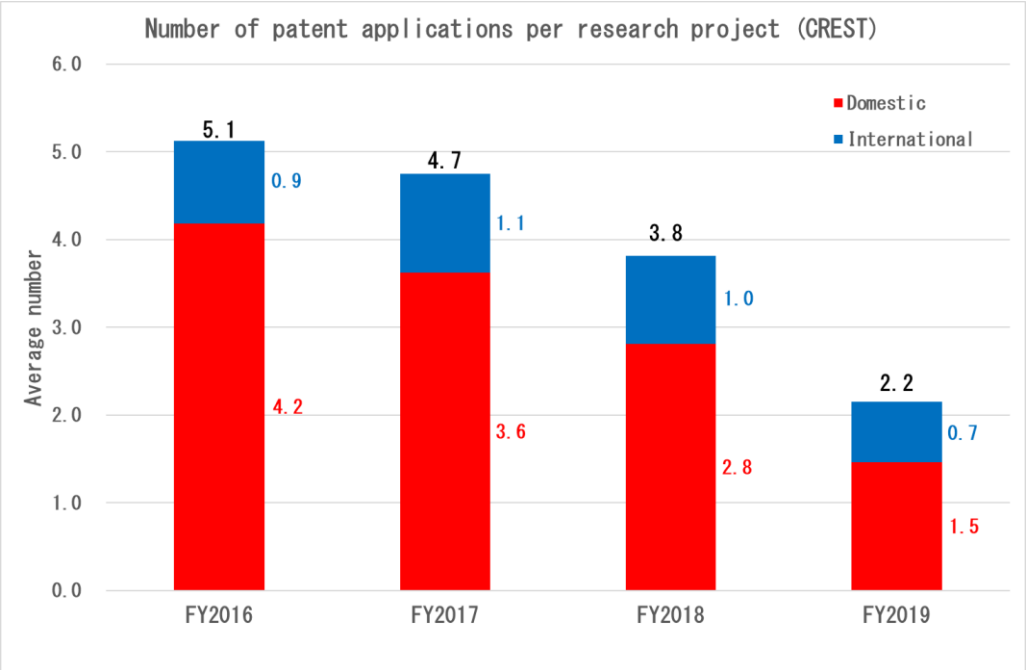


Figure A2-46. Number of patent applications per research project at CREST

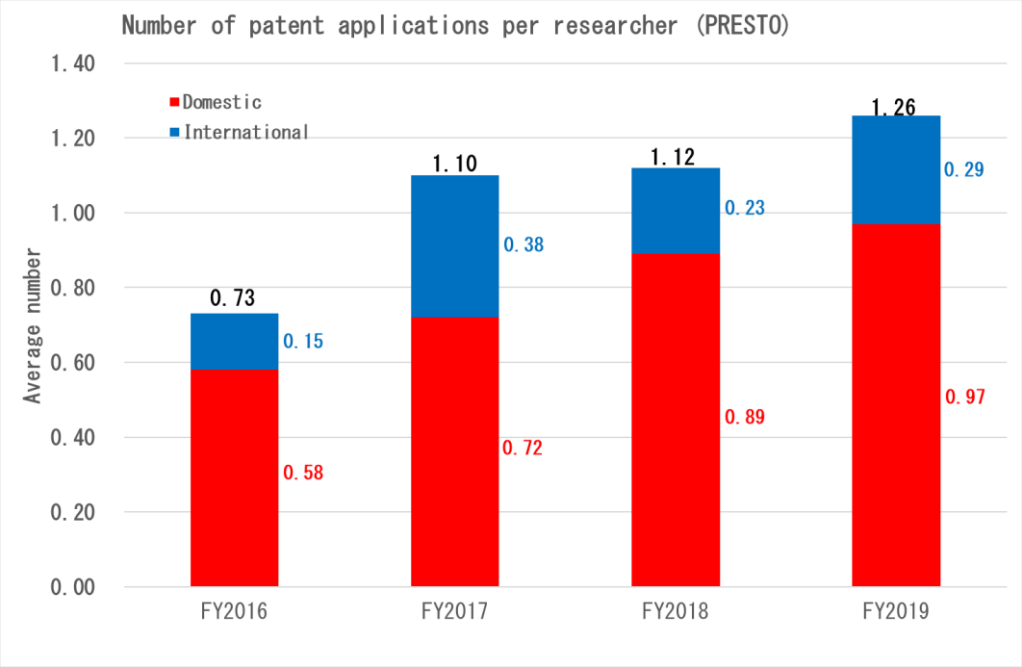


Figure A2-47. Number of patent applications per researcher at PRESTO

2.4.5 Award

Table A2-6 summarizes the outstanding awards that researchers received for each program during the survey period.

Table A2-6. Awards received

Awarded FY	Prize	Winner	Program
2016	Bälz Prize	Hiroshi Ohno	CREST
	Bälz Prize	Kiyoshi Takeda	CREST
	Bälz Prize	Koji Hase	PRESTO
	Bälz Prize	Kenya Honda	CREST
	Uehara Prize	Hidenori Ichijo	CREST
	Uehara Prize	Seishi Ogawa	CREST
2017	Bälz Prize	Masashi Yanagisawa	ERATO
	Roger Adams Award.	Hisashi Yamamoto	ACT-C
	Solvay Prize	Susumu Kitagawa	ERATO
	Uehara Prize	Kunihiro Matsumoto	CREST
	Medal with Purple Ribbon	Kozo Kaibuchi	CREST
	Medal with Purple Ribbon	Shinichi Takagi	CREST
	Medal with Purple Ribbon	Ikue Mori	CREST
2018	Wolf Prize	Makoto Fujita	CREST
	Van Hippel Award	Hideo Hosono	ERATO
	Medal with Purple Ribbon	Ryoichiro Kageyama	CREST