Roadmap 2023 —
Basic Concepts for Promoting Large Scientific Research Projects

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Working Group on Large Scientific Research Projects
Research Environment Subcommittee, Science Committee
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Contents

Introduction

Large-scale scientific research projects (hereinafter, “Large Projects”) have achieved dramatic advances in various fields by harnessing cutting-edge technology and knowledge to tackle research issues that have been untouched by humanity, and they are taking the lead in academic research around the world. It is necessary to promote these projects through a long-term perspective while gaining the wide support of society and the general public. On a policy level, the “Sixth Science and Technology Basic Plan” (approved by the Cabinet on March 26, 2021) emphasizes the necessity of promoting Large Projects that will open up the frontiers of academic research worldwide and facilitate the development and utilization of advanced large-scale facilities and equipment. This is to be done from the perspective of promoting fundamental academic research that produces diverse and exceptional knowledge in order to strengthen the basic capabilities underlying science, technology and innovation.

At the same time, since Large Projects require enormous amounts of funding, it is vital that they have clear scientific goals set through careful preparation by the research community and that they are carried out taking into full account the country’s academic policies. It is also necessary that they are advanced strategically and systematically, taking into consideration not only domestic and international trends in academic research, but also the current state of, and future outlook for, financial expenditures.

Based on this perspective, the Working Group on Large Scientific Research Projects (hereinafter, the “Working Group”) formulated “Roadmap 2023 — Basic Concepts for Promoting Large Scientific Projects” (hereinafter, “Roadmap 2023”), with the aim of clarifying the priorities for promoting large projects.

1. Large Scientific Research Projects

(1) Significance and Necessity of Promoting Large Projects

Japan’s Large Projects up to now have harnessed cutting-edge technology and knowledge to tackle research issues never approached by scientists heretofore, achieving groundbreaking results that lead academic research around the world and contributing to the dramatic development of the relevant research fields. They have also provided the environment and facilities for a wide-range of university-based research communities, and have played a major role in the development of academic research in Japan. For example, the Kobayashi-Masukawa Theory, which explains the breaking of CP symmetry, was proven through B Factory experiments, and neutrino oscillation, which proves that neutrinos have mass, was discovered at the Super-Kamiokande Observatory, both of which discoveries led to Nobel Prizes in physics.

In this way, Large Projects are of great significance as they showcase Japan’s research capabilities to the world, attract excellent researchers from other countries, and contribute to the development of human resources in the relevant fields, as well as give dreams and hopes to the people of Japan, including the children who will lead the next generation.

Up to now, Large Projects have generally been considered to have the following basic characteristics, and their topics have been promoted as important issues in academic policy.

Henceforth, they should continue to be promoted based on this approach. These Large Projects:

- Are carefully conceived and prepared through independent consideration based on researchers' intellectual curiosity and inquisitiveness and through consensus-building within the research community, with the aim of exploring truths that will contribute to the development of humanity.
- Harness cutting-edge technology and knowledge to tackle research issues that have not been addressed by humankind, and are expected to achieve groundbreaking results that will lead academic research around the world.
- Support broadly research and education at universities and other institutions, raise public interest in science, technology, and academic research, demonstrate Japan's leadership in international competitiveness and cooperation, and contribute to the betterment of the world.
- Are nationwide projects in which multiple research organizations form an organic network, many researchers participate in a clearly defined implementation structure, major themes are addressed as a whole.
- Center on institutions possessing joint use and joint research functions, such as interuniversity research institutes and joint use and joint research centers, in order to contribute to the strengthening of the academic research foundations in Japan as a whole.

(2) **Significance and Impact of Formulation of Roadmap**

① **Significance of Roadmap Formulation**

Requiring huge investments, Large Projects have been difficult to initiate and implement smoothly in recent years due to Japan's severe financial situation. Similar situations have arisen in other advanced countries, and as research becomes more advanced, the need for larger facilities and equipment has increased, sparking the trend toward greater international cooperation. For this reason, it has become essential for Japan to promote Large Projects in various fields of basic science where Japan has strengths while keeping in view both international competition and international cooperation. Moreover, it is necessary to clearly prioritize the stable and continuous investment of greater resources in Large Projects while gaining the widespread support from society and the public, with this as the basis of the nation's academic policy.

Based on this understanding, the Working Group has formulated five Roadmaps to date,[1] and based on these Roadmaps, Large Projects have been promoted through government funding. While not guaranteeing budgetary support, the Roadmaps have clarified the priorities of Large Projects, and should be fully considered when advancing related policies. Since the circumstances surrounding academic research change significantly depending on academic trends, societal demands, the international situation and so on, the priorities identified in the Roadmaps need to be reviewed at appropriate periods.

Overall, the Roadmaps function to:

- Enable strategic and systematic policy decisions to be made based on thorough scientific assessment;

[1] 2010, 2012, 2014, 2017, 2020.

- Enable Large Projects to be advanced while gaining the support of society and the public;
- Make it possible to respond quickly and appropriately to international competition and cooperation;
- Enable opportunities for the research community to proactively consider future goals and the necessary conditions to achieve them from a broad perspective;
- Foster interactions between different research communities and promote interdisciplinary approaches to complex scientific problems.

Additionally, overseas, the European Strategic Forum for Research Infrastructures (ESFRI) and the National Science Foundation (NSF) in the United States are also formulating and promoting plans for large-scale projects. In promoting Large Projects in Japan, the Government should utilize such plans for large-scale projects as necessary, clarify the division of roles with overseas research institutions and researchers, and build a system for collaboration and cooperation. At the same time, it is necessary to use Japan’s Roadmaps to promote its projects with a greater awareness of international cooperation and collaboration.

② Impact of Roadmap Formulation

The formulation of the Roadmap is expected to:

- Facilitate the incorporation of the benefits of a bottom-up approach in various ways even in projects with a top-down decision-making structure;
- Enable the Government and the research community to respond quickly and appropriately when new opportunities to support Large Projects arise;
- Make it easier for government organizations involved in research and development other than MEXT to ascertain academic trends and demands in each field;
- Contribute to promoting international cooperation in those academic fields where the expansion of research has made international cooperation essential by showing Japan’s approaches to advancing Large Projects.

Moreover, the Government has been promoting strategically and systematically the plans designated in the Roadmap through the “Project to Promote Large Scientific Frontiers (hereinafter, “Frontier Projects”) based on the priorities of the Large Projects designated in the Roadmap.[2] In addition, the projects have been supported by various other financial sources. While previously the projects targeted for support were mainly in fields that required large-scale experimental facilities, the formulation of the Roadmaps has had the effect of diversifying and expanding the relevant academic fields, with projects centered on the humanities and life sciences being created and the building of nationwide academic information networks progressing.

As described above, the formulation of the Roadmaps has strengthened the linkage between large-scale projects envisioned by academia and national policies. The Large Projects listed in the Roadmaps are progressing steadily, and continued initiatives are expected in the future.

2. Formulation of Roadmap 2023

(1) Formulation Policy

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[2] For further information, refer to the reference materials for the Frontier Projects that were launched with the issuance of the Roadmaps.

All of the Roadmaps to date have been formulated based on the “Master Plan for Large-Scale Academic Research Projects” issued by the Science Council of Japan. With the Science Council of Japan deciding not to formulate a traditional “master plan” this time, the Working Group decided to formulate the most recent Roadmap by soliciting proposals for it and basing it on its own unique policy.

The Working Group considered the basic concept, target plans, evaluation methods, etc. for the formulation of Roadmap 2023, and in December 2022, it decided on its “Basic Concept for the Roadmap Formulation Policy to Promote Large Academic Research Projects.” The formulation guidelines for Roadmap 2023 follow the basic characteristics and functions of previous Roadmaps, but new requirements were set, such as clarifying the scope of the budget, deciding on the location of facilities, and stipulating that the project proposing person be a department head or higher, in order to select more feasible and excellent Large Projects. In addition, proposals were solicited through a public offering, and only those that were assessed at a certain level through document screening and direct information gathering were included in the Roadmap.

The evaluation criteria were based on the assessments of Large Projects that the Working Group had conducted up to then and the circumstances and issues surrounding current academic research. Ten criteria were set, including the addition of the new criteria of “Scientific Goals” and “Human resource development of young researchers.” Regarding “Scientific Goals,” a certain degree of evaluation in this regard had been conducted in the formulation of the Roadmaps to date through the category of the “Academic significance of the Plan”; however, it was decided to confirm the clarity and significance of the proposals from an independent perspective. Concerning the “Human resource development of young researchers,” this criterion was added in light of the importance of human resource development in today’s research environment. In addition, other points that should be taken into consideration in the evaluation include whether a system has been created to obtain not only the agreement but also that support of the research community, as well as the ripple effects of the proposed project on industry. On top of this, as a way to demonstrate community support for the projects, applications had to include letters of support from relevant academic societies.

(2) Screening of Projects Included in Roadmap 2023

Based on the above-mentioned formulation policy and guidelines, the Government made a public call for proposals for Roadmap 2023, and received 47 applications (including six that were listed in Roadmap 2020 and wished to continue to be listed). The Working Group then screened the applications.

The evaluation was conducted through a document screening and a direct request for further information and explanation. In order to ensure an appropriate evaluation of the various proposals, the document review was carried out by not only members of the Working Group but also specialists from a wide range of fields, and a detailed evaluation was conducted based on the contents of the applications. After that, 18 projects were requested to provide in person further explanations and information. Of them, 12 projects (including five that were continued from Roadmap 2020) were included in Roadmap 2023.

3. Projects listed in Roadmap 2023

The following 12 Projects are listed in Roadmap 2020.

Research field	Project name	Project rationale/aim	Implementing organizations		Financial cost (in millions of yen)	Project period	Main outstanding points	Main issues, points for consideration, etc.	Remarks
			Core organization	Collaborating organizations					
Basic medical science	Establishment of world-leading research and training center for infectious diseases with a high containment laboratory (BSL-4)	The goal of the Project is to contribute to the improvement of global health through the formation of a world-class research hub on Class 1 pathogens and the fostering of human resources that will play leading roles in this field. The results will help elucidate the pathology of infectious diseases caused by Class 1 pathogens, establish diagnostic and treatment methods, and develop effective preventive measures to ensure the safety and security of the public, as well as contribute to the international infectious disease control system led by the WHO and other organizations. To achieve this goal, the Project will proceed with the necessary preparations to operate the BSL-4 facility, which was completed in July 2021 for the purpose of research and human resource development, and then to conduct trial operations and full-scale operations in stages.	Nagasaki University	Hokkaido University, The University of Tokyo, Osaka University, other universities around Japan, National Institute of Infectious Diseases, other related organizations	Total cost: 9,950 Utilities costs: 1,170 Personnel costs: 3,120 Servicing and maintenance costs: 4,510 Other operating costs: 1,150	**Preparation of facilities and equipment** 1st to 2nd year: Trial operation 3rd to 10th year: Annual inspections, regular replacement of pipes, etc. **Facilities safety management, development of operational system** 1st to 2nd year: development of operational system, preparation of various manuals 3rd to 10th year: Facilities safety management, review of operational system **Operations** 1st year: Designation by Minister of Health, Labor and Welfare: BSL-2, 3 research and human resource development 10th year: Designation by MHLW Minister: Operation of BSL-4 facility, BSL-4 joint research and HRD	As the only BSL-4 facility for academic research in Japan, the center is an indispensable facility for Japan to advance cutting-edge pathogen research, and it is recognized as having important academic and social significance. It is commendable that the construction of the facilities was completed in 2021 after long-standing dialogue with local residents that achieved a level of understanding with them.	The Project is required to take initiatives to achieve unique research results while also taking into consideration its relationships with competing centers overseas, by further clarifying what research outcomes and targets the Project is aiming for, as well as its scientific goals and achievement plans. In addition, the understanding of local residents is necessary for the stable operation of facilities, and strict risk management and security measures must be implemented.	Project is a continued listing

Integrated engineering	Research Network for Spintronics and Quantum Information Science & Technology	Spintronics is a new fusion of electricity and magnetism that utilizes both the charge and spin degrees of freedom in electrons, and it will become a core field of quantum science and quantum information technology in the future. It will provide the essential scientific and technological foundation for realizing innovative energy-saving devices, neuro/brain morphic elements, and classical quantum information fusion devices. Based on the achievements made since its adoption in Roadmap 2020, the Project links several outstanding research institutions, centering on five core universities, into a collaborative network, develops and strengthens this network as an international collaborative research hub, and contributes to future academic development and the creation of innovative information technology.	The University of Tokyo	Tohoku University, Osaka University, Kyoto University, Keio University	Total cost: 8,100 Facilities, equipment costs: 3,400 Utilities costs: 800 Database maintenance costs: 200 Personnel costs: 2,500 Travel costs: 400 Servicing and maintenance costs: 500 Other operational costs:	1st to 2nd year: Strengthening of functions of Center for Spintronics Research Network, expansion of international networks 3rd to 8th year: Building of academic foundation in line with the goals of the Academic Roadmap, development of industrial applications in possible fields. Opening schools for students and young people to develop human resources. Hosting international conferences, disseminating research results and promoting international exchange, and promoting collaborative research and brain circulation. 9th to 10th year: Summarization of overall results and presentation at an international conference, results published online and in book form.	An "all-Japan" system is being established and strengthened by bringing together the initiatives of leading domestic research institutions that have achieved outstanding results. Expectations are high within the academic community that this Project will be of great academic significance, making optimal use of Japan's uniqueness. In order to maintain Japan's prominence in this field, the Project is pursuing a strategy of fusing classical and quantum physics centering on spintronics. The results are expected to have an impact not only in basic science but also in industrial applications.	The "fusion of classical and quantum physics" requires efforts to produce new results that go beyond simple "combinations." While it is anticipated that important academic results will be produced for each individual research topic, it is important to consider how to proceed with the formation of research centers and ensure their independence, and it will be necessary to consider long-term directions.	Continued listing

Research field	Project name	Project rationale/aim	Implementing organizations		Financial cost (in millions of yen)	Project period	Main outstanding points	Main issues, points for consideration, etc.	Remarks
			Core organization	Collaborating organizations					
Integrated engineering	Global co-creation infrastructure with high-repetition high-power laser facility	The development of high-power lasers is making great advances, and the field is expected to lead to many new academic breakthroughs and new technological developments. Harnessing Japan's strengths and systems nationwide, the Project will build a global co-creation platform based on a unique high-repetition and high-pulse laser. Through the exploration of the quantum vacuum (fields), the pursuit of nuclear fusion energy (plasma), and the creation of ultra-high-pressure novel quantum materials (solids), the Project aims to play a world-leading role in pioneering high-energy-density, extreme quantum science. By promoting interdisciplinary and industry-academia collaboration in the same space, the Project broadly aims at contributing to the creation of an environment for science and technology innovation, the transformation of the industrial structure, and development of human resources.	Institute of Laser Engineering, The University of Osaka	Kansai Institute for Photon Science, National Institutes for Quantum Science and Technology; Institute for Materials Research, Tohoku University; Institute for Solid State Physics, The University of Tokyo; Institute for Laser Science, University of Electro Communications; Kyoto University Institute for Chemical Research; Photonics and Electronics Engineering Education and Research Center, Kyoto University; RIKEN Center for Advanced Photonics	Total cost: 39,047 Facilities, equipment costs: 32,300 Utilities costs: 1,425 Database maintenance costs: 250 Personnel costs: 1,500 Travel costs: 215 Servicing and maintenance costs: 2,857 Other operational costs: 500	**Construction, initial investment, strengthening of functions** 1st to 6th year: Construction, installation of mega-laser, 10 PW laser, laser quantum beam laser 1st to 6th year: Preparation of experimental area **Operations** 6th to 10th year: Operation of laser equipment, information gathering and system optimization for smart systems 6th to 10th year: Operation of experimental area	By taking advantage of Japan's strengths in high-repetition, high-power lasers to conduct pioneering research, the Project is expected to realize applications in a wide range of fields, including materials science, plasma science, and astrophysics. In addition, the main implementing body has a strong track record in joint facilities utilization and joint research, and the Project preparations, including the formation of a research community, are well advanced.	While the Project's technological advantages and plans are at a high level, the actual outlook for the expected academic results needs to be further specified and clarified. Moreover, since this is a field in which technological innovation occurs at a rapid pace, the Project base needs to be operated and managed with a strategy for maintaining Japan's technological prominence over the long term.	
Physics	Neutrino research in ultra-low radiation environment	The Kamioka Liquid Scintillator Anti-Neutrino Detector (Kam LAND) experimental facility is a world-leader in double beta decay, one of the most important issues in particle and nuclear physics research, and in neutrino geoscience, a field pioneered at the facility. However, after its long period of operation, KamLAND has undergone serious aging. The probability of a major discovery in double beta decay research, however, will be greatly increased by overcoming the aging and deterioration problem and improving its performance to collect five times as much light. The Project will advance geoneutrino observations to elucidate the composition and activity of the Earth's interior, and develop distinctive low-energy neutrino astronomy. Moreover, as a flagship project for research into extremely rare underground phenomena at Kamioka, the Project will contribute to the development of the extremely low radiation underground astrophysical particle research community.	Research Center for Neutrino Science, Tohoku University	Obihiro University of Agriculture and Veterinary Medicine, University of California, Berkeley and San Diego, University of Tennessee, Duke University, University of North Carolina, Triangle Universities Nuclear Laboratory, University of Washington, Massachusetts Institute of Technology, Virginia Tech, University of Hawaii, Boston University, University of Delaware, University of Amsterdam	Total cost: 9,440 (figures in parentheses are Japan's share of cost: 8,640) Facilities, equipment costs: 6,075 (5,275) Utilities costs: 430 (430) Personnel costs: 320 (320) Travel costs: 65(65) Servicing and maintenance costs: 50 (50) Other operational costs: 2,500(2,500)	**Construction** 1st year: Ultra-low radioactivity super-clean facilities 1st to 3rd year: Improvement of KamLAND's performance 5th year: Installation of Xenon **Operations** 2nd to 10th year: Joint utilization of super-clean facilities 4th to 10th years: Earth and celestial neutrino observation 5th to 10th year: Double beta decay research	Geoneutrino research is a unique field pioneered in Japan, and the Project is expected to produce results that address fundamental issues in particle and nuclear research. The Project is also attracting many young researchers, including students, and will contribute to the fostering of young talented researchers who will lead the future in this field.	As the research advances, it is expected that there will be increasing consideration of long-term future plans and work for which it will be responsible, so a personnel plan for the stable progress of the Project must be formulated in concrete terms. Moreover, there will be a need to more clearly communicate the mutually complementary relationships and advantages in other research regarding neutrinos.	

Research field	Project name	Project rationale/aim	Implementing organizations		Financial cost (in millions of yen)	Project period	Main outstanding points	Main issues, points for consideration, etc.	Remarks
			Core organization	Collaborating organizations					
Physics	Promotion of High-energy Neutrino Astroparticle Physics Research with the IceCube-Gen2 Neutrino Observatory	This is a core project aimed at enabling high-statistics observations of high-energy cosmic neutrinos by the IceCube-Gen2 International Neutrino Observatory. It promotes multi-messenger astronomy by integrating observations of neutrinos, electromagnetic waves (ranging from radio waves to gamma waves), and gravitational waves, and fosters interdisciplinary research through these combined observations. The IceCube-Gen collaboration, which includes universities and research institutes from 15 countries around the world, is responsible for operating IceCube-Gen 2, which will be constructed in the deep Antarctic ice near the Amundsen-Scott South Pole Station (USA).	International Center for Hadron Astrophysics, Chiba University		Total cost: 5,437 Facilities and equipment costs: 400 Utilities costs: 250 Detector manufacturing and testing costs: 4,200 Data center installation costs: 100 Personnel costs: 385 Travel costs: 80 Servicing, maintenance costs: 22	**Construction, initial investment** 1st to 2nd year: Construction of detector production line 1st to 8th year: Manufacturing and testing of deep glacier buried detector 3rd to 9th year: Construction on Antarctica site 4th to 8th year: Installation and partial operation of observation data center **Operations** 4th to 9th year: Start of partial observations 9th year: Start of full-fledged operation of observation data center 10th year: Start of full-fledged operations and observations (expected to be in operation	The Project is a plan to expand the capabilities of IceCube, which has already produced outstanding results in the observation of high-energy neutrinos. Further significant outcomes are expected, driven by the Project's strong scientific goals that aim to pioneer new frontiers in our understanding of the Universe. Moreover, this is an international collaborative project in which Japanese researchers, including early-career researchers, are playing key roles in both hardware development and physics analysis. The project is recognized as making a significant contribution to HRD and international "brain circulation."	It will be important to further enhance joint usage and collaborative- research opportunities through support from the university headquarters. In addition, it will be necessary to broaden the researcher community to encourage wider participation and to strengthen outreach efforts in order to increase public awareness and acceptance of the Project.	
Physics	CTA International Ground-Based Gamma Ray Observatory	CTA is the next-generation international ground-based gamma-ray observatory that aims to capture the extreme universe and shed light on mysteries such as black holes, the origin of cosmic rays, and dark matter. In addition to conventional electromagnetic wave and cosmic ray observations, CTA will also collaborate with facilities opening the window on the observation of gravitational waves and neutrinos, making CTA an important pillar of multi-messenger astronomy. The CTA Project is being carried out by 1,600 people from 25 countries, and will become the world's only large-scale astronomy facility in the very-high-energy gamma ray field. To enable observation of the entire sky, a total of 73 telescopes with three different apertures will be installed in the northern and southern hemispheres and will be operated for 20 years.	Institute for Cosmic Ray Research, The University of Tokyo	Nagoya University, RIKEN, Hiroshima University, Kyoto University, Konan University, Tokai University, Aoyama Gakuin University, Ibaraki University, Yamagata University, Saitama University, Chiba University, Osaka University, 8 other domestic institutions, and 182 overseas institutions	Total cost: 75,410 (Japan's share in parentheses: 8,010) Facilities, equipment costs: 55,800(4,910) Utilities costs: 2,556(580) Database preparation cost: 1,440(460) Personnel costs: 6,570(700) Travel costs: 1,310 (270) Servicing, maintenance costs: 7,734(1,090)	**Construction, initial investment, strengthening of functions, etc.** 1st to 6th year: Production of telescopes **Operations** 1st to 6th year: Successive starting of operation with completed installation of telescopes 7th to 10th year: Integrated operation of all telescopes	This is a core international project for observation of high-energy gamma rays, and is regarded as a valuable research project that will play a leading role in the development of multi-messenger astronomy. With Japan's investment in areas where Japan has strengths, Japan will be directly involved in the efficient operation of the Project, and Japanese researchers, including young researchers, are playing important roles.	Japan's share of the funding is relatively small, and there is a risk that the direction and progress of the Project will be strongly influence by the actions of Europe, which is leading the Project. Efforts must be made on Japan's side to increase Japan's presence in the Project. In addition, much of the planning period will be occupied by the construction phase, and so it will be necessary to create a system that allows young researchers to be involved in the producing of research results.	

Research field	Project name	Project rationale/aim	Implementing organizations		Financial cost (in millions of yen)	Project period	Main outstanding points	Main issues, points for consideration, etc.	Remarks
			Core organization	Collaborating organizations					
Physics	High Magnetic Field Collaboratory-Formation of Unified Next Generation All Japan Facility	The Project is the high magnetic field collaboratory formation as a national high magnetic field research organization. By introducing the world's highest performance quasi-steady magnetic field and cryogen-free superconducting magnets, the Project will be the world leader in materials science, the field where Japan is highly competitive internationally, particularly in research on semiconductors, magnets, and superconducting materials. The results of this research will contribute to solving information, energy, medical and other issues that are important for the nation and society. At the same time, through interdisciplinary research under a high magnetic field of 1,200 Tesla, the Project aims to discover unknown phenomena in the universe, life, chemistry, and other fields, enrich humankind's understanding of matter, and contribute to humanity through the producing of innovative knowledge and the creation of new fields of science.	The Institute for Solid State Physics, The University of Tokyo	**Core collaborating organizations:** Institute for Materials Research, Tohoku University, Graduate School of Science, University of Osaka **Collaborating organizations:** Molecular Photoscience Research Center, Kobe University, Research Center for Development of Far-Infrared Region, Fukui University, Research Center for Utilization of High Magnetic Field, Osaka Metropolitan University	Total cost: 4,380 Facilities, equipment costs: 1,300 Utilities costs: 500 Database preparation costs: 20 Personnel costs: 300 Travel costs: 100 Servicing, maintenance costs: 500 Other operation costs: 1,660	**Installation, initial adjustment** 1st to 3rd year: Quasi-steady magnetic field introduction, commissioning 1st to 4th year: Installation, commissioning of 33T cryogen-free superconducting magnet 1st to 4th year: Preparation, installation, commissioning of 100T non-destructive pulse magnetic field and sharing joint-use magnetic field equipment **Operations** 4th to 10th year: Quasi-steady magnetic field operation 5th to 10th year: 33T cryogen-free superconducting magnet operation 5th to 10th year: Operation of joint-use 100T non-destructive pulse magnetic field and sharing joint-use magnetic field equipment	As the leader in this field, Japan is enhancing its academic predominance in the field through its unique technologies. Since its listing in Roadmap 2020, the Project has been highly evaluated, making steady progress in its implementation and with its updating and installation of new equipment. Moreover, the Project is recognized as being highly feasible, as it is actively seeking cooperation with overseas institution and the inflow of its own funds. Furthermore, the Project has established cooperative ties with industry, with expectations that it will contribute to industrial fields.	The Project is focusing efforts on enhancing its versatility, and from now, it will need to take measures aiming at further academic research by deepening collaboration with research organizations in a variety of fields. Moreover, it will be desirable for the Project to clarify the direction and path for future advances in materials science from a global and interdisciplinary perspective.	Continued listing
Physics	The Thirty Meter Telescope TMT	The ultimate challenge for humankind is to understand the formation of stars, galaxies, and large-scale structures in the universe expanding since the Big Bang, as well as to explore planetary formation and the birth of life. As the core observational facility for this endeavor, a 30-meter optical-infrared telescope TMT will be built on Maunakea in Hawaii, the optimal location for ground-based astronomy, and it will be made available for joint-use by universities. In collaboration with the wide-field observations by the Subaru Telescope, TMT will promote research that will revolutionize the understanding of Earth-like exoplanets, the first stars in the universe, the history of the expansion of the universe, and more. In the construction of the telescope carried out through international cooperation, Japan will be responsible for essential components of the telescope structure, the control system, primary mirror segments, and major parts of the observation instruments.	National Astronomical Observatory of Japan	TMT International Observatory (TIO), California Institute of Technology, University of California, National Research Council Canada, Indian Department of Science and Technology, Association of Universities for Research in Astronomy (AURA), US National Science Foundation (NSF)	Total cost: (Japan's share): 42,684 Facilities, equipment costs: 37,304 Preparation for joint use (construction period): 1,340 Personnel costs: 1,100 Travel costs: 240 TIO share (construction period): 2,700	**Construction** 1st year: TIO evaluation of the main telescope structure, preparation and prototyping of the primary mirror (segmented mirror), detailed design of observation instruments, study of scientific operation and preparation for joint-use operations 2nd to 10th year: Manufacturing, transportation, on-site installation and adjustment of telescope structure; manufacturing of the primary mirror (segmented mirrors), manufacturing, assembly, and comprehensive testing of observation instruments; study of scientific operation and preparation for joint-use operations **Operations** 10th year: Early science operations	As a next-generation optical-infrared telescope, the TMT will be a core facility for observation having world-leading performance, and it is expected to produce major academic results in astronomy, such as the direct imaging of Earth-like exoplanets, the search for materials related to life, and the detection of the first stars. In addition, the Project's implementation body's sincere efforts over a long period of time to resolve delays in the Project caused by opposition from some local residents merits praise.	While there have been some improvements in the situation in Hawaii, some areas remain unclear, such as the involvement of the U.S. NSF and agreements with local residents, and there is a risk of further delays and changes in the Project plan. In the implementation of the Project and the provision of government support, the government needs to closely monitor the situation and respond carefully and appropriately.	

Research field	Project name	Project rationale/aim	Implementing organizations		Financial cost (millions of yen)	Project period	Main outstanding points	Main issues, points for consideration, etc.	Remarks
			Core organization	Collaborating organizations					
Physics	"Micro-collective phenomena" of ultra-high temperature plasmas and fusion science	The greatest challenge in the commercialization of fusion energy is making the fusion system more compact. Making the core smaller increases the temperature gradient in the plasma, generating complex fluctuations that can lead to deterioration of confinement and sudden instabilities. In order to elucidate the causes and effects of plasma-specific fluctuations that are common not only to fusion reactors but also to the space and astrophysical plasmas, the Project will construct an experimental system that controls and manipulates the microscopic state of ultra-high temperature plasma with high precision, and measures it with the world's highest resolution. By linking the measurements with theoretical simulations, the Project will reveal the guiding principles that drive fusion innovation.	National Institute for Fusion Science	Kyushu Univ., Univ. of Osaka, Univ. of Tokyo, Chubu Univ., National Institutes for Quantum Science and Technology	Total cost: 33,040 Facilities, equipment costs: 21,300 Personnel costs: 400 Operational costs: 11,340	**Construction, initial investment, strengthening of functions** 1st to 5th year: Preparation, production, installation of plasma equipment 8th year: Augmentation of plasma equipment 1st to 4th year: Transfer, installation of measuring equipment, etc. 6th to 7th year: Augmentation of measuring equipment, etc. **Operations** 2nd to 4th year: Phase 1 experiment 6th to 10th year: Phase 2 experiment	This is a highly feasible plan that makes the most of the achievements to date. Its aim of expanding into interdisciplinary research of nuclear fusion is expected to play an important role in pointing out new directions in nuclear fusion research.	While the scientific goal of this Project is to understand and elucidate plasma physics, it will be necessary to clarify and specify the expected outputs with benchmarks. Furthermore, in regards to interdisciplinary development, it is necessary to go beyond the narrow definition of "interdisciplinary" and to expand the research results to a wide range of fields, while also providing thorough explanations to the public.	
Physics	LiteBIRD - A Satellite for Exploring the Universe before the Hot Big Bang with Measurements of Cosmic Microwave Background Polarization	The LiteBIRD Project aims to search across the cosmos for primordial gravitational waves, the existence of which is predicted by the inflationary cosmology, and to verify the major inflationary cosmology theories. For this, the Project focuses on the spiral pattern (primordial B mode) that primordial gravitational waves imprint on the polarization distribution of the cosmic microwave background radiation. In this Project, in order to observe the primordial B mode, JAXA will develop the LiteBIRD satellite equipped with three cooled telescopes and a multi-color high-density superconducting detector array as a strategic medium-sized mission through domestic and international cooperation. The aim is to discover the primordial B mode and elucidate its full nature through three years of all-sky observations.	Japan Aerospace Exploration Agency (JAXA)	High Energy Acceleration Research Organization, The University of Tokyo, Okayama University, Centre national d'études spatiales (CNES, France), Canadian Space Agency (CSA), and 40 other organizations	Total cost: 31,190 Facilities, equipment costs: 29,246 Personnel costs: 1,518 Travel costs: 147 Other operational costs: 279	**Construction, initial investment, strengthening of functions, etc.** 1st to 3rd year: Satellite concept study and design 4th to 6th year: Detailed design of satellite body 7th to 9th year: Satellite manufacturing and testing **Operations:** 9th year: Launch, initial operation 10th year: Initial operation and regular observations	If the Project's scientific goals are clear and the observations are successful, it will have a major academic impact in the field of astrophysics. Moreover, the Project has made highly feasible plans based on Japan's unique strategies, and a system has been established to promote the Project through international cooperation. Since its listing in Roadmap 2020, the Project has been highly evaluated for the all-out efforts made to realize the mission, including reviewing the Project plan to minimize the impact of NASA's withdrawal from the Project.	As there have been delays in the progress of some of the Project's plans, it will be necessary to accelerate the technological development of the Project going forward. Although at present, there are no competing plans, it will be important to maintain close cooperation with participating organizations, particularly those overseas, in order to achieve the Project's scientific goals.	Continued listing

Research field	Project name	Project rationale/aim	Implementing organizations		Financial cost (millions of yen)	Project period	Main outstanding points	Main issues, points for consideration, etc.	Remarks
			Core organization	Collaborating organizations					
Chemistry	Attosecond Laser Facility (ALFA)	The Project will harness the cutting-edge laser technology and free electron laser technology that have been developed in Japan over many years to construct, install, and operate the Attosecond Laser Facility (ALFA) as an advanced research center accommodating attosecond laser light sources, offering an environment that can be used by researchers all over the world. The establishment of the user facility, ALFA, will afford an ideal infrastructure to researchers in Japan and abroad to conduct frontier research and develop cutting-edge light source technologies, leading to promotion of the international presence of science and technology in Japan.	The University of Tokyo	RIKEN, High Energy Accelerator Research Organization, Institute for Molecular Science (National Institutes of Natural Sciences), Keio University, The University of Electro-Communications	Total cost: 24,580 Facilities, equipment costs: 19,167 Utilities costs: 2,000 Database preparation cost: 440 Personnel costs: 852.6 Travel costs: 70 Servicing and maintenance costs: 661 Other operational costs: 1,390	**Construction, and preparation of infrastructure** 1st to 3rd year: Preparation of light sources, advanced measuring devices, and basic components for beamlines (BLs) A, B, and C. Start of the construction of infrastructure. **Installation of Beamlines** 2nd to 4th year: Completion of BLs A, B, and C and advance measurement equipment and start of test operations. Preparation of a synchronization system with an accelerator-based BL D. Installation of measuring equipment and a soft X-ray photoelectron spectrometer and construction of accelerator housing. Joint use of BL-ABC 4th to 6th year: User operation of BLs A, B, and C and advanced measurement systems. Installation of BL D, completion of the installation of infrastructure for user operation. **Joint use of BL-D** 6th to 8th year: Preparation for user operation of BL D, and its test operation 9th -10 year: Start of user operation	The Project has been prepared based on the recent development of advanced laser technologies and the accumulation of research results in attosecond and ultrafast laser science. The advanced attosecond laser beam lines to be installed in ALFA has given the Project unique advantages over laser facilities in other countries. Since its listing in Roadmap 2020, the Project has made significant progress in the preparation of the laser and measurement systems and the arrangement of the construction site. With the high-end laser beam lines and ideal infrastructure of ALFA, the Project is expected to establish ALFA as an international core hub for cutting-edge research in attosecond and ultrafast laser science.	It will be crucial to attract users from a wide range of research communities both in Japan and abroad. More concrete surveys and investigations are needed to explore an ideal direction of basic and applied research, with which the strengths of the facility can be enhanced, forging the strategy for promoting collaborative research among users. Further outreach activities should be conducted to gain support for "attosecond science" from society and the public.	Continued listing

Interdisciplinary	Establishment of the integrated global ocean observation system "OneArgo" and promotion of ocean interdisciplinary research	The Project will build an integrated ocean observation system named OneArgo. It will expand the current Argo float observation network, which constantly measures water temperature and salinity down to a depth of 2,000 meters in the global oceans, to the ocean floor and to measurement of biogeochemical variables. The Project's aim is: 1) to detect climate change signals in the full ocean water column, 2) to elucidate ocean interior processes related to the carbon cycle, and 3) to understand the status of ocean acidification and deoxygenation and the ecosystem responses. Over a period of around 10 years, the Project will be responsible for approximately 25% of the overall OneArgo project, leading internationally in the implementation of the global observation network while also establishing a system for the domestic use of data and promoting integrated marine research.	Tohoku University	Japan Agency for Marine-Earth Science and Technology, Japan Meteorological Agency	Total cost: 33,797 Facilities, equipment costs: 23,416 Utilities costs: 20 Float communications costs: 3,367 Float transport costs: 1,984 Equipment development costs: 850 Personnel costs: 2,700 Travel costs: 385 Vessel chartering costs: 600 Other operating costs: 475	**Construction, initial investment, strengthening of functions, etc.** 1st to 8th year: Float procurement and deployment 1st to 10th year: Strengthening of the data management system 1st to 10th year: Technical development of floats/sensors **Operations** 1st to 10th year: Float operation 1st to 10th year: Data management, distribution 1st to 10th year: Data product creation and publication 1st to 10th year: Production of scientific results	This Project is of great social significance as the successor to the Argo Project, which achieved major results in climate change research. By incorporating biological and chemical observations, the Project is expected not only to advance understanding of climate change but also to have an impact on academic research in various fields.	While this is a large-scale international joint project, the policies of other countries regarding the Project are unclear. In order to proceed with the Project, it will be necessary to carefully ascertain the situation related to the securing of funding by other countries from an appropriate risk management perspective. Moreover, strategic efforts are required so that Japan can lead the Project not only in observation activities but also in producing academic results.	

5. Promotion of Large Projects in the future

(1) Points for Consideration in Implementation of Large Projects

As mentioned above, Large Projects open up new frontiers in academic research through cutting-edge research and lead academic research worldwide; however, they also require a large amount of funding. Thus, it is necessary to gain broad support from society and the public with a long-term, strategic vision. In promoting future Large Projects, particular attention should be paid to the following points.

① Setting of Clear Scientific Goals and Milestones

Most of the Large Projects are long-term plans that require a span of more than ten years to complete. In order to make these Large Projects involving many researchers over a long period of time successful, it is necessary to clearly define the Project's scientific goals and target achievement levels, such as by answering questions like: "What will be clarified through this Project?" and "What will remain as its legacy after the Project is completed?" Clarifying these points make it possible not only to proceed with the project plan with the long-term support of the research community, but also to gain the understanding of the general public. Moreover, properly grasping the competitive, complementary, or cooperative relationships with other projects will contribute to the formulation of efficient research plans and research methods.

In addition, the setting of appropriate milestones (for goals and expected scientific achievements) in line with the progress of the project plan is a crucial element in project management. Progress management based on these factors will not only ensure the achievement of the final scientific goal but also lead to the dissemination of information to the outside world and the necessary revision of the project plan at the right times.

② Appropriate Personnel Planning and Fostering of Young Researchers

Since Large Projects require a lot of personnel over a long period, the Project should be implemented with staff not only from the implementing body (core institution) but also from collaborating institutions and other research communities. With a shortage of human resources in various fields, it is essential that project plans be formulated from a concrete perspective, particularly with regard to the securing of project personnel.

Moreover, it is important to prepare an environment that can ensure that young researchers and others (including technical staff and research assistants) can participate actively in the projects and gain diverse experience. This will lead to the fostering of human resources that will support the project field in the future and is essential for making the project sustainable. It is particularly desirable to develop human resources who will support research in Japan from a long-term perspective, such as by proactively appointing young people to positions of responsibility in international joint projects. Such human resource development initiatives are also important from the perspective of creating career paths for young researchers. Sufficient consideration should be given to providing appropriate career support that will enable young researchers to make use of their experience and be active even after the project ends.

③ Strengthening of Risk Management Capabilities

As various research facilities and equipment are becoming more sophisticated and larger in scale recently, many Large Projects are being planned and executed through international collaboration. While this is desirable in terms of ensuring the success of a complex project by combining the strengths of each country and fostering human resources through international brain circulation, it also presents the risk that various changes in the international situation could affect research activities. Moreover, for large-scale facilities and equipment to be installed overseas, new developments in the local situation could greatly impact the research plan.

In implementing such international joint projects, the implementing body must exercise strong leadership and strengthen project management so that it can deal with various unforeseen circumstances, and put into place a system that will mitigate risks and deal appropriately with unexpected situations.

④ Appropriate Measures against Facilities Deterioration and Safety Management

Many of Japan's large-scale research facilities were built and started operations 20 to 30 years ago, and the serious deterioration of the core parts of the facilities is becoming a major problem. Since the research facilities and equipment built and installed for Large Projects are expected to be in operation for long periods of several decades, it is necessary to fully incorporate maintenance procedures and measures against deterioration into the project plan in advance.

This is related to the most important aspect of the Project: the safe and stable operation of the facilities. The Project must be carried out based on thorough discussions, including with the research community, on striking a correct balance between the upgrading of equipment, its operation, and measures to deal with aging equipment.

⑤ Promotion of Initiatives for Gaining Public Understanding

It has already been mentioned that Large Projects must be carried out with the support of society and the public. Although the research content and scientific objectives of Large Projects may be difficult for the general public to grasp at first glance, it is essential to proactively and continuously disseminate information that is easy to understand about the Project through the mass media, SNS, and other channels. In particular, outreach approaches to young people will contribute to the fostering of talented young researchers engaged in future research, and multifaceted initiatives for promoting relevant awareness activities in collaboration with educational institutions are important.

In addition, since many research facilities handle materials that require strict management, it is essential to gain the understanding of local residents to ensure the stable operation of the facilities. Continuous and careful dialogue with society over the long term and building trust with the public by the appropriate disclosure of a variety of information are essential.

All of these cautionary points are not only common to many Large Projects but also relate to issues facing the research environment in Japan in general. The various initiatives that have been undertaken based on these important points to note, as well as the issues that have actually occurred in Large Projects and the process for solving them, are valuable lessons that many other projects can profit by. It is hoped that the sharing of such experience of both success and failure across a broad range of fields will lead to better research activities.

(2) Proper Evaluation and Progress Management

In addition to formulating the Road Map, the Working Group is also evaluating and managing the progress of the "Frontier Projects" that are being implemented based on the Roadmap. In promoting the projects listed in the Roadmap, the Working Group will also need to appropriately follow up on the status of the responses to the issues and the cautionary points pointed out in this report.

The evaluation and progress management of the "Frontier Projects" will be conducted in line with the "Management of Large-Scale Academic Research Projects" guidelines (approved by the Working Group in April 2023). The implementing organizations will also be expected to fully understand the project aims and objectives detailed in the guidelines before beginning implementation of their projects.

Conclusion

The Working Group has been formulating Roadmaps to bolster the strategic and systematic implementation of Large Projects. The Large Projects listed in the Roadmap up to now have been steadily progressing with the support of the government, and it is essential that this system be fundamentally maintained while undergoing continuous review and further development in order to deepen collaboration between the research community and academic administrations.

Extremely long-term research is required to obtain new knowledge in basic science. Based on the priorities stipulated in the Roadmap, we urge the national government to make all efforts to ensure stable and continuous funding from a long-term perspective in order to steadily move forward with these excellent Large Projects.

Furthermore, we hope that not only individual Large Projects will be promoted, but that, by participating in the Roadmap formulation process, researchers will be able to confirm the position of their own research in light of trends in the global research community and the future direction their research should move toward, thus contributing to the overall development of academic research.