Cross-ministerial Strategic Innovation Promotion Program (SIP)

Research and Development Plan on Innovative Technologies for Exploration of Deep Sea Resources

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Cabinet Office, Government of Japan
Bureau of Science, Technology and Innovation

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Overview of the Research and Development Plan

1. Introduction

Japan is a maritime nation surrounded by seas on all sides and has the world's sixth largest ocean area with the inclusion of its exclusive economic zone (EEZ). The country oversees and benefits from marine waters some twelve times the size of its land area. The seafloor slopes steeply offshore from its coasts into the deep sea, which has been identified as an area with high potential for mineral resources essential for sustainable economic and social development. If the development of rare mineral resources found in the deep seas within Japan's jurisdiction becomes economically feasible, it will not only provide a steady supply to help develop its key industries, but will also significantly contribute to its national security.

The 1st Period SIP Ocean program, Next-generation Technology for Ocean Resources Exploration (SIP 1), launched the research and development (R&D) of marine mineral resources such as hydrothermal deposits, cobalt-rich crusts, and rare-earth deposits. From the project's third year, the main target for R&D was focused on sub-seafloor hydrothermal deposits at depths of less than 2,000 m. On the other hand, mineral resources have been found to exist in large quantities even at water depths exceeding 2,000 m. For example, deep sea mud with rare-earths in the waters around the island of Minamitori-shima has drawn interest in Japan for its valuable resources. However, the deposits are located at the abyssal ocean floor at 5,000 to 6,000 m depth. Developing these resources will require research breakthroughs that far exceed those needed to develop offshore oil and natural gas; the technologies for exploration and recovery have not been established yet anywhere in the world.

The Third Basic Plan on Ocean Policy formulated in 2018 called for the promotion of development and use of marine mineral resources and laid down an integrated approach from the government toward research, development and commercialization of marine mineral resources. Promoting the development of marine mineral resources located deep in the ocean requires wider application of technologies to operate multiple Autonomous Underwater Vehicles (AUVs) in the deep sea achieved in SIP 1 and, in order to raise operational efficiency of AUVs, R&D on a terminal system on the seafloor that provides long-term power supply and data transmission without the need to go to the surface. At the same time, technologies to extract mineral resources from the deep ocean floor and efficiently pump them on board ships have to be developed as well.

The main goal of this project is to develop technologies for marine mineral resources including deep sea mud with rare-earth deposits, which have been considered promising among deep sea resources but have not yet been undertaken anywhere in the world. In other words, the objective is to advance challenging R&D toward laying the foundation for the technologies required to develop deep sea mineral resources in the future. This includes conducting a survey needed to roughly assess the amount of rare-earth mineral resources that has not yet been identified in the seafloor mud around Minamitori-shima and developing the technology to recover highly concentrated rare-earth deposits identified by the resource survey from the deep sea bottom to a ship. A system will be built that can simultaneously operate multiple AUVs efficiently in the deep seas, which will be necessary in order to carry out surveys of deep sea mud containing rare-earth metals and other operations over a wider area in the future. The project aims to establish world-leading technologies capable of collecting and recovery of deep sea mineral resources mud, which are impossible with current technologies, by dramatically improving the efficiency of exploration on deep sea resources (by more than 30 times), developing the world's most advanced exploration system that will enable surveys of oceanic waters at depths of up to 6,000 m (accounting for 94% of the Japanese EEZ), and transferring the technologies to the private sector.

2. Research Subjects

The main subjects for R&D are given below. Research and development can be broadly divided into three areas, namely survey and analysis, technological development and system verification, and will be undertaken through four themes. However, Themes 1, 2-1, and 2-2 will be carried out with mutual collaboration between themes rather than independently of each other, in consideration of the exit strategy of technology transfer in Theme 3.

(A) Theme 1: Survey and Analysis of Marine Mineral Resources
(B) Theme 2-1: Development of Survey Technologies
(Operations of Multiple AUVs and a Terminal System to Recharge AUVs in the Deep Ocean Resources)
(C) Theme 2-2: Development of Production Technologies
(Collecting and Lifting of Rare-earth Deposits)
(D) Theme 3: Verification of Survey and Development System

3. Implementation Structure

The Program Director (PD), Shoichi Ishii, is responsible for the management of the entire program from a strong governance perspective and performs the program management integrally in the following manner. The technological development and accumulation of know-how in Themes 1, 2-1 and 2-2 will be carried out with the participation of private sector companies. For Theme 3, the theme leader is appointed from the private sector and the private sector will take the lead with the aim of finding practical applications and commercialization of the survey and development systems. To achieve these goals, the PD will establish a management structure with full vertical and horizontal cooperation and that integrates all the theme leaders and Management Agency representatives.

In addition, the Cabinet Office's National Ocean Policy Secretariat, Ministry of Education, Culture, Sports, Science and Technology (MEXT); Ministry of Economy, Trade and Industry (METI); the Japan Oil, Gas and Metals National Corporation (JOGMEC); Ministry of Land, Infrastructure, Transport and Tourism (MLIT); and the National Institute of Maritime, Port and Aviation Technology (MPAT) have been actively collaborating since the beginning of the project.

Furthermore, through the establishment of the Advisory Board, which is composed of experts from industry, academia and government, to give advice to the program from the standpoint of science and engineering, and the creation of the collaborative/cooperative structure in the Promotion Committee, which is based on the collaboration of nine ministries, the program is under an “All- Japan” organization of industry, academia and government working for the further advancement of technologies for ocean resource exploration for Japan’s future.

4. Intellectual Property Management

The Intellectual Property Committee shall be placed under the Management Agency or the research institution of the principal investigator contracted by the Management Agency to properly manage intellectual property, provide incentives to inventors and persons contributing to commercialization, and increasing benefits to the public.

5. Information Management

In carrying out the program, its scope shall first be clearly defined and a rigorous information management system for the program will be established to maintain rules and regulations. In addition, the Management Agency shall take necessary measures in accordance with the Common

Standards Group for Information Security Measures for Government Agencies and Related Agencies (FY2016) stipulated by the Japanese government.

6. Evaluation

Each year, prior to the evaluation conducted by the governing board and the evaluation by the evaluation working group organized by the lead program, the PD will perform a self-assessment, after which various reviews by the Advisory Board and self-evaluation in the Promotion Committee will be carried out in preparation for the SIP governing board evaluation.

7. Exit Strategies

The survey and exploration technologies developed in the program will be verified for their practical application and effectiveness, the technologies will be strategically transferred, and a business model for deep sea resources will be developed to make them commercially available to private sector companies. Private sector companies that have received the technology transfer will provide exploration tools for deep sea surveys in Japan and overseas, services for deep sea resource survey technologies, services for applied technologies, services for deep sea resource production technologies, etc. The goal will be to develop a system that provides a wide range of opportunities to use the technologies and foster industries. Through close collaboration between industry, academia and government, a framework will be developed to ensure that the outcomes of the R&D can be successfully passed on and developed further into the future to revitalize the marine survey industry.

1. Introduction

1.1 Background and Current Situation in Japan and Overseas

Japan lacks natural resources and has relied on imports for much of its energy and resource needs, which makes the infrastructure that supports people’s lives and industries vulnerable. In particular, Japan is dependent on specific countries producing many of the rare nonferrous metal mineral resources that are indispensable for sustainable economic development. And with the rapid expansion of global demand for these resources in recent years, it is imperative for Japan to secure a stable supply.

Meanwhile, recent studies have discovered and estimated the high potential of such minerals resources (including rare-earth elements) in the deep seas within the Japanese EEZ.

In response to the supply risk for rare metals, measures such as diversification of supply sources, recycling promotion, development of alternative materials, and stockpiling have been implemented. But even though the prices of rare metals have lately been stable, the structural problem has yet not been resolved. If along with these measures, the potential for production within the Japanese EEZ can be identified and a set of technologies ranging from surveying to production can be developed and verified, then such efforts will greatly contribute toward ensuring a stable supply and the national security of Japan in the future.

Furthermore, there has lately been an active push for seabed exploration and ocean research in other countries with the aim of securing interests in marine resources and sustainable ocean use. These trends have been particularly notable in the waters surrounding Japan. Japan has so far focused on building up world-class oceanic research capabilities, but as competition from other countries becomes more intense, there is now a need to strengthen our international competitiveness by building on the nation’s strengths even further, integrating the individual components of marine technologies into a system, and developing world-class marine research services that leverage these technologies.

1.2 Significance and Importance of the Policy

Japan is the sixth largest maritime nation in the world, controlling about 12 times its land area. Its offshore seas are deep with precipitously sloped seafloors. One striking feature of these waters is that 65% of the entire area have a depth of 2,000 to 6,000 m (see Figure 1-2). These oceanic regions have been identified as sites with high potential for marine resources such as cobalt-rich crust, methane hydrate, and rare metals. If the development of rare mineral resources in the deep seas within Japan's jurisdiction becomes economically feasible, it will not only provide a steady supply to help develop its key industries, the development will also significantly contribute to its national security.

The Third Basic Plan on Ocean Policy, which was approved by the Cabinet in May 2018, also makes the importance of developing marine mineral resources clear by stating, “As well as further strengthening and developing the technologies for marine resource exploration and production developed in the past, we will pioneer initiatives to develop and demonstrate these technologies at depths below 2,000 meters with an eye to turning basic research into commercial and practical applications.”

Under the SIP framework, industrial, academic and governmental institutions collaborate with the relevant ministries to promote “All-Japan” R&D in order to achieve the goals that address the abovementioned policy and other policy issues that are vital to the nation. It is essential to create a productivity revolution for deep sea resource development by implementing the results of R&D as a practically applicable system for the private sector. In addition, it is important to build the world's first deep-sea system for operating multiple AUVs, develop the technology for creating high-resolution subseafloor geological maps, try to establish the core technologies that will make it possible to assess the amount of resources in high-concentration zones, and undertake projects to develop these zones.

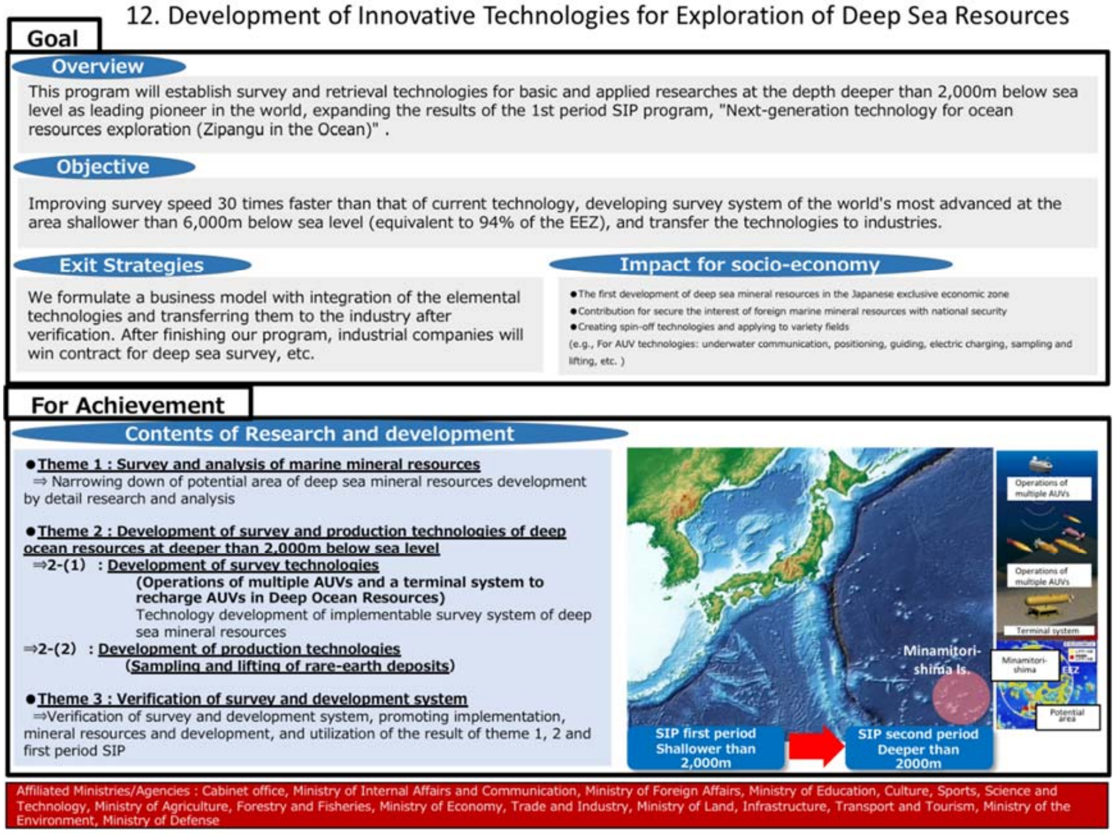
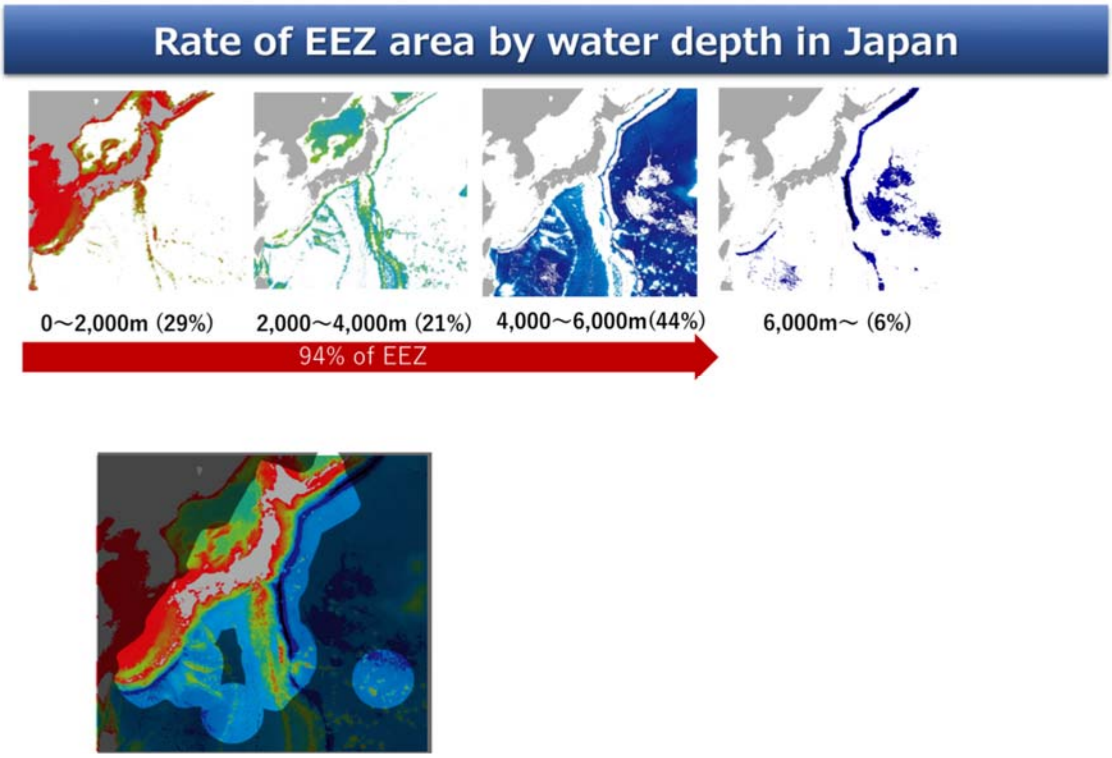


Figure 1-1. Overall concept of the Innovative Technologies for Exploration of Deep Sea Resources



(Source: Information processed from the Ocean Newsletter, Ocean Policy Research Institute)
Figure 1-2. Percentage area of Japanese EEZ by depth

1.3 Objectives and Aims

1.3.1 Realizing Society 5.0

〇With the prospect of dramatic improvements in ocean exploration efficiency accelerated by progress in automation and remote operation, marine R&D is now entering a new stage. We are now not limited to exploration from ships on the ocean surface; the role of surface and underwater robots, such as AUVs, and the use of satellites has become more important than ever in order to comprehensively grasp the conditions of the deep, vast ocean.

〇Leveraging near real-time big data acquired through ocean exploration using robotics and state-of-the-art sensors, it is now possible to freely explore the deep sea resources lying out of human reach by using artificial intelligence (AI) to create integrated control of exploration systems and provide visual displays based on value and purpose. This is expected to broaden the policy options available for a country with scarce resources such as Japan.

〇Through the merging of cyber and physical space, it is now possible to transcend the barriers of extreme environment that characterize the deep ocean and fully enjoy the blessings of the vast ocean. This will greatly contribute toward transforming the Japanese economy and help lead to the realization of Society 5.0.

〇Surveying the entire seabed at depths of less than 2,000 m (30% of the EEZ = 3.4 times the national land area) using the results of SIP 1 will require more than a hundred years. However, if the outcomes of the 2nd Period Ocean SIP program (SIP 2) are used, the survey can be completed within 10 years even when the vast ocean floor at depths of up to 6,000 m (94% of EEZ = 11 times the national land area) are included. At present, methods for producing deep sea mineral resources have yet to be established, production will be possible for the first time in the world if the outcomes of SIP 2 are used (5 years from now). The use of production technologies based on deep sea data over a wide area obtained by the survey technologies that are being developed will not only dramatically improve the efficiency of deep sea mineral resource production by Japan, but will also provide a global advantage in terms of ensuring resources and national resource security.

1.3.2 Social Goals

〇The development and use of the vast ocean are a foundation of Japan's economy and society, while at the same time preservation of the marine environment is also a foundation for humanity’s future survival. Thus, securing interests in marine resources and sustainable ocean use have become critical issues globally.

〇Our goal is to develop and verify the core technologies that will enable the development of potential resources in the deep seas and create a framework for effectively transferring technologies and know-how for industrialization, through close collaboration between industry, academia and government.

〇We will also build a sustainable model to fully enjoy the bounties of the sea and awaken a wide range of interest from the public, especially among young people who will lead the next generation, to take up the challenge of uncharted frontiers.

1.3.3 Industrial Goals

〇Rare metals are scarce resources that support Japan's key industries, which are mostly produced in specific countries, and have issues related to stable supplies caused by the uneven distribution of resources. We therefore aim to determine the potential for producing rare metals from deposits available within our EEZ and to develop and verify a set of technologies ranging from surveying to production. This will contribute toward ensuring a stable supply of rare metals and national resource security in the future.

〇The use of robots and big data to efficiently explore and manage Japan's vast EEZ will produce a considerable ripple effect on a wide range of social and economic fields such as shipbuilding, marine transportation, fisheries, construction of civil works, communications, environment, and ocean defense.

1.3.4 Technological Goals

〇To allow for resource development within the ocean’s extreme environment, we must overcome the tough challenges that are beyond what are expected on land or in shallow waters. We therefore plan to bring together the knowledge from various fields, such as marine engineering, robotics and resource engineering, with the aim of developing component technologies, as well as creating an integrated system with a view toward future commercialization.

〇Technologies developed in this program will likely be applicable to a variety of fields. We will promote collaboration and networking with other fields and industries in order to generate innovation, which will hopefully lead to many spin-offs.

1.3.5 Institutional Goals

〇We will help create the guidelines for environmental impact assessment of various collection and retrieval methods, such as by predicting the spreading of mud on the seafloor that may occur in future development projects.

〇In light of the international trends as exemplified by the United Nations Convention on the Law of the Sea (UNCLOS), we will investigate and consider legal issues as well as define the issues moving forward, in order to manage both the preservation of the marine environment and the development of mineral resources.

〇We will provide data and a scientific foundation on sustainable use of the ocean in order to enhance our role in international forums.

1.3.6 Global Benchmarks

〇Japan has focused on cultivating world-class oceanic research capabilities, such as for example the observation of global environmental changes from ships and buoys, manned and unmanned underwater exploration in the deep seas, seismogenic zone and subseafloor biosphere excavation using the Deep Sea Scientific Drilling Vessel “*Chikyu*”, and the installation of an observation and monitoring system of submarine cables called the Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET).

〇AUVs are expected to play a leading role in ocean surveys in the future. Although several countries have individual AUV technologies that are more advanced, no country has a system for conducting complete resource exploration that combines various technologies, including environmental impact assessment. By improving on the results of SIP 1, it will be possible to offer world-class marine research services.

〇We can build on Japan's strengths by focusing on deep sea mineral resources, such as the rare-earth elements found at water depths of more than 2,000 m, which are extremely rare globally, and conduct intensive R&D as well as technological demonstrations.

1.3.7 Collaboration with Local Governments

〇The island of Minamitori-shima is part of Ogasawara Village, Tokyo and is located at the easternmost part of Japan about 1,950 km away from Tokyo. A 1,370 m airstrip has been constructed with regular departures and arrivals of Japan Self-Defense Force aircraft; Japan Meteorological Agency staff; and other personnel who are stationed on the island. A development project is underway for specific remote island port facilities that will serve as a base for activities on the conservation and use of EEZ and other ocean areas, in accordance with the Act on the Preservation of Low-Water Line.
〇When exploring the waters around Minamitori-shima, it may be possible to use the island as a base for supplies and exchanging personnel. Collaboration with the Tokyo Metropolitan Government and related ministries and agencies will be vital for its smooth implementation.

2. Research and Development

A. Theme 1: Survey and Analysis of Marine Mineral Resources

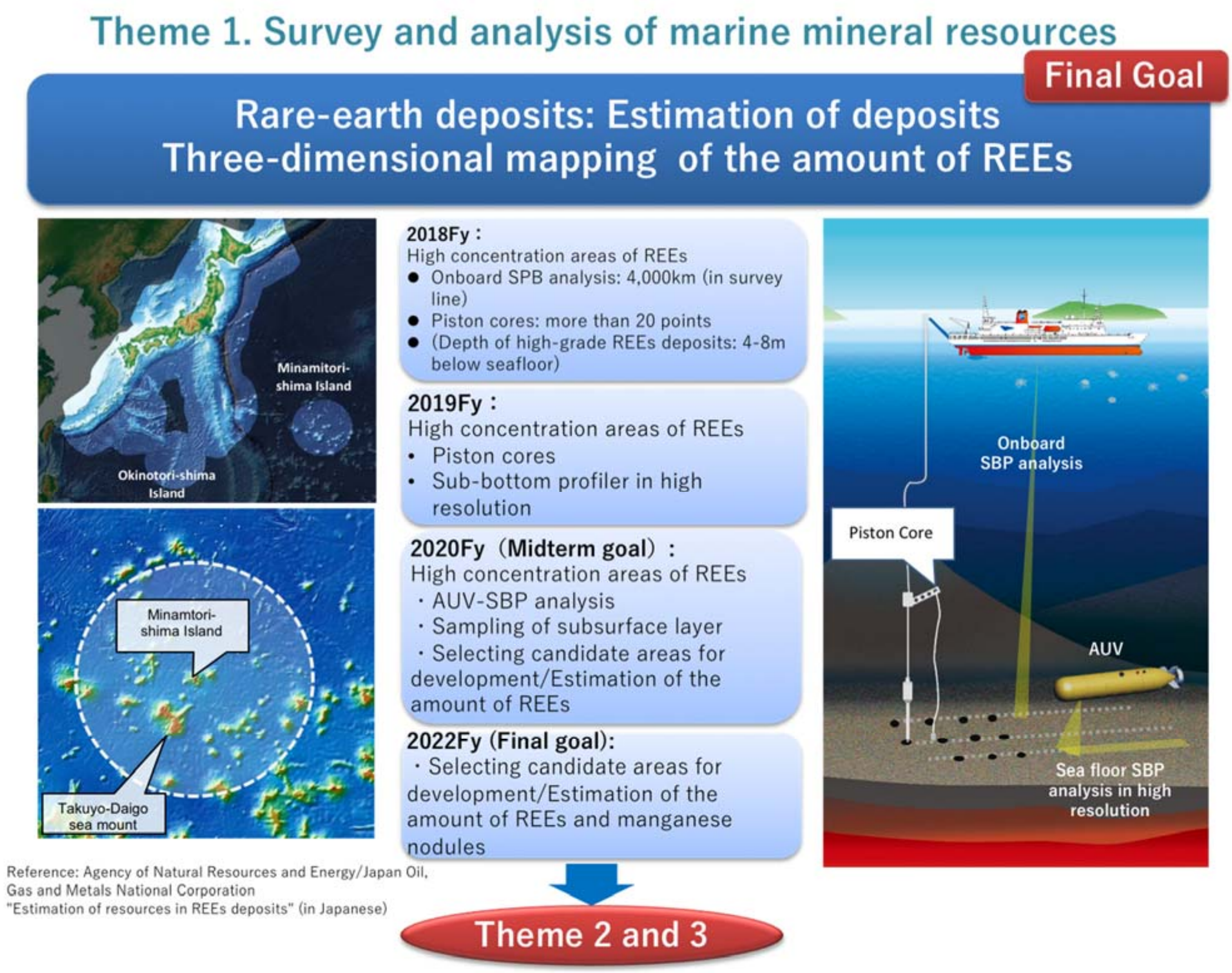


Figure 2-1. (A) Research and technological development goals

A.1 Goals of R&D/technology development

[Summary]

After narrowing down the number of sites with high development potential across zones with high concentrations of rare-earth deposits around the waters of Minamitori-shima, we will provide information on the location and quality of high-concentration layers at sites slated for technological development in Theme 2-2: Development of Production Technologies (Collecting and Recovery of Rare-earth Deposits) and others, and conduct a rough assessment of the amount of resources at these sites. In selecting sites, we will also study the density and composition of manganese nodules distributed on the surface layer and evaluate their resource value.

We will add existing data to the data obtained, conduct sedimentary facies analysis and geological mapping of the surface layer using seismic stratigraphy, and identify various geoscientific indicators. In addition, we will conduct a high-resolution sub-bottom profiling (SBP) survey on the seafloor using AUVs, which are operable up to a depth of 6,000 m and which will be adopted in Theme 2-1: Development of Survey Technologies (Operations of Multiple AUVs and a Terminal System to Recharge AUVs in Deep Ocean Resources). We will then compare the survey results with those from shipboard SBP to verify the seafloor SBP data. To date, no other country has reported conducting assessments of seafloor resources of rare earths.

A.2 Organization

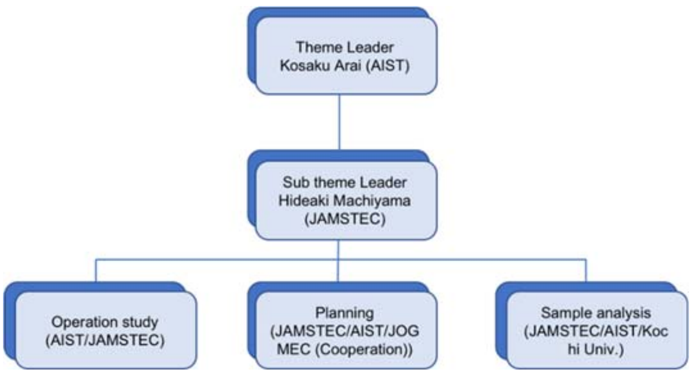


Figure 2-2. Organization chart (A)

[Procedure]

(1) To determine the thickness distribution of seabed sediment layers that may potentially show high concentrations of rare-earths by using shipboard SBP, we will conduct a marine survey scaled down to intervals of several kilometers, using a research vessel from FY2018–2020, while previous data had been obtained at intervals of 3.75 minutes (1/16 degrees, approximately 7 km). We will also perform detailed analysis and evaluation of the SBP data obtained.

(2) Using the data from step (1) above, we will assess the continuity of layers with concentrations of rare-earth elements (REE+Y) by using a piston corer (PC). In particular, we will conduct a marine survey from a research vessel in FY2018–2020 scaled down (to several kilometers over areas that were indicated as possibly having shallow subseafloor concentrations by the SBP survey) to 3.75-minute intervals from the 7.5-minute (1/8 degrees, approximately 14 km) grid in the previous year’s survey. We will also analyze and evaluate the geological layer sample data we obtain.

(3) We will conduct quantitative surveys from FY2020–2021 to determine the concentration, composition, and distribution of manganese nodules that were found to be distributed in large quantities on the seafloor during the FY2018 research cruise. We will also perform analysis of

SBP reflected intensities, which were taken during the high-resolution seafloor SBP survey using 6,000 m class AUVs, together with survey and analysis by using image data.

(4) We will analyze the results of steps (1) and (2) above and assess the approximate amount of rare-earth resources in the mud in FY2020.

(5) We will assess the approximate amount of resources combined with those from step (3) above by FY2022.

(6) Using the assessments in steps (2) and (3), we will conduct a high-resolution seafloor SBP survey using the 6,000 m class AUVs to be introduced in Theme 2-1 to verify the validity of the data.

For the implementation, JAMSTEC and the National Institute of Advanced Industrial Science and Technology (AIST) will draw up the plan with collaboration from JOGMEC under the direction of the theme leader. AIST will primarily conduct the surveys, while JAMSTEC will take the lead in carrying out the plan for sample analysis.

A.3 Related ministries and agencies: Cabinet Office, MEXT, METI, Ministry of Defense (MOD) (Acquisition, Technology & Logistics Agency (ATLA)),

B. Theme 2-1: Development of Survey Technologies (Operations of Multiple AUVs and a Terminal System to Recharge AUVs in Deep Ocean Resources)

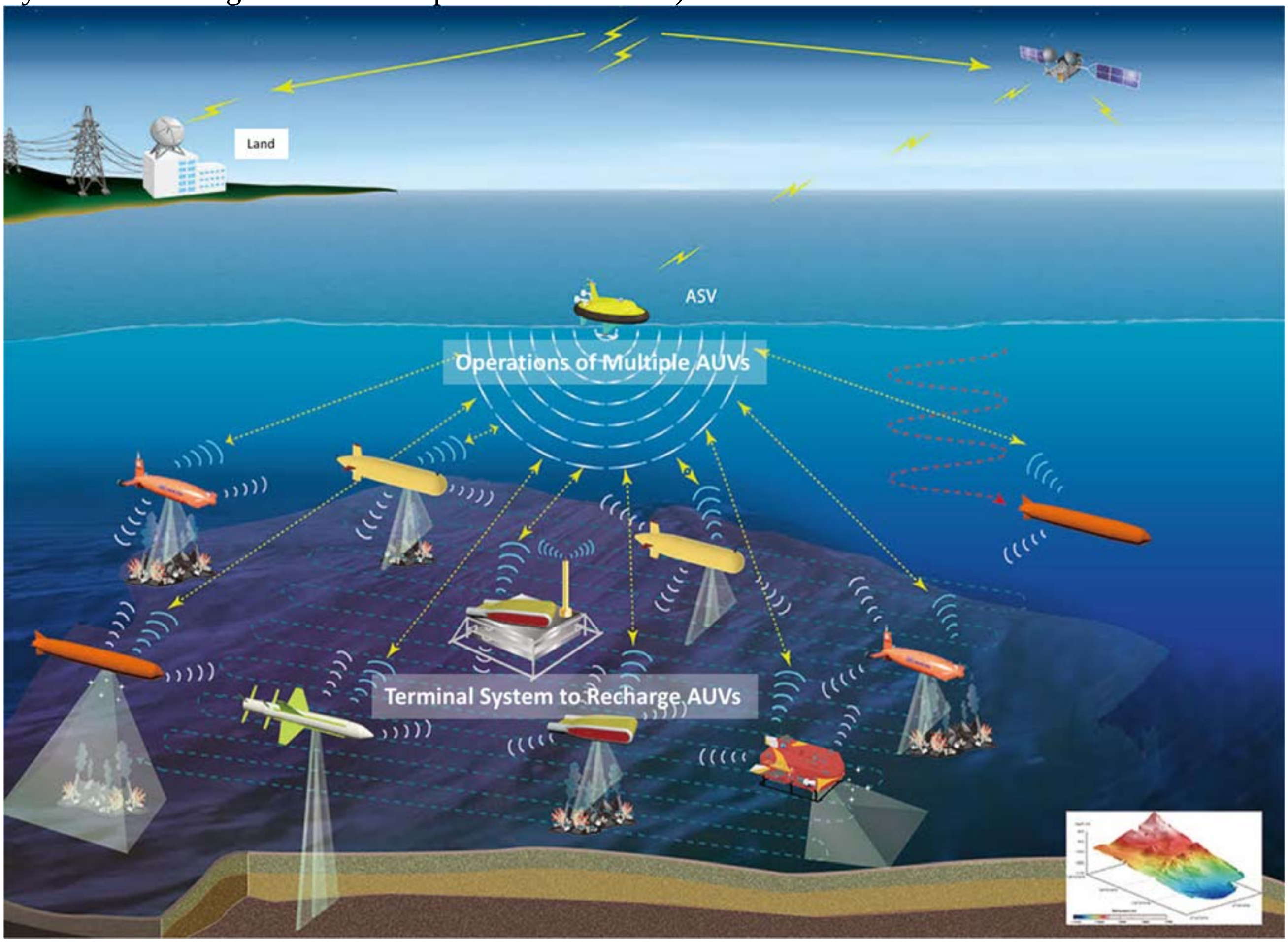


Figure 2-3. (B) Research and technological development goals: Development of survey technologies for deep ocean resources

B.1 Goals of R&D/technological development

[Summary]

In order to build a viable deep ocean resource survey system, we will develop the technologies for operating multiple deep sea AUVs that can efficiently survey detailed bathymetric feature and subseafloor structure with multiple AUVs, as well as the technologies for a terminal system on the deep ocean floor that will enable sustained surveys over long periods of time at ocean depths of more than 2,000 m. For the first goal, we will demonstrate multiple AUV operation using five AUV units so that we can get a technological prospect for the operation of 10 units, while for the second goal, we will demonstrate a terminal system for battery recharging AUVs on the deep ocean floor capable of operating continuously for more than 5 days as a target to get a technological prospect for future operations. Therefore, we set intermediate and final goals using the step-by-step approach shown below. Details of the R&D plan will be reviewed each fiscal year and development will proceed depending on the progress of research.

○ First stage: For multiple AUVs, we will develop a system capable of both acoustic precision positioning and communicating simultaneously and a terminal system for recharging on the deep ocean floor, and then conduct underwater demonstrations in stages up to a depth of 2,000 m. Second stage: To expand the developments which have been demonstrated in the first stage and confirm their technical usefulness, we will conduct a long-term underwater demonstration test at a depth of 2,000 m using a deep ocean floor terminal designed for a depth of 6,000 m.

○ Expected outcome: In SIP 1, ocean floor resource surveys had mainly targeted hydrothermal deposits. However, by making it possible to conduct surveys deeper than before at more than 2,000 m depths and by establishing resource Deep Ocean Resources technologies capable of long-term survey, this R&D will enable us to survey rare-earth deposits and other resources that are found in deeper parts of the ocean, thereby encouraging further exploration and development of ocean floor resources.

○ Positioning with respect to the state-of-the-art: At present, the world's most advanced technology for operating multiple AUVs in Europe is a system that requires one Autonomous Surface Vehicle (ASV) for each AUV. But while multiple AUVs are alternately controlled and positioned by one ASV in SIP 1, the technique results in control/positioning delays, which in turn leads to control difficulties, as the number of units increase. Thus, for this technological development, we will develop an integrated system capable of controlling and positioning multiple AUVs simultaneously with one ASV. Moreover, we will enable near real-time data transfer by dramatically increasing acoustic communication speed, with a view to achieving Society 5.0. Therefore, if the multiple AUV operation is proven to be effective and made practically applicable, it will be the world's most advanced technology of its kind. Furthermore, leading the world in developing a terminal system on the deep ocean floor, which includes underwater recharging and docking technologies at a depth of over 2,000 m, will enable long-term operations without returning to the mother ship and further increase the efficiency of operations.

○ Ripple effects on society: The technology for operating multiple AUVs has yet to be established. Establishing this technology will make it possible to implement it in private-sector marine research and other businesses in Japan and dramatically improve the economic feasibility of deep sea research activities. Moreover, incrementally promoting the standardization of acoustic communications among Japanese companies and conducting demonstrations with the aim of commercializing ocean floor terminals will inspire new industries and technological developments in fisheries, civil engineering, and other fields.

B.2 Organization

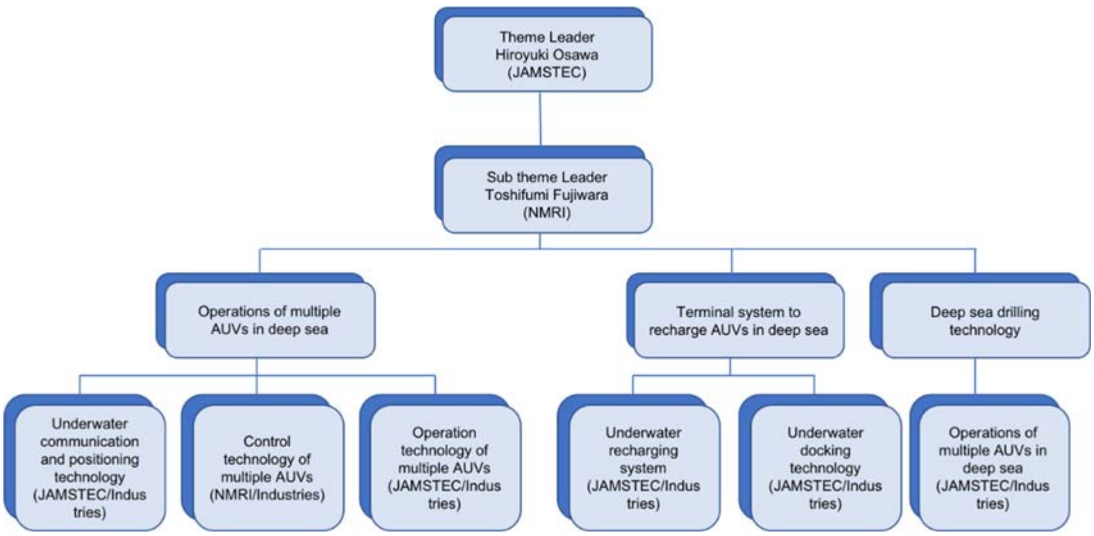


Figure 2-6. Organization chart (B)

[Procedure]
In order to speed up development and make sure that this technology can actually be implemented after the development period, we will in principle carry out the system development using component technologies with technology readiness levels (TRL) of 3 or higher and using methods that combine these component technologies to achieve the development goals. At the same time, we will efficiently carry out the development as an industry, academia and government collaboration including the private-sector businesses and NMRI (National Maritime Research Institute) that are conducting R&D on operation methods for multiple AUVs in SIP 1. To achieve our goals, system development will be carried out using the following component technologies.

- ○ Basic tools required for development of deep ocean resource survey technologies
  First, we will adopt the basic tools that are indispensable equipment and are core to the development of deep ocean resource survey technologies: deep sea AUV (6,000 m specification), ASV and AUV support equipment (acoustic positioning and communications equipment, etc.).
- ○ Development of technology for operating multiple deep sea AUVs
  To achieve the state-of-the-art simultaneous operation of multiple AUVs with one ASV, we will develop a simultaneous control system using the component technologies necessary for group multiple AUVs, such as acoustic communications and positioning. As a mission, we will also equip AUVs with available sensor technologies and the latest R&D equipment, and develop systems to carry out environmental monitoring, detailed measurements of the bathymetric feature and subseafloor structure, etc. Moreover, we will develop group control technology for multiple AUVs to achieve more accurate and more efficient seabed exploration. Furthermore, as part of developing operation technologies, we will develop technologies that will enable over a long time ASV operations, which is indispensable for more efficient explorations.
- ○ Development of a terminal system on the deep seafloor
  We will develop a system capable of recharging and data transmission from the deep seafloor in order to achieve long-term AUV operations in the deep seas of more than 5 days.

B.3 Related ministries and agencies: Cabinet Office, Ministry of Internal Affairs and Communications (MIC), MEXT, METI, MLIT

C. Theme 2-2: Development of Production Technologies (Collecting and Lifting of Rare-earth Deposits)

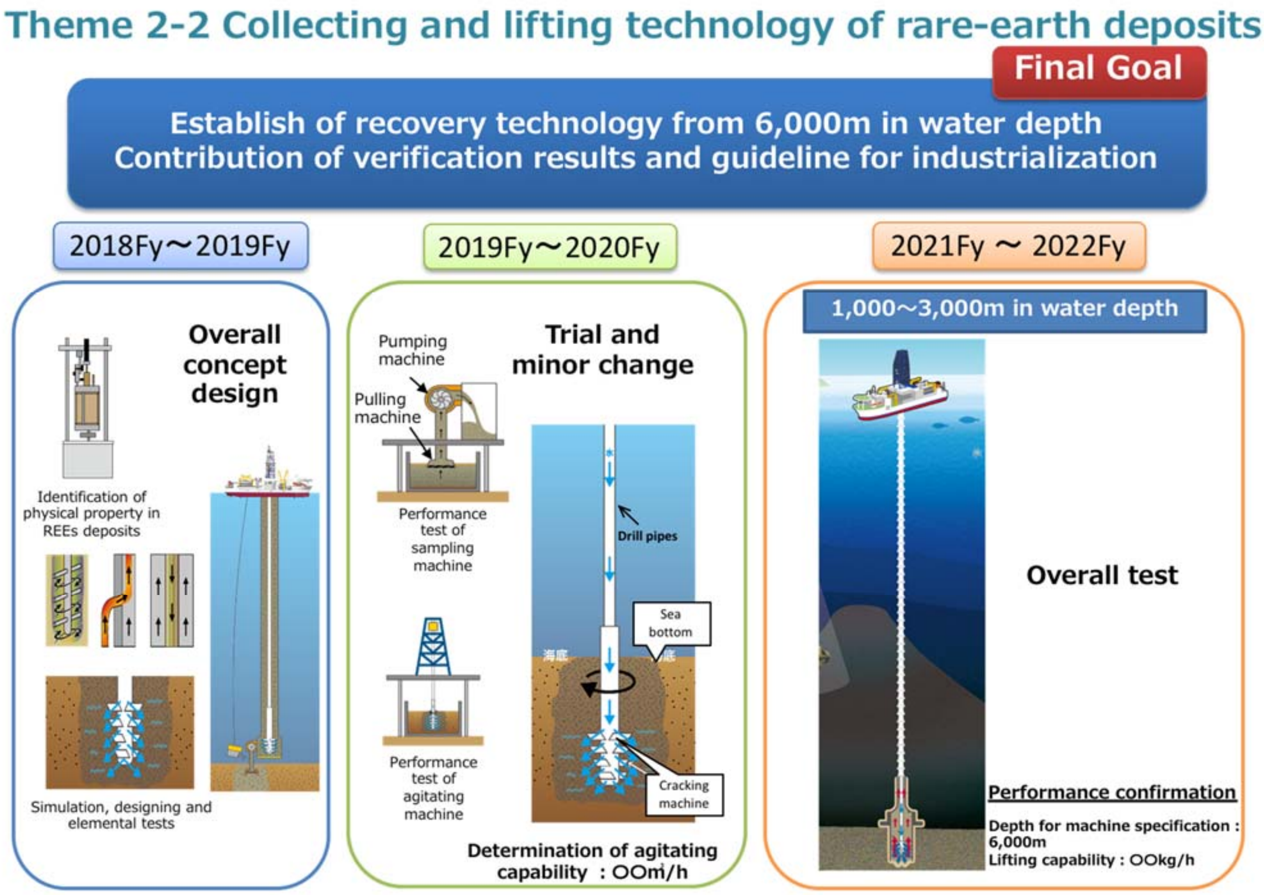


Figure 2-7. (C) Research and technological development goals

C.1 Goals of R&D/technological development

[Summary]

We will help establish world-leading technologies for continuous collecting and recovery of rare-earth deposits in the deep sea mud by the end of FY2022 by using the Deep Sea Scientific Drilling Vessel "*Chikyu*." In particular, we will verify the relationship between efficiency and specifications of the equipment required for each field work in the deep seas, namely mud agitating, collecting and lifting, and contribute to the development of techniques for efficiently collecting rare-earth deposits. This will be accomplished by verifying the series of operations in the actual sea, from mud agitating, which makes it easy to extract and pump up the seafloor mud (containing rare earths); mud collecting, which extracts the mud into the recovery pipe; and then mud lifting, which circulates fluid in the pipe to pump up the mud to the ship.

○ Five-year goal: Acquire knowledge and expertise to contribute to the development of technologies for agitating, collecting and lifting of rare-earth deposits.

○ Expected outcome: Acquire the know-how for agitating, collecting and lifting of rare-earth deposits; acquire the technologies for commercializing agitating, collecting and lifting; and collect basic data.

○ Positioning with respect to the state-of-the-art: In September 2017, JOGMEC succeeded in continuously pumping from hydrothermal deposits on a 1,600 m deep seabed in Okinawa. However, the current R&D aims to acquire the knowledge and expertise on agitating, collecting and lifting technologies for highly viscous rare-earth deposits at 5,000 to 6,000 m depths. These attempts will be a first in the world. If used, the outcome will enable the world's first production of deep sea mineral resources.

○ Ripple effects on society: This will help establish basic technologies for commercializing the development of ocean floor resources such as rare-earth deposits, contribute to revitalizing industries, contribute toward ensuring a stable supply of mineral resources that are essential to Japan as an industrial nation, and lead to national resource security and independence from the influence of other countries' policies.

○ TRL of technologies at present and at completion of the plan (progress of technological development)
Deep sea agitating technology at depths greater than 2,000 m: TRL1 → TRL4
Deep sea collecting technology at depths greater than 2,000 m: TRL1 → TRL4
Deep sea lifting technology at depths greater than 2,000 m: TRL1 → TRL4

C.2 Organization

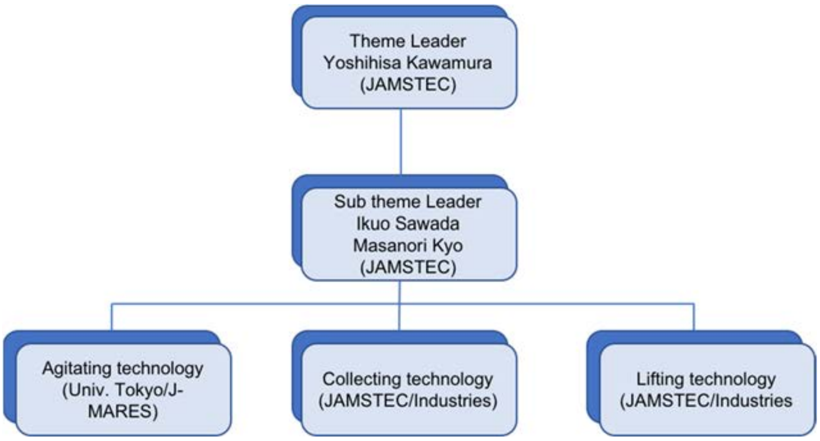


Figure 2-8. Organization chart (C)

[Procedure]

From the very beginning, we will encourage active participation from the private sector in order to complete the R&D within the specified period and increase the likelihood of commercialization after the development period. When deciding on the overall policy, we will conduct reviews and evaluations, while consulting outside experts and others, so that the overall plan is technologically consistent. After deciding on the overall policy, we will utilize the findings of companies with proven achievements for each component technology, while at the same time collect the numerical data and information required for a conceptual study through experiments and numerical calculations, and then complete the conceptual design. During the design and production period after the conceptual design is completed, we will establish an organization in which private sector businesses are integrated and share the work, and then implement the plan under the management and supervision of JAMSTEC. To achieve our goals, we will carry out the following steps.

○ To determine the properties of rare-earth deposits and the upper layer of mud deposits off the coast of Minamitori-shima, and obtain the basic data required for agitating, collecting and lifting of rare-earth deposits, we will carry out numerical calculations and experiments on each component technology and narrow down the requirements for various types of equipment suitable for agitating, collecting, and lifting.

Requirements for individual components will be adjusted to create the best conceptual design that takes into account reducing environmental impact as well.

- ○ Based on the conceptual design, we will set the specifications for 6,000 m-deep agitating, collecting and lifting equipment, and then design and create prototypes for each equipment. For the agitating equipment, we will verify its performance on land, and if necessary, conduct a mud agitating test in shallow waters to verify its performance. Furthermore, we will carry out a test of the strength required from the mud lifting pipe (corresponding to the actual equipment) and design the hoisting tool.
- ○ We will conduct performance verification tests of the prototype mud collecting and lifting equipment on land and create prototypes for the necessary lifting pipe. Furthermore, we will make prototypes of the hoisting tool and verify its shipboard handling.
- ○ We will conduct a performance test to adjust the overall system of agitating, collecting and lifting, set a goal for the overall system, and decide on the underwater location for final verification (water depth). Improvements will be made on each equipment as necessary.
- ○ We will conduct an integrated test of agitating, collecting, and lifting of seafloor mud at a depth of about 1,000 m to verify recovery performance. Technical and operational issues will be identified, improvements will be made to equipment, and operational manuals will be revised.
- ○ We will produce the lifting pipe required for the final verification test underwater.
- ○ We will conduct an integrated test of mud with rare-earth deposits or similar seafloor mud to verify that the desired recovery performance is attained.
- ○ Using basic data related to the recovered rare-earth mud and the various parameters obtained for each equipment, we will verify that the overall system and each component technology can achieve the desired performance in rare-earth muds recovered from a depth of 6,000 m through simulation and other methods.

C.3 Related ministries and agencies: Cabinet Office, MEXT, METI, MLIT, Ministry of the Environment (MOE)

D. Theme 3: Verification of Survey and Development System

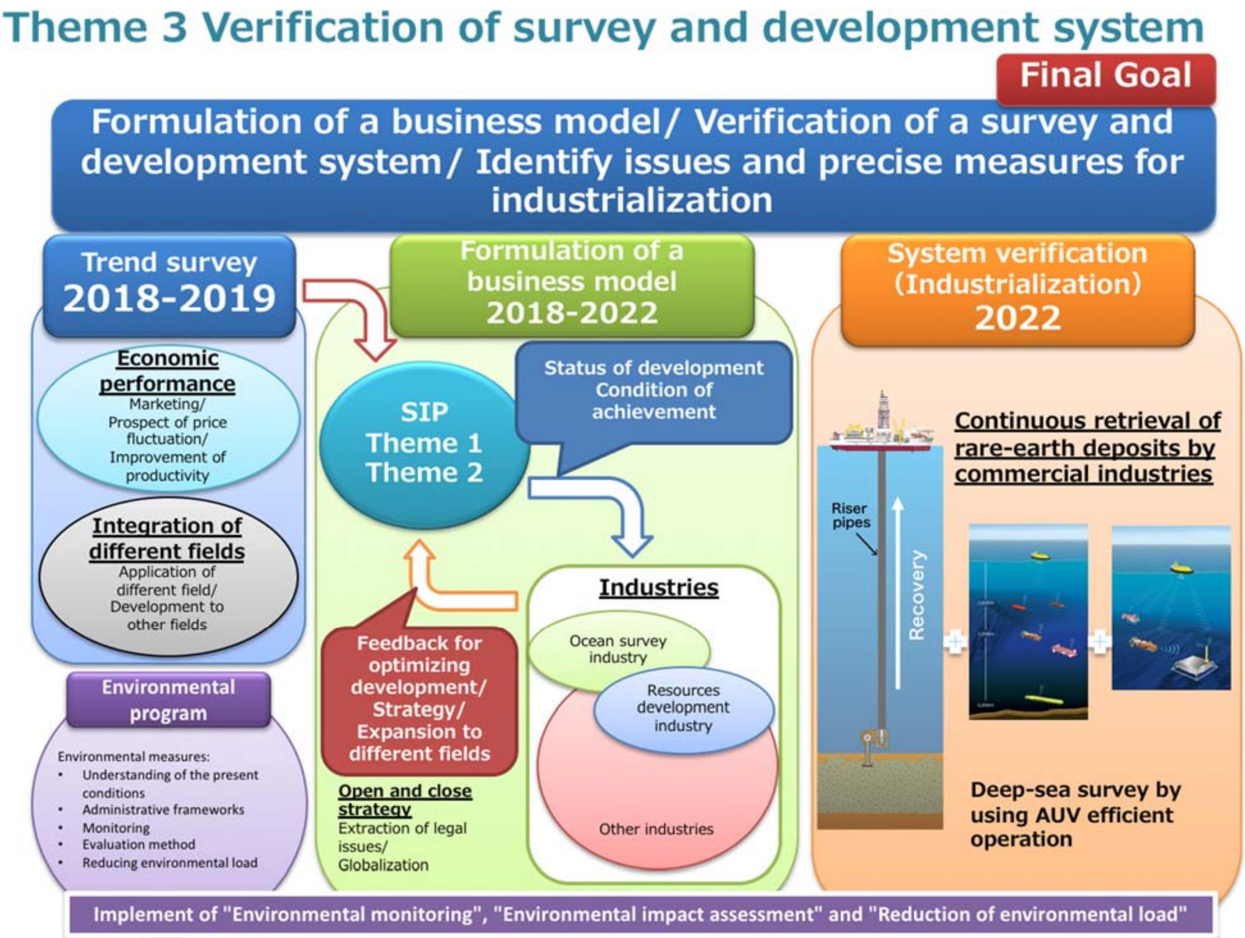


Figure 2-9. (D) Research and technological development goals

D.1 Goals of R&D/technological development

[Summary]

As exit strategies to this program, we aim to create a framework that enables the commissioning of marine surveys to meet various needs and allows for future exploration and development of deep sea resources. A roadmap will be developed for creating a business model for deep sea resources, while passing on and ensuring continued development of the technologies with the active participation of industries. To accomplish this, we need to optimize the survey and development system so that it will be able to properly handle new technological advances and user requests, while taking into account the outcomes available from Themes 1, 2-1, and 2-2 as necessary. Therefore, it is necessary to provide a feedback mechanism in the R&D procedures of Themes 1 and 2. This will allow us to build a framework that creates a virtuous cycle to enhance the competitiveness of technologies that will have been developed, while matching needs and seeds. For the outcomes that will have been developed, we will have to select suitable private sector companies and transfer technologies in stages, and the private sector companies that receive the technology transfer will have to be able to provide research services and conduct project studies for future resource development. We aim to take each step in stages toward commercialization summarized in the series of steps in Theme 3, clearly defining our exit strategies, and transferring the technologies to the private sector through integrated verifications of the survey and development system in actual seas. We will seek active private sector participation from the initial stage of the program, since it is necessary to let the private sector companies themselves develop techniques for conducting surveys at lower costs and build on improvements for efficient operations in order to achieve the exit strategies of commissioning new marine surveys and building a business model for deep sea resources.

D.2 Organization

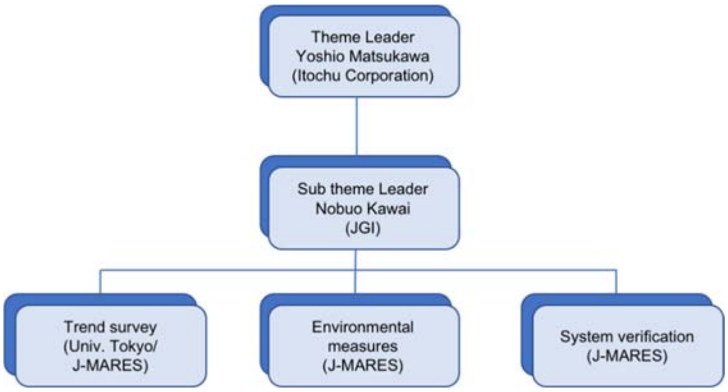


Figure 2-10. (D) Organization chart

[Procedure]

The Research and Development Partnership for Next Generation Technology of Marine Resources Survey (J-MARES) and the University of Tokyo have been selected as the main implementing organizations through public solicitation. J-MARES is responsible for all four tasks below, while the University of Tokyo is in charge of trend surveys (related to rare-earth deposits) and cost reductions related to environmental monitoring. To help advance the theme goals, we invited a theme leader from Itochu Corporation (Itochu) to underpin the system verification, business model, and exit strategies, and a sub-theme leader from JGI on behalf of J-MARES, which has participated in the verification of the integrated marine resource survey system since SIP 1, to strengthen the process.

○ Survey and analysis of trends in Japan and overseas

In the first stage (FY2018–2019), we will conduct a comprehensive survey and analysis of domestic and overseas trends related to deep sea resource development to identify issues for commercialization. In particular for economic feasibility, we will analyze the future supply and demand outlook and price trends of rare metals assuming various scenarios and collect a wide range of information on the potential for market development and improving profitability. Furthermore, we will encourage the integration of different fields by steadily strengthening cooperation with the best partners while observing trends in related technologies, so that we can adopt and apply cutting-edge technologies in other industries, or conversely, design spin-offs to other fields.

○ Environmental considerations

We will compare and verify mining on land and under water in relation to environmental measures. From the first year of the plan, we will use the environmental impact assessment method (including developed equipment) that was an outcome of SIP 1 and begin preliminary environmental monitoring (such as ecosystem surveys using images and biological distribution surveys using genetic tests) in waters where rare-earth mud recovery demonstrations are planned in the future.

Based on the data obtained from these efforts, we will review methods for reducing environmental impact while paying particular attention to balancing both environmental conservation and economic potential in light of international trends and in anticipation of future commercialization.

○ Formulation of a business model

Putting deep sea resource development on track for commercialization will require technological prowess, financial power, and management skills to overcome many tough challenges. Creating an optimal system by combining unique technologies and harnessing the strengths of business enterprises are essential to beating the global competition. It is important to aim for successful commercialization by building strategic partnerships with the participation of motivated companies in the fields of marine engineering and resource development, as well as from other fields. In setting up this business model, we will define our open/close strategy to clearly distinguish the information and know-how that should be kept confidential and intellectual property that should have exclusive rights secured through patents from the methods and models that should be shared and disseminated through international standardization as well as define the policies for their management and use. For example, the Japan Fisheries Research and Education Agency (FRA) has already been studying applications of ocean floor surveying technologies, especially the long-term AUV operation system including the ocean floor terminal, to fishery resource surveys, aquaculture production processes, etc.

○ System verification

In FY2022, we will conduct the comprehensive system verification as a step toward creating a deep sea resource business model. This will be accomplished by comprehensively combining the technologies that have been developed to date and conducting an integrated test in the deep seas with the participation of core private sector companies. We aim to carry out the system verification where it will be most effective, in the seas around Minamitori-shima Island where rare-earth mud exists at depths of 5,500 m to 6,000 m, in order to ensure the prospects for future commercialization. However, the final selection of the scope and location of system verification will be determined objectively in the evaluation stage of the second to third year, based on the results obtained so far as well as on social trends and prospects, and from the standpoint of maximizing R&D results under time and financial constraints. Through this process, we will facilitate the transfer of the acquired technologies and know-how to the private sector and establish a solid foundation to support the succession and continued development of the technologies for future commercialization.

D.3 Related ministries and agencies: Cabinet Office, MIC, MEXT, Ministry of Agriculture, Forestry and Fisheries (MAFF), METI, MLIT, MOE, MOD (ATLA), Ministry of Foreign Affairs

3. Implementation Structure

3.1 Leveraging Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

This project will be implemented with the structure given in Figure 3-1 using operating expense grants to JAMSTEC.

JAMSTEC will assist the PD and Promotion Committee and provide the cooperation necessary to review the R&D plan, manage progress and funds for R&D, provide administrative support work for self-assessments, make evaluation documents, and conduct related research and analysis. In addition, it will coordinate the shared use of ships, using its wealth of expertise on marine R&D to carry out more efficient R&D. JAMSTEC separately manages grants for SIP operating costs from other grants. When undergoing audits based on the provisions of Article 39 of the Act on General Rules for Independent Administrative Agencies (Act No. 103 of July 16, 1999), audits will be conducted to ensure that accounting is performed appropriately and in keeping with the management system.

3.2 Appointment of Principal Investigators

To conduct the R&D discussed in Section 2 as efficiently as possible, we will enter into contracts with the following research institutions for each area of R&D and establish a system for cooperation between ministries and agencies. Depending on the development task, implementing organizations will be selected through public solicitations so that knowledge and skills from the private sector can be widely assimilated into the project.

- ○ For Section 2.A on the survey and analysis of marine resources, JAMSTEC and AIST, which has abundant experience in geological surveys, will draw up the plan under the direction of the theme leader selected from AIST, in collaboration with JOGMEC. AIST will primarily conduct the surveys, while JAMSTEC will take the lead in carrying out the plan for sample analysis together with Kochi University; these institutions jointly operate the Kochi Core Center.
- ○ For Section 2.B on the development of survey technologies, JAMSTEC and MPAT will work together in collaboration.
- ○ For Section 2.C on the development of production technologies, JAMSTEC will play a central role and work together with private sector companies.
- ○ For Section 2.D on the verification of survey and development system, J-MARES and the University of Tokyo have been selected as the main implementing organizations through public solicitation. J-MARES is responsible for all four tasks, while the University of Tokyo is in charge of trend surveys (related to rare-earth deposits) and cost reduction for environmental monitoring.

3.3 Streamlining the Research Platform

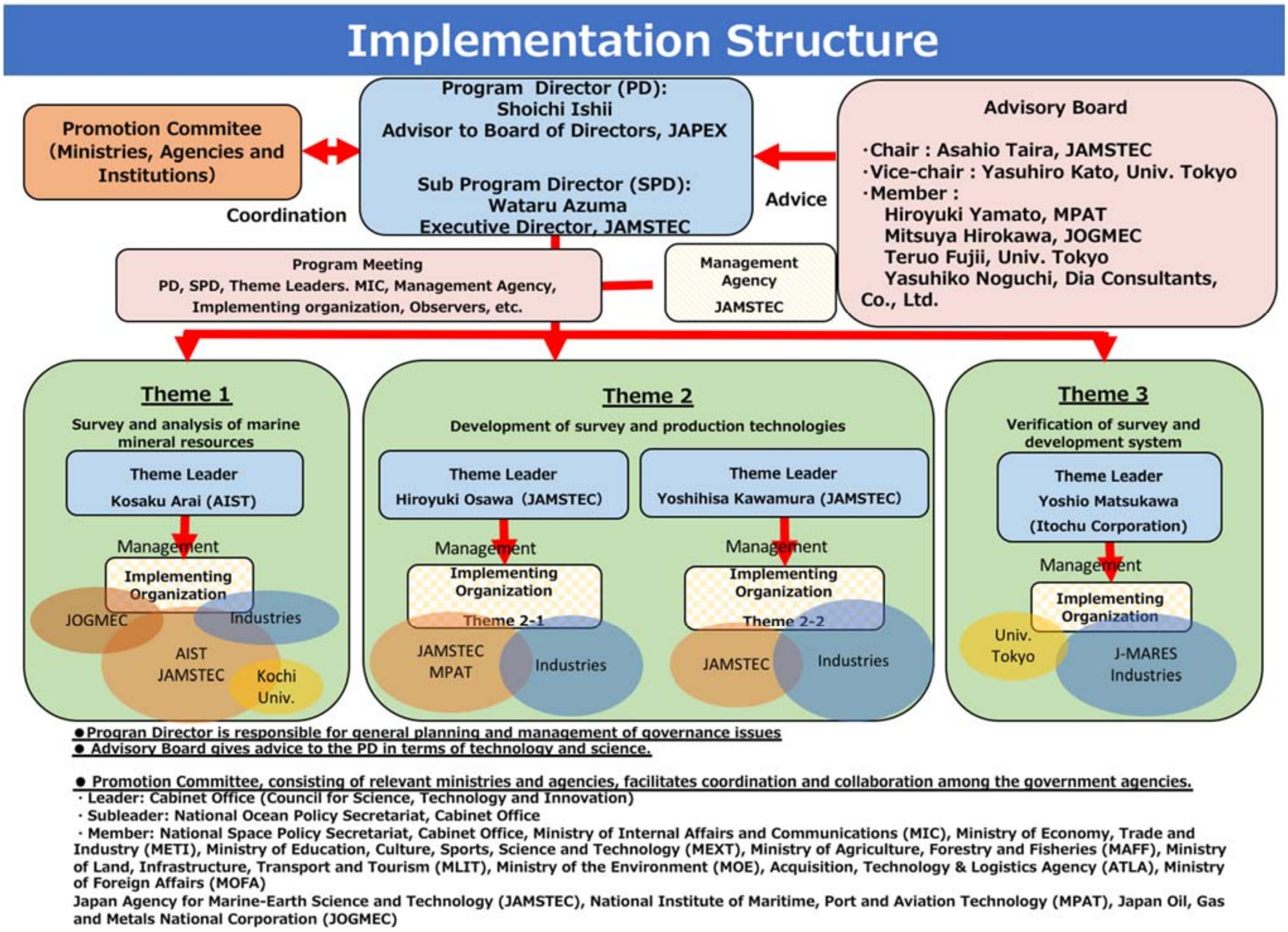


Figure 3-1. Implementation Structure

3.4 Cross-ministerial Collaboration

This program will be implemented through the collaboration of nine ministries: Cabinet Office, MIC, MEXT, MAFF, METI, MLIT, MOE and MOD (ATLA). The Promotion Committee composed of the eight ministries given above has already been established and held meetings with active discussions on the R&D plan. The Cabinet Office's National Ocean Policy Secretariat, MEXT, METI, JOGMEC, MLIT and MPAT have been actively collaborating since the beginning of the project. In addition, MIC and MAFF (Fisheries Agency) have been submitting ambitious proposals.

3.5 Contribution from Industry

Future contributions from industries (including human and material contributions) are expected to reach about 3% of the total R&D expenditures (sum of government and industrial contributions).

4. Matters Related to Intellectual Property

4.1 Intellectual Property Committee

〇The Intellectual Property Committee (IP Committee) shall establish polices for each institution that established one with regards to publication of R&D results and for filing, maintaining, and licensing of patents etc. (IP rights), as well as to regulate the management and use of research outcomes, including data and know-how.

〇The details of management method etc. of the IP Committee shall be determined by JAMSTEC.

〇JAMSTEC shall make decisions and coordinate regarding the application procedures for individual patents after the program ends, however, deliberations and management will be conducted by the IP Committee set up at each research institution.

4.2 Agreement on Intellectual Property

〇JAMSTEC shall stipulate in advance the handling of confidentiality, background IP rights (IP rights owned by the principal investigators and the research institutions of the principal investigators, etc. before joining the program, as well as IP rights acquired independent of SIP project expenses after joining the program), foreground IP rights (IP rights arising from SIP project funding within the program), etc. through contracts or other means with contractors.

4.3 Handling of Foreground Intellectual Property Rights

〇In principle, foreground IP rights shall be subject to Article 19, Paragraph 1 of the Industrial Technology Enhancement Act, and shall belong to the research institution (contractor) of the principal investigator who is the inventor.

〇The consent of the IP Committee is required when a subcontractor etc. invents and the IP rights are assigned to the subcontractor etc. In doing so, the IP Committee may attach conditions.

〇If the IP rights holder does not actively seek to commercialize the IP, the IP Committee shall recommend to transfer ownership of the IP rights to those who are actively pursuing commercialization and granting of licenses to those who are actively pursuing commercialization.

〇For those who leave during the participation period, JAMSTEC may require uncompensated transfer of IP ownership and shall be able to grant the license to all or part of the outcomes obtained from SIP project funding during the relevant participation period (in case of participation over multiple years, all outcomes from the beginning of participation) at the time of withdrawal.

〇In principle, the costs of filing applications for and maintaining IP rights etc. shall be borne by the IP holder. In case of joint applications, the shareholding ratio and cost sharing shall be determined through consultation between the joint applicants.

4.4 Licensing of Foreground Intellectual Property Rights

〇Foreground IP rights may be licensed by the IP holder to other program participants according to the conditions set by the IP holder (or “according to the agreement among program participants”).

〇Foreground IP rights may be licensed by the IP holder to third parties according to the conditions set by the IP holder, as long as the conditions do not favor third parties more than the program participants.

〇If there is a risk that the IP holder's handling of said conditions etc. may interfere with the SIP (including not only the R&D but also the practical application and commercialization of the outcomes), the IP Committee shall coordinate to obtain a reasonable solution.

4.5 Consent for Transferring Foreground Intellectual Property Rights, and Granting or Transferring Exclusive Licenses

○In accordance with Article 19, Paragraph 1, Item 4 of the Industrial Technology Enhancement Act, transferring foreground IP rights, and granting or transferring exclusive licenses shall have to be reported to JAMSTEC, except when transferring due to a merger or split, or when transferring IP rights and granting or transferring exclusive licenses to subsidiaries, parent companies, etc. ("when transferring IP rights etc. due a merger etc.").

4.6 Handling of Intellectual Property Rights at the End

○ At the end of R&D, the IP Committee shall discuss how to deal with IP rights with no interested parties for ownership etc. (abandoned or be taken over by JAMSTEC).

4.7 Participation of Overseas Organizations (Foreign-based Companies, Universities, Researchers, etc.)

○From the standpoint of proper execution and management, a point of contact or representative agent that can handle paperwork related to R&D contracts etc. shall be present in Japan as a general rule.

5. Matters Related to Evaluation

5.1 Evaluating Body

The Governing Board shall invite outside experts etc. to conduct the evaluation, based on the reported results of self-assessments conducted by the PD, JAMSTEC, etc. The Governing Board can also conduct evaluations by field or by project.

5.2 Implementation Period

○There will be a prior evaluation, annual end-of-fiscal-year evaluation, and final evaluation.

○After completion, a follow-up evaluation will be conducted as necessary after a certain period of time (3 years in principle).

○Aside from those given above, evaluations may also be conducted during the fiscal year as necessary.

5.3 Evaluation Items and Criteria

From the standpoint of evaluating necessity, performance, effectiveness, etc. and in keeping with the "General Guidelines for the Evaluation of R&D by the National Government (December 6, 2012, approved by the Prime Minister of Japan)," the evaluation items and criteria are given below. Evaluations will not end at merely assessing achievement/non-achievement; their causes, factors, etc. will also be analyzed and improvement strategies will be proposed.

(1) Significance of the project, consistency with the goals of the SIP program

(2) Relevance of goals (especially outcome goals), levels of achievement on the progress chart toward goals

(3) Is it being properly managed? In particular, how effectively is cross-ministerial collaboration being leveraged?

(4) Strategies and levels of achievement toward practical application and commercialization

(5) During the final evaluation, anticipated effects or ripple effects. Is there a suitable and clear follow-up method etc. set up for after completion?

5.4 Method for Applying the Evaluation Results

- 〇Prior evaluation of the plan for the following fiscal year and thereafter will be conducted, and the results will be reflected in the plan etc. for the following fiscal year and thereafter.
- 〇End-of-fiscal-year evaluation of achievements up to the concerned fiscal year and of the plan for the following fiscal year and thereafter will be conducted, and the results will be reflected in the plan etc. for the following fiscal year and thereafter.
- 〇Final evaluation of achievements up to the final fiscal year will be conducted, and the results will be reflected in the follow-up after completion.
- 〇Follow-up evaluation of the progress of practical application and commercialization of the outcomes of each project will be conducted, and improvement strategies etc. will be proposed.

5.5 Disclosure of the Results

- ○ In principle, the evaluation results will be publicly disclosed.
- ○ The Governing Board conducting the evaluation will not be publicly disclosed because it also deals with undisclosed R&D information etc.

5.6 Self-assessment

5.6.1 Self-assessment by Principal Investigators

The PD shall select the principal investigators who will perform the self-assessment (In principle, the main researcher/research institution for each research subject will be selected). The selected principal investigators shall apply the evaluation items and criteria described in Section 5.3 to assess both achievements after the previous evaluation and future plans. Aside from assessing achievement/non-achievement, their causes and factors, etc. will also be analyzed and improvement strategies etc. will be summarized.

5.6.2 Self-assessment by Program Director

While looking at the results of the self-assessment by principal investigators and referring to third-party and expert opinions as necessary, the PD shall apply the evaluation items and criteria described in Section 5.3 to assess both achievements of the PD him- or herself, JAMSTEC and each principal investigator as well as future plans. Aside from assessing achievement/non-achievement, their causes and factors, etc. will also be analyzed and improvement strategies etc. will be summarized. Based on the results, the PD shall decide whether or not to continue research for each research body etc. and give the necessary advice to principal investigators etc. This will make it possible for the structure to improve in a self-directed manner.
Using all these results, the PD shall prepare the documents to be submitted to the Governing Board, with the support of JAMSTEC.

5.6.3 Self-assessment by Management Agency

Self-assessment by JAMSTEC shall be conducted to check whether administrative procedures for expenditures are being properly implemented etc.

6. Exit Strategies

6.1 Promotion of Exit-oriented Research

○We will promote the SIP together with industry, academia and government in order to develop internationally competitive component technologies, and by integrating these technologies into a system, we will efficiently develop private sector businesses etc. that will take the lead in the marine survey industry.

○Depending on the state of technologies etc., we will strategically transfer technologies to private sector businesses, such as exploration service companies, exploration equipment manufacturers and marine engineering companies, in order to revitalize the marine survey industry while ensuring that the new surveying technologies and know-how gained through SIP can be effectively passed on and development continued. The utility for local governments, public institutions, and use in public works will be taken into account.

○We will actively work to obtain in-kind contributions (contribution of goods or services, provision or payment in-kind, etc.) from companies etc. participating in the program.

○Collaboration to leverage rapid technological advances in other fields, such as rechargeable batteries and automatic controls for installation into AUVs, has been effective. We will actively incorporate these technologies and promote R&D to help generate open innovation.

6.2 Policies for Wider Adoption

○For the technological development outcomes of the program, we will develop a framework to enable wider adoption while taking our open and closed strategy into consideration, with the aim of establishing practical applications of these technologies.

○In development of technologies related to communications, control, etc. for AUVs, we will collaborate with related institutions to incorporate worldwide knowledge and expertise, standardize protocols, etc. to develop systems that can be used by a wide range of users.

○On technologies for collecting rare-earth mud, we will prepare implementation manuals etc. for relevant methods to create outputs that can be widely implemented by private sector businesses, while securing intellectual property rights of core areas of the project with the goal of obtaining patents.

○On environmental monitoring and other technologies associated with mineral resource development, we will create an environment that will facilitate their wider use in Japan and overseas with the goal of international standardization.

7. Other Important Matters

7.1 Legal Basis

This project is undertaken based on Article 4, Paragraph 3, Item 7-3 of the Act for Establishment of the Cabinet Office (Act No. 89 of 1999), Basic Policy on Science, Technology and Innovation Promotion Expenditures (Council for Science, Technology and Innovation meeting on May 23, 2014), Implementation Policy on Science, Technology and Innovation Promotion Expenditures (Council for Science, Technology and Innovation meeting on May 23, 2014), and Cross-ministerial Strategic Innovation Promotion Program (SIP) Operation Guidelines (Governing Board of Council for Science, Technology and Innovation meeting on May 23, 2014).

7.2 Flexible Plan Revisions

This plan shall be reviewed on an ad hoc basis, with a focus on accelerating and maximizing the outcomes.

7.3 History of PD and Personnel

7.3.1 Program Director (PD)

Shoichi Ishii
(April 2018–present)

7.3.2 Sub-PD

Wataru Azuma
(September 2018–present)

7.3.2 Directors (Project Officers)

Hiroshi Furuta
(April 2018–March 2019)

Motoi Eto
(March 2019–present)

Toru Sasaki
(August 2018–present)

7.3.3 Officers in Charge

Aki Tanaka
(April–October 2018)

Kazuki Matsumoto
(April 2018–present)

Issa Kagaya
(January 2019–present)

7.3.4 Theme Leaders/Sub-leaders

Theme 1
Kosaku Arai
(June 2018–present)

Theme 1 Sub-leader
Hideaki Machiyama
(December 2018–present)

Theme 2-1
Hiroyuki Osawa
(June 2018–present)

Theme 2-1 Sub-leader
Toshifumi Fujiwara
(June 2018–present)

Theme 2-2
Yoshihisa Kawamura
(November 2018–present)

Theme 2-2 Sub-leader
Ikuo Sawada
(June 2018–present)

Theme 2-2 Sub-leader
Masanori Kyo
(June 2018–present)

Theme 3
Yoshio Matsukawa
(June 2018–present)

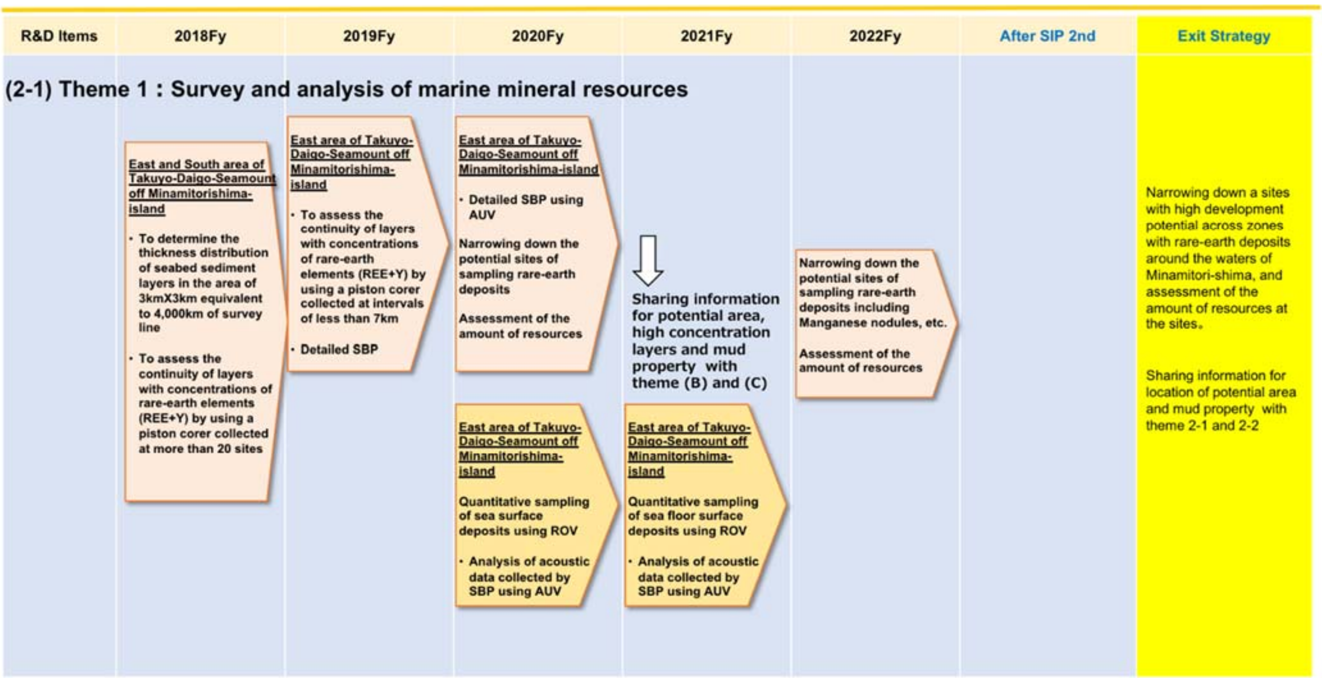
Theme 3 Sub-leader
Nobuo Kawai
(November 2018–present)

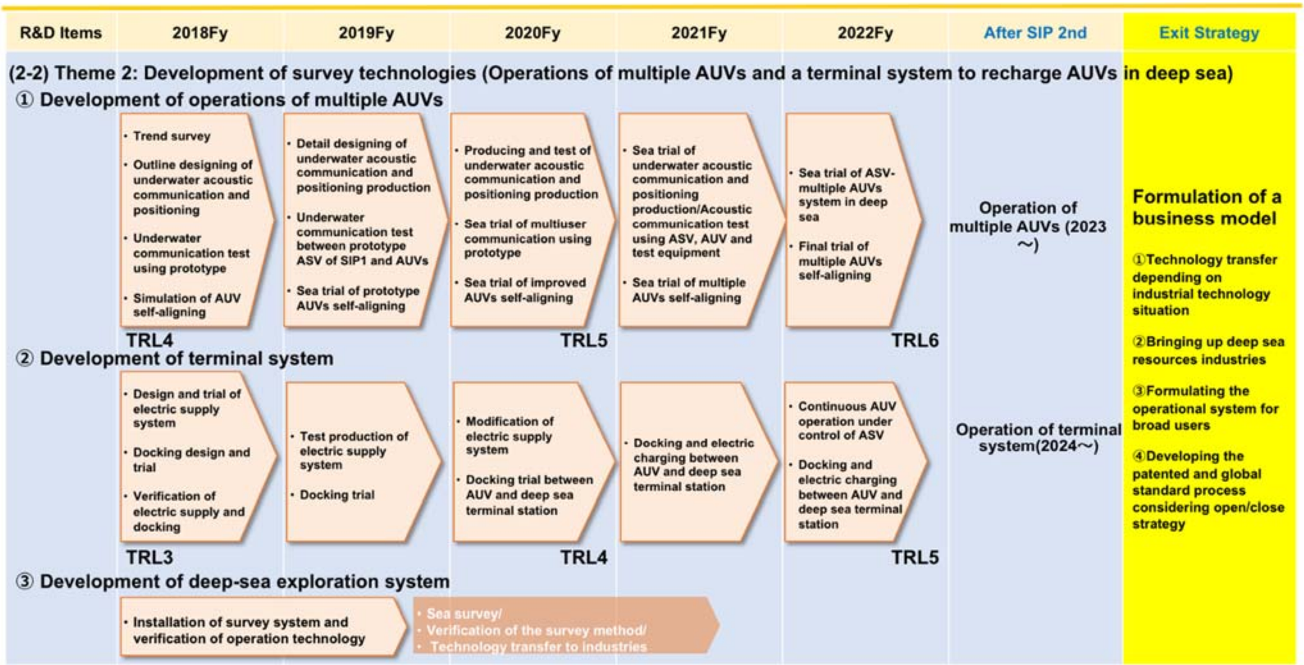
FY2019 Financial Plan

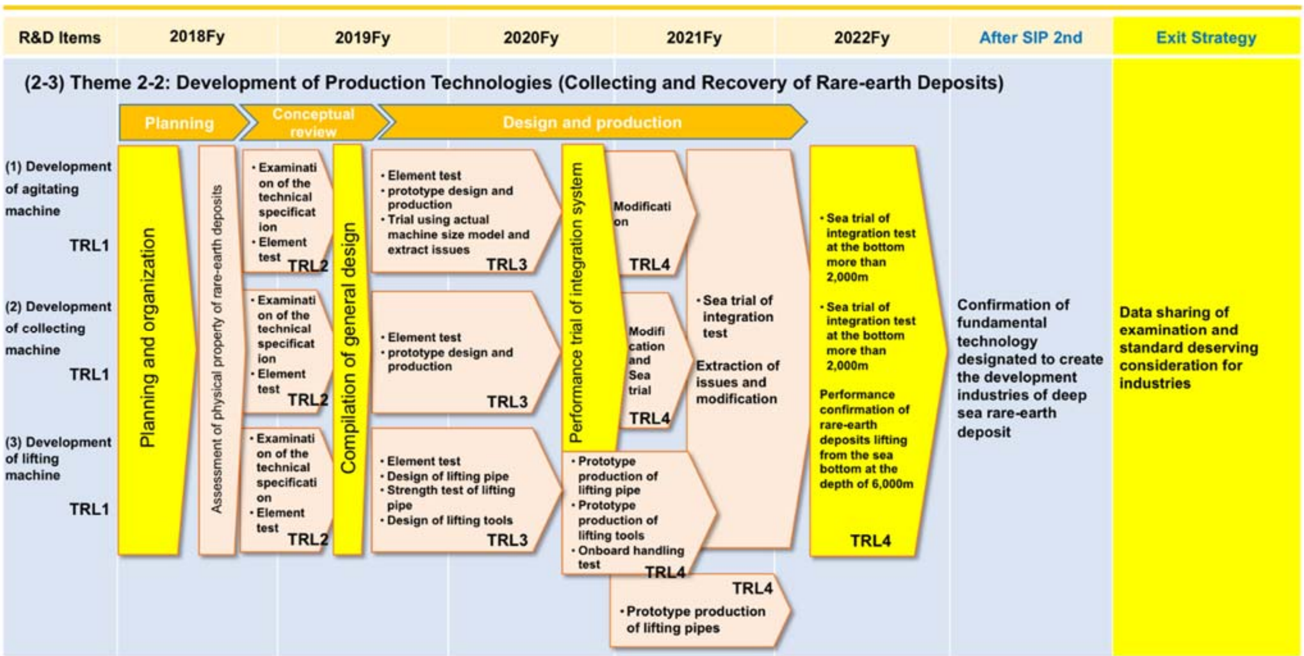
FY2019 Total 3020 (million yen)
(Statement of Expenditures)

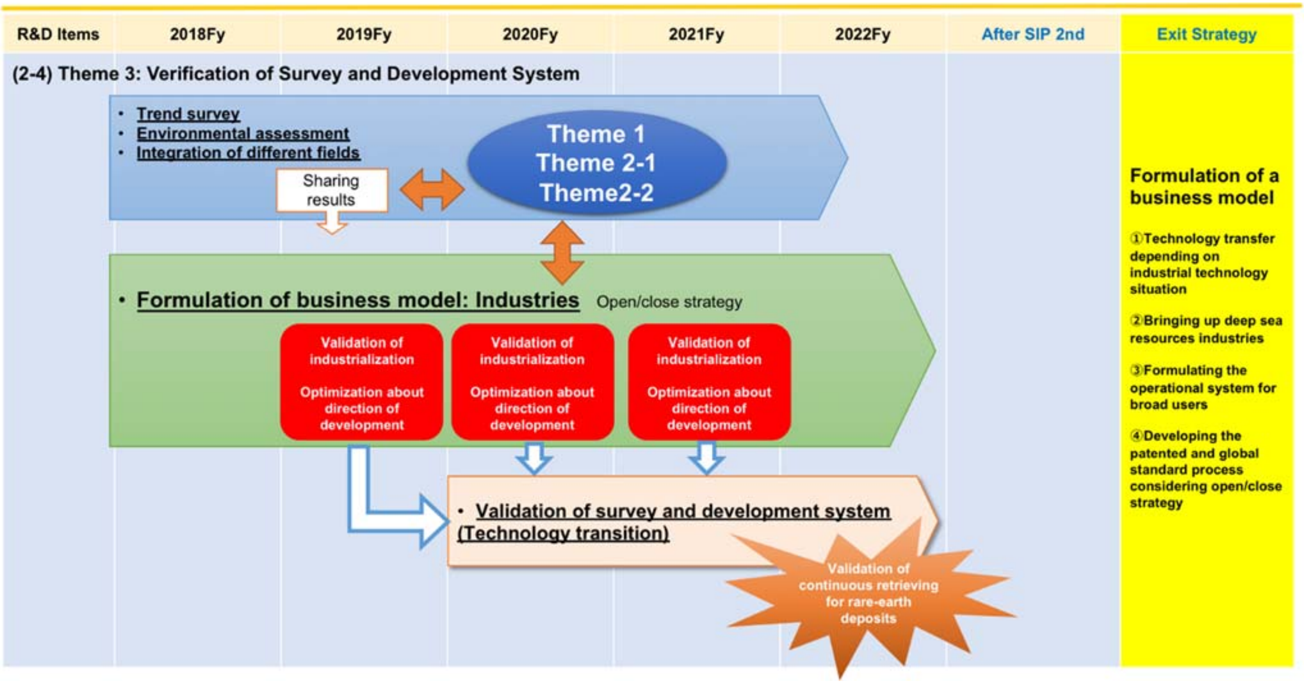
1. Research expenses etc. (including administrative and overhead expenses)	2,870 (million yen)
(by R&D area)	
(A) Survey and analysis of resources	242 (million yen)
(B) Survey technologies for deep sea resources	1,631 (million yen)
(C) Production technologies for deep sea resources	568 (million yen)
(D) System verification	429 (million yen)
PD Discretionary expenses	0 (million yen)
2. Project promotion expenses (personnel, evaluation, meetings, etc.)	150 (million yen)
3. Necessary expenses for work to enhance the project*	0 (million yen)
(Total)	3,020 (million yen)

Project Schedule




R&D Items
2018Fy
2019Fy
2020Fy
2021Fy
2022Fy
After SIP 2nd
Exit Strategy
(2-2) Theme 2: Development of survey technologies (Operations of multiple AUVs and a terminal system to recharge AUVs in deep sea)
① Development of operations of multiple AUVs
· Trend survey
· Outline designing of underwater acoustic communication and positioning
· Underwater communication test using prototype
· Simulation of AUV self-aligning
· Detail designing of underwater acoustic communication and positioning production
· Underwater communication test between prototype ASV of SIP1 and AUVs
· Sea trial of prototype AUVs self-aligning
· Producing and test of underwater acoustic communication and positioning production
· Sea trial of multiuser communication using prototype
· Sea trial of improved AUVs self-aligning
· Sea trial of underwater acoustic communication and positioning production/Acoustic communication test using ASV, AUV and test equipment
· Sea trial of multiple AUVs self-aligning
· Sea trial of ASV-multiple AUVs system in deep sea
· Final trial of multiple AUVs self-aligning
TRL4
TRL5
TRL6
Operation of multiple AUVs (2023 ~)
Formulation of a business model
①Technology transfer depending on industrial technology situation
②Bringing up deep sea resources industries
③Formulating the operational system for broad users
④Developing the patented and global standard process considering open/close strategy
② Development of terminal system
· Design and trial of electric supply system
· Docking design and trial
· Verification of electric supply and docking
· Test production of electric supply system
· Docking trial
· Modification of electric supply system
· Docking trial between AUV and deep sea terminal station
· Docking and electric charging between AUV and deep sea terminal station
· Continuous AUV operation under control of ASV
· Docking and electric charging between AUV and deep sea terminal station
TRL3
TRL4
TRL5
Operation of terminal system(2024~)
③ Development of deep-sea exploration system
· Installation of survey system and verification of operation technology
· Sea survey/
· Verification of the survey method/
· Technology transfer to industries


R&D Items
2018Fy
2019Fy
2020Fy
2021Fy
2022Fy
After SIP 2nd
Exit Strategy
(2-3) Theme 2-2: Development of Production Technologies (Collecting and Recovery of Rare-earth Deposits)
Planning
Conceptual review
Design and production
(1) Development of agitating machine
TRL1
(2) Development of collecting machine
TRL1
(3) Development of lifting machine
TRL1
Planning and organization
Assessment of physical property of rare-earth deposits
· Examination of the technical specification
· Element test
TRL2
Compilation of general design
· Element test
· prototype design and production
· Trial using actual machine size model and extract issues
TRL3
· Element test
· prototype design and production
TRL3
· Element test
· Design of lifting pipe
· Strength test of lifting pipe
· Design of lifting tools
TRL3
Performance trial of integration system
Modification
TRL4
Modification and Sea trial
TRL4
· Prototype production of lifting pipe
· Prototype production of lifting tools
· Onboard handling test
TRL4
· Sea trial of integration test
Extraction of issues and modification
TRL4
· Prototype production of lifting pipes
· Sea trial of integration test at the bottom more than 2,000m
· Sea trial of integration test at the bottom more than 2,000m
Performance confirmation of rare-earth deposits lifting from the sea bottom at the depth of 6,000m
TRL4
Confirmation of fundamental technology designated to create the development industries of deep sea rare-earth deposit
Data sharing of examination and standard deserving consideration for industries



Promotion of technological research and development depending on maturity of technology

- We introduce the Technology Readiness Level (TRL) method developed by American Petroleum Institute (API) as technology R&D index to promote efficient project development.
- We promote project development attending TRL to correspond among plan, project operation and final goal.

Examples of TRL（Technology Readiness Level）							
Project development, etc.							
Study of possibility		Study of element technology		Development of system technologies		Validation of technology Test and operation	
TRL 0	**TRL 1**	**TRL 2**	**TRL 3**	**TRL 4**	**TRL 5**	**TRL 6**	**TRL 7**
Basic study Basic technology development	**Formalization of concept** Analytical and experimental validation	**Validation of concept** Trial in the laboratory	**Production of prototype concept** Reliability function test of elements and system	**Production of prototype system** Environmental assessment for design and production system	**Integrated system** Design, production and modification(I/F test)	**Practical machine (Development)** Sea trial and modification	**Practical machine (Operation)** Pilot phase of continuous operation and modification
	Desk test machine	Production of prototype machine for function test	Component and system	Prototype model	Demonstration model	Production/ operational model	Production/ operational model