Development of Innovative Technologies for Exploration of Deep-Sea Resources

cross-ministerial Strategic Innovation Promotion Program

SIP

戦略的イノベーション創造プログラム
Cross-ministerial Strategic Innovation Promotion Program

As a maritime nation, our goal is to explore the deep sea.

Rare-earth sediments lie on the seafloor 6,000 m below the ocean surface. Locating, collecting, and lifting these sediments to the ocean surface is the first world-class challenge.

As a maritime nation, Japan has the world's sixth largest exclusive economic zone (EEZ), which is twelve times larger than its land area.

Japan's EEZ is also the world's fourth largest in terms of water volume. Recent studies have identified potential sites of rare-earth deposits and other mineral resources on the floor of deep sea. A zone with high concentrations of rare-earth elements has already been found on the sea bottom off Minamitori Island.

However, locating, retrieving, and lifting these mineral resources from a huge area of the seafloor is the first world-class challenge.

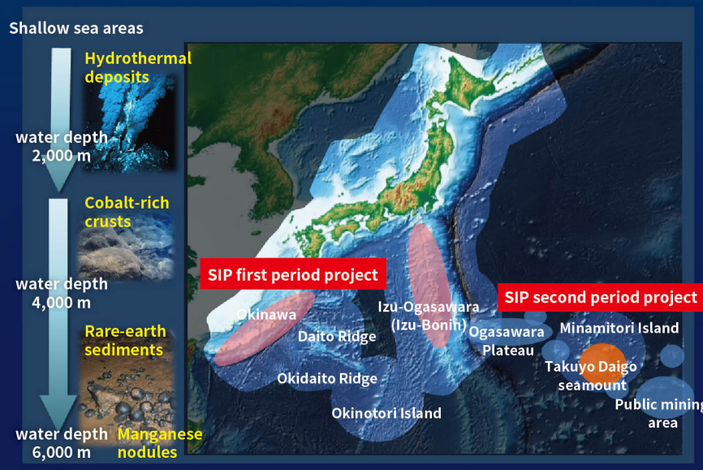
"Development of Innovative Technologies for Exploration of Deep-Sea Resources" is among the issues under the Cross-ministerial Strategic Innovation Promotion Program (SIP). By the end of the SIP in FY2022, we aim to narrow down potential sites and to estimate the amount of rare-earth elements (REEs) at these sites, and to establish retrieval technologies while considering the conservation of marine environment.

To this end, we intend to develop a smart survey system that allows multiple autonomous underwater vehicles (AUVs) to be operated simultaneously.

This program, with its focus on joint efforts by government, industry and academia to achieve program goals, is expected to pave the way toward an innovative business model for the development of the deep-sea mineral resources.

We are confident that our program will enhance marine industrial activities and help open a new page for Japan as a maritime nation.

We ask for your continued understanding and support.



Distribution of ocean resources around Japan

Program Director,
Development of Innovative Technologies for Exploration of Deep-Sea Resources

Corporate Advisor, Japan CCS Co.,Ltd.
Shoichi Ishii

Implementation Structure for "Development of Innovative Technologies for Exploration of Deep-Sea Resources"

Program Director

Shoichi Ishii
Corporate Advisor, Japan CCS Co.,Ltd.

Sub Program Director

Wataru Azuma
Executive Director JAMSTEC

Promotion Committee

〈Leader〉Cabinet Office
(Council for Science, Technology and Innovation)
〈Sub Leader〉National Ocean Policy Secretariat, Cabinet Office
National Space Policy Secretariat, Cabinet Office
Ministry of Internal Affairs and Communications (MIC)
Ministry of Foreign Affairs (MOFA)
Ministry of Education, Culture, Sports, Science and Technology (MEXT)
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
Ministry of Economy, Trade and Industry (METI)
Japan Oil, Gas and Metals National Corporation (JOGMEC)
Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
National Institute of Maritime, Port and Aviation Technology (MPAT)
Ministry of the Environment (MOE)
Ministry of Defense (MOD)

Management Agency

JAMSTEC
〈Budgeting and administration〉

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Teruo Fujii/ Professor, the University of Tokyo
Hiroyuki Yamato/ Advisor, Nippon Kaiji Kyokai

Theme 1

Survey and analysis of marine mineral resources

We are narrowing down potential sites with high concentrations of REEs and making a rough estimate of the amount of REEs on the seafloor surrounding Minamitori Island in the Japanese EEZ.

Theme leader Kosaku Arai (AIST)

Participating organizations
National Institute of Advanced Industrial Science and Technology (AIST)
JAMSTEC
Kochi University
Industries

Theme 2-1

Development of survey technologies

System for operation of multiple Autonomous Underwater Vehicles (AUVs) and a terminal system for the deep sea equipped with a battery charger

We are establishing survey technologies to efficiently investigate deep-sea resources by developing technology for operating multiple AUVs and a deep-sea terminal system.

Theme leader Hiroyuki Osawa (JAMSTEC)

Participating organizations
JAMSTEC
MPAT
Industries

Theme 2-2

Development of production technologies

(Technology for collecting and lifting rare-earth deposits)

As a world leader and pioneer, we are developing production technologies for cracking and pulverizing solidified rare-earth deposits and then collecting and lifting the cracked deposits by the Deep-Sea Drilling Vessel Chikyu.

Theme leader Yoshihisa Kawamura (JAMSTEC)

Participating organizations
JAMSTEC
Industries

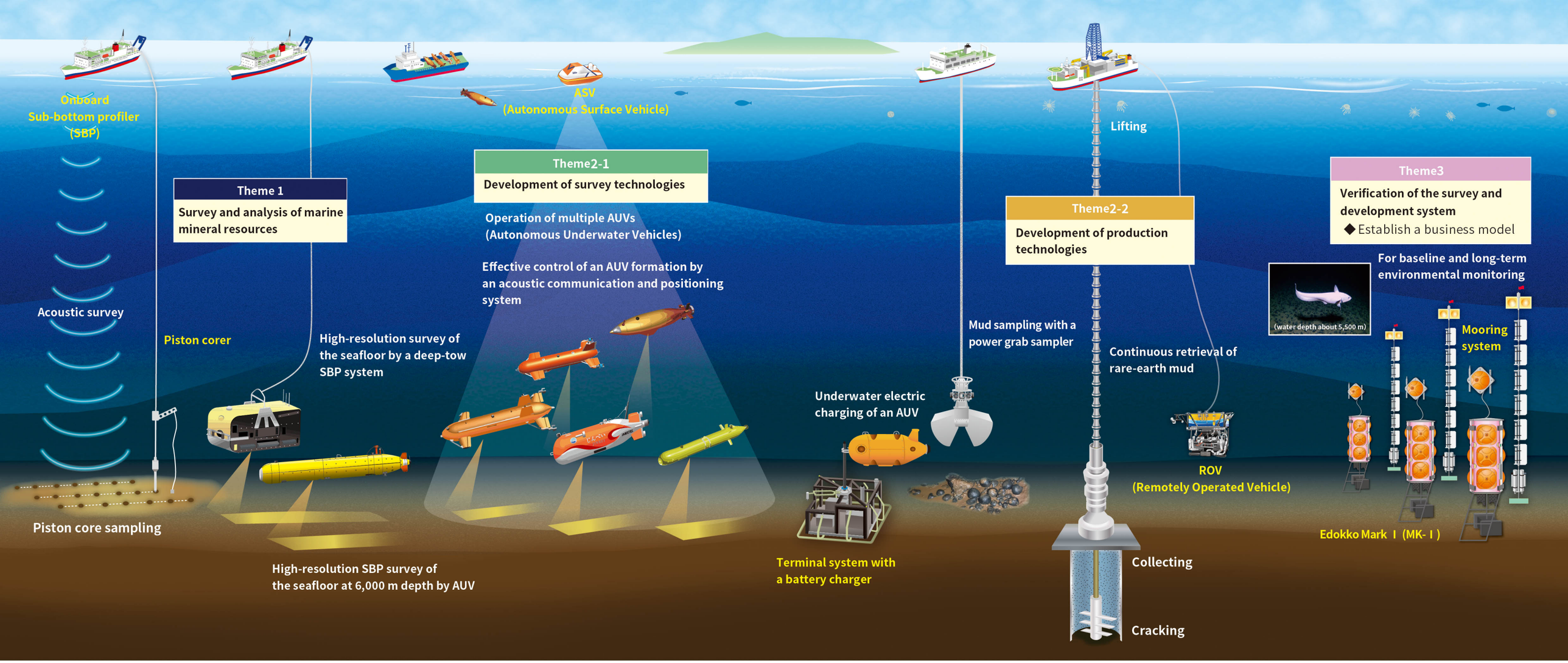
Theme 3

Verification of the survey and development system

We are paving the way toward the establishment of a future business model for verifying in a comprehensive manner the engineering system developed through the research activities of themes 1, 2-1, and 2-2.

Theme leader Yoshio Matsukawa (Itochu Corporation)

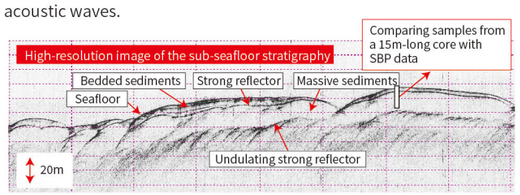
Participating organizations
Research and Development Partnership for Next Generation Technology of Marine Resources Survey (J-MARES)
The University of Tokyo
Industries



Theme 1 Survey and analysis of marine mineral resources

■ Estimation of deposits with the onboard sub-bottom profiler

Under theme 1, we are surveying the seafloor surrounding Minamitori Island with a sub-bottom profiler (SBP) during research cruises. The sub-bottom profiling system identifies and characterizes layers of sediment below the seafloor, including those with high concentrations of rare-earth elements (REEs), by detecting reflected acoustic waves.



Cross section of geological structure beneath the floor of the deep sea

■ Identification of high-concentration layers by collecting geological samples

By collecting core samples and integrating the sample analysis data with data obtained by the SBP, we will be able to estimate with greater accuracy the amounts of rare-earth minerals in the deep sea around Minamitori Island.

Theme 2-1 Development of survey technologiess

<Operation of multiple Autonomous Underwater Vehicles (AUVs) and a deep-sea terminal system with a battery charger>

■ Operation of multiple AUVs

We are developing an acoustic system for the operation of multiple AUVs by integrating “communication” and “positioning” functions, and developing a technology for controlling multiple AUVs during sea-bottom surveys with high efficiency and high precision.

■ Terminal system for recharging AUV batteries in the deep sea

To facilitate long-term operation of the AUVs in the deep sea, we are developing a deep-sea terminal system for docking the AUVs and recharging their batteries and also for transferring data.

Theme 2-2 Development of production technologies

<Technology for collecting and lifting rare-earth deposits>

■ Determination of the total assembly design of equipment for cracking and pulverizing solidified deposits and collecting and lifting the cracked deposits

Establishing production technology for the retrieval of deep-sea resources is a huge challenge.
We are employing the Deep-Sea Drilling Vessel Chikyu, with its long pipes and mud circulation system, to implement a conceptual design by taking into consideration the results of simulations and land-based experiments.

■ Characterization of the physical properties of the geological formation bearing the rare-earth deposits

Under theme 2-2, the important technologies that make it possible to develop rare-earth resources in the deep sea have three components: “cracking,” “collecting,” and “lifting.” We acquire basic data for each of these components by identifying geological features of the layers bearing rare-earth deposits.

■ Simulation

We are reviewing the design and performance of an underwater pump and hydrocyclone. We are also investigating various scenarios by conducting computer simulations of this system.

Theme 3 Verification of the survey and development system

■ Survey of market trends and formulation of a business model

Under theme3, we have been surveying the most recent trends in the demand for rare-earth elements in domestic and international markets as well as the feasibility of a commercial operation.

■ Environmental measures

To achieve sustainable development of marine resources, we have been conducting environmental monitoring in the target area using the environmental impact assessment method established during the first period of the SIP. We are continuing this monitoring with the Edokko Mark Ⅰ ecosystem observation system and a mooring system for observing bottom layer flows. This observation method has been proposed as an International Organization for Standardization (ISO) standard. We are also coordinating an international training course for administrators and engineers from Pacific Island countries.

「Geological survey of the deep seafloor off Minamitori Island」

We have conducted a survey using the sub-bottom profiler (SBP) on board research vessels along survey lines with a total length of more than 10,000 km to narrow down potential areas of rare-earth deposits. We have identified sediment layers covering an undulating strong reflector 20–30 m below the seafloor by examining stratigraphic images obtained with the SBP. We have succeeded in obtaining high-resolution SBP images by using a deep tow system, which is operated at 100 m above the deep seafloor.

For geological core analysis, we have obtained piston cores from more than 50 sites located at intervals of 7 km and measured concentrations of rare-earth elements in core samples. We are attempting to ascertain the relationship between the distribution and layer thickness of rare-earth sediments and their quality in the deep sea off Minamitori Island.

Collected cores

Retrieving a piston core

「Sea trials of the acoustic/positioning system and formation control」

We conducted sea trials for acoustic communication for the operation of multiple AUVs. The ASV HUBSea relays information on the location and status of the AUVs by converting the wireless signal from the mother ship to an acoustic signal that is communicated to two AUVs, Jinbei and Yumeiruka.
Through the successful completion of a sea trial, we verified the effectiveness of the acoustic communication and positioning system for the operation of multiple AUVs. We also completed another sea trial to demonstrate control of a formation of two AUVs.

Our goal for multiple AUV operation is to successfully operate five AUVs using a newly developed ASV by FY2022, the last year of the project.
The operation of multiple AUVs is expected to enable underwater surveys for deep-sea exploration to be completed faster and with more precision overall. This technology is also expected to have a large impact on various industries through the development of multiple control technologies for different types of AUVs.

Sea trial of acoustic communication among the AUVs, the ASV, and the mother ship

Sea trial for formation control of AUVs

「Sampling of a large amount of rare-earth sediments for composition tests」

We sampled a substantial amount of rare-earth sediment from the deep seafloor in the Minamitori Island area. Rare-earth sediment was retrieved with a power grab sampler with the help of on-line video images. The power grab operation was conducted twice, and more than 3 m3 of sediments were retrieved from the seafloor at a water depth of more than 5,000 m. The collected sediment samples will be used for composition tests to obtain basic data for research and development.

Sampling with a power grab

Collected rare-earth sediment sample
(The black spheres are manganese nodules)

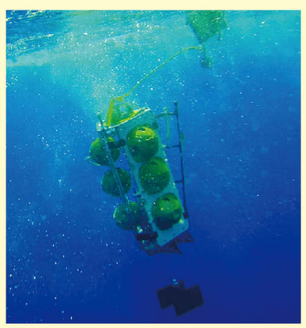
Sampling by the power grab at a water depth of about 5,000 m

Retrieval of the power grab after sample collection

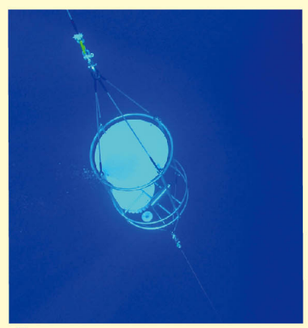
「Starting a baseline survey for environmental monitoring」

It is important to understand the potential impact on the marine environment of mineral resource development in the deep sea. Thus, we have started a long-term program of environmental monitoring around the potential development sites.
For this baseline survey, we are using an observation instrument with an attached camera called the Edokko Mark Ⅰ-365, which was developed during the first period of the SIP by JAMSTEC with the collaboration and craftmanship of small businesses in the Tokyo area as a free-fall probe for the deep sea. The Edokko Mark Ⅰ can obtain continuous observations for a year in the deep sea and is expected to capture disturbances caused by sediment sampling and changes to the ecosystem.
Measurements of water currents, temperature, turbidity, and settling particles by a mooring system also provide important baseline reference information for deep-sea exploration.
These methods for assessing environmental impact established in the SIP first period are being proposed as a global ISO standard.

Images of living organisms on the deep seafloor captured by the Edokko Mark Ⅰ-365



The Edokko Mark Ⅰ-365



Mooring observation system with attached sediment trap

Participating organizations

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

National Institute of Advanced Industrial Science and Technology (AIST)

National Institute of Maritime, Port and Aviation Technology (MPAT)

Research and Development Partnership for Next Generation Technology of Marine Resources Survey (J-MARES)

The University of Tokyo

Kochi University

What is the cross-ministerial Strategic Innovation Promotion Program (SIP)?

SIP is a national, cross-ministerial program of the Cabinet Office that is outside the framework of the respective ministries and traditional disciplines.Council for Science, Technology and Innovation(CSTI) plays a leading role in coordinating SIP, with the aim of realizing innovative performance in research and development.

SIP contributes to economic recovery by improving Japan's ability to promote research, solving social issues through application of core innovation models, creating new markets and employment opportunities, and strengthening industrial competitiveness.

The second period of SIP began in FY2018, following the first period, which began in FY2014.

SIP promotes innovation along its entire path, from basic research to exit strategies (practical application/commercialization). It is managed by the Program Directors (PDs) with the cooperation of government, industry and academia.

Cabinet Office

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Japan Agency for Marine-Earth Science and Technology

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Cross-ministerial Strategic Innovation Promotion Program

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