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SHINSEI-MARU+ “Cruise Report”
KS-24-J02C

Verification tests on seabed property estimation technology and Doppler verification technology using underwater lasers

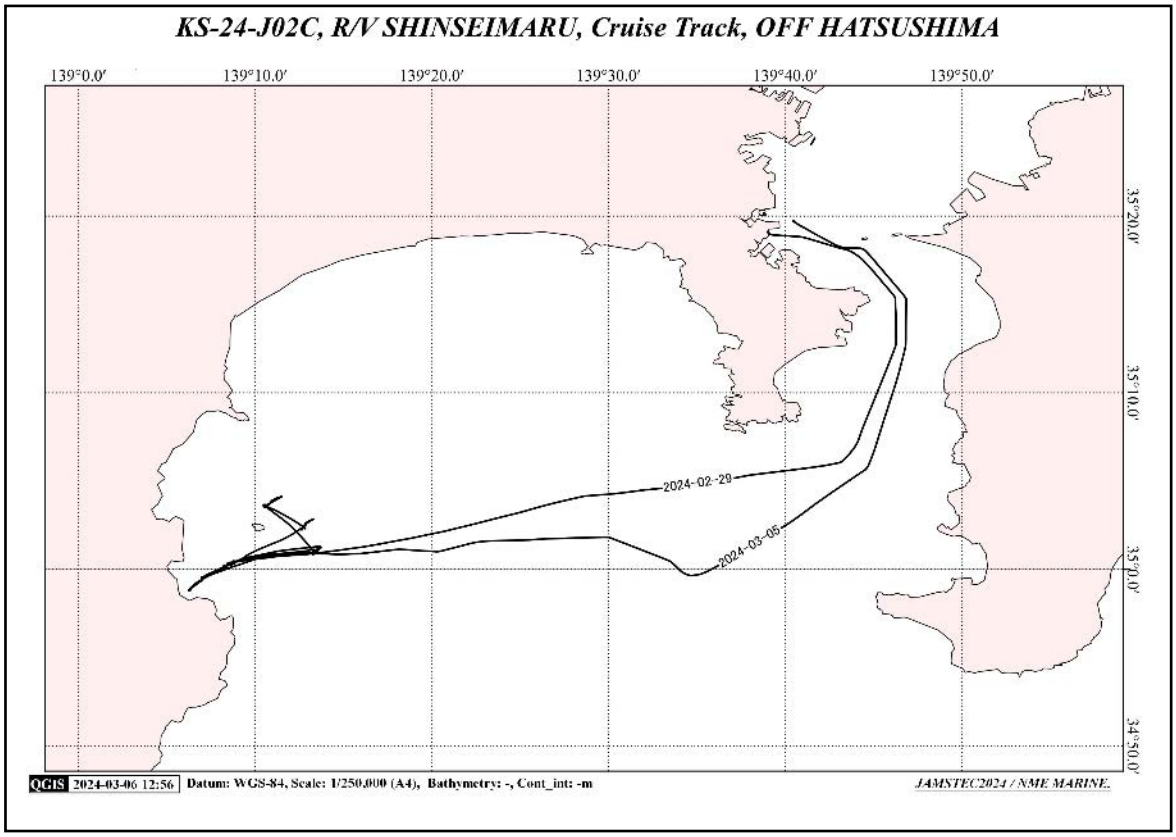
East of Hatsuchima, Sagami-Bay

Feb.29, 2024 – Mar.7, 2024

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

1. Cruise Information

● Cruise ID : KS-24-J02C
● Name of vessel : SHINSEI-MARU
● Title of cruise : Verification tests on seabed property estimation technology and Doppler verification technology using underwater lasers
● Chief Scientist [Affiliation] : Shojiro Ishibashi [JAMSTEC]
● Cruise period : 29/02/2024 – 07/03/2024
● Ports of departure / call / arrival : Yokosuka/JAMSTEC – Yokosuka/JAMSTEC
● Research area : East of Hatsushim, Sagami-Bay, JAPAN
● Research map



2. Research Proposal and Science Party

● Title of proposal
Verification tests on seabed property estimation technology and Doppler verification technology using underwater lasers

● Representative of Science Party [Affiliation]
- Japan Agency for Marine-earth Science and TeChnology (JAMSTEC)
- Mitsubishi Electric Defense and Space technologies corporation (MEDS)
- Technical Manager, Tamagawa Electronics Co., Ltd. (TME)
- Hamamatsu Photonics K.K.(HPK)
- Nippon Marine Enterprises Co., Ltd (NME)

● Science Party (List) [Affiliation, assignment etc.]

- Shojiro Ishibashi	Senior Researcher, Technology Development Department, JAMSTEC
- Kiyotaka Tanaka	Research Assistant, Technology Development Department, JAMSTEC
- Takamitsu Okada	Engineering Researcher, MEDS Co., Ltd.
- Daisuke Tetsuta	Engineering Researcher, MEDS Co., Ltd.
- Keisaku Takada	Engineering Researcher, MEDS Co., Ltd.
- Takashi Saito	Engineering Researcher, TME Co., Ltd.
- Morifumi Takaesu	Observation Technician, NME Co., Ltd.

● Operation team of the “KAIKO Mk-IV”

- Submersible Op. Manager	TEPPEI KIDO
- 1st Submersible Tec. Off.	SEIJI SHIGETAKE
- 2nd Submersible Tec. Off.	SHOTA IHARA
- 2nd Submersible Tec. Off.	YUDAI SAKAKIBARA
- 2nd Submersible Tec. Off.	WATARU ASANO
- 3rd Submersible Tec. Off.	KUNIHIRO IWATA

● Captain and crew of the R/V Yokosuka (List) [Affiliation, assignment etc.]

- Captain	YOSHIYUKI NAKAMURA
- Chief Officer	KANTO ASAJI
- 2nd Officer	TOMONARI KAJISA
- 3rd Officer	RIKU MATSUDA
- Chief Engineer	WATARU KUROSE
- 1st Engineer	KATSUTO YAMAGUCHI
- 2nd Engineer	KAZUKI ONO
- 3rd Engineer	AKINORI TERAKAWA
- Chief Electronics Op.	HIROKI ISHIWATA
- 2nd Electronics Op.	MISATO TAKI
- Boat Swain	YUKI YOSHINO
- Able Seaman	TATSUO FUJII
- Able Seaman	NAO ISHIZUKA
- Able Seaman	YUTA OHJIRI
- Able Seaman	TORU NAKANISHI
- Sailor	SHINNOSUKE INOUE
- Sailor	KEITO SEGUCHI
- No.1 Oiler	YUJI HIGASHIGAWA
- Oiler	RYO SATO
- Assistant Oiler	MASAKAZU ISHIDA
- Assistant Oiler	KYOTARO MRUYAMA
- Assistant Oiler	KOITARO SARAMOTO
- Chief Steward	TORU WADA
- Steward	MASARU SUGIYAMA
- Steward	KENICHI OKUMURA

3. Research/Development Activities

● (Individual activity title)
- Responsible personnel

- Purpose, background

This test is an initiative related to “Research on underwater submarine hybrid sensing using reflected laser" (FY R2-FY R6 | 5 years), which was adopted by the Security Technology Research Promotion System in 2020. This research focuses on optical exploration technology for seabed mineral resources and aims to realize complex underwater seabed sensing by understanding the underwater propagation characteristics of laser reflected from seabed. In order to establish

underwater vehicle technology that actively incorporates underwater optics, we focused on the characteristics of laser reflected from seabed and seawater, and focused on the following: ① Obtaining time-information from reflected laser, ②Detecting reflectance from reflected laser, ③ Extraction of Doppler components from reflected laser to seawater.

This test is positioned as an evaluation test aimed at demonstrating the technology related to ① -③ above, and each demonstrator developed in this research will be mounted on the underwater vehicle "Kaiko" and performance tests will be conducted in deep sea. Each demonstrator has undergone multiple tank tests and shallow sea tests, and the desired functions and performance have been confirmed, and performance tests will be conducted in deep sea waters starting in 2023. Deep-sea tests for the KS-23-J08C are being carried out using the Shinsei-Maru as the mother ship and each demonstrator mounted on the “Kaiko”.

This test uses three types of technical verification machines. Regarding ① and ②, we will conduct ``(1)Physical property estimation test using underwater laser reflection" using the ”Green-laser demonstrator" and ``UV-laser demonstrator”. Regarding ③ , we will conduct ``(2)Performance evaluation test of the Doppler demonstrator", which measures the relative velocity from the Doppler shift of a laser reflected from suspended particles in seawater. The knowledge gained from each test result will be reflected in improvement in preparation for the sea tests (two times) scheduled for next fiscal year (2024).

- Activities (observation, sampling, development

< (1)Physical property estimation test using underwater laser reflection >

In this test, the “Green-laser demonstrator" and ``UV-laser demonstrator" installed onboard “Kaiko” were used to measure the laser reflectance of several seabed-mockups placed on the seabed. This provided the basic data needed for an algorithm to classify estimate physical properties of seabed sediments.

Based on the specifications and performance of both demonstrators, the minimum measurement altitude was set at approximately 2m and the maximum measurement altitude was set at approximately 15m. Fig. 1 shows an overview of this test. The “Green-Laser Demonstrator" and “UV-Laser Demonstrator" were installed on the “Kaiko”" at the same time, and were attached to the main frame on both sides of the rear of the “Kaiko” Both the power supply system and signal system were controlled arbitrarily from the support ship by using the payload I/F of “Kaiko”.

In this test, an underwater mock-up storage case was installed inside the sample basket of “Kaiko” and the vessel dived. The seabed-mockup storage case (hereinafter referred to as the “storage-case”) is a metal case that stores a mockup that simulates the seabed (seabed-mockup). The storage-case was stored in a storage rack frame (hereinafter referred to as the “rack-frame”) installed inside the “Kaiko” sample basket. The rack-frame is able to store 3-5 storage-cases (maximum 6 containers). Fig. 2, Fig. 3 and Fig. 4 shows an overview of the seabed-mockup, the storage-case and the rack-frame, respectively. Fig. 5 shows the appearance of “Kaiko”, which is equipped with both demonstration aircraft.

In this test, “Kaiko” first landed on the seabed at an arbitrary location, took out the storage-case from the rack-frame, and installed it on the seabed. At this time, the storage-cases were placed at intervals of approximately 3-5 meters. After setting up multiple storage cases on the seabed, the team took off from the bottom and began measurements by irradiating laser beams at each storage-case from an arbitrary altitude. Since the measurement ranges of the Green-laser demonstrator and the UV-laser demonstrator are different, the target altitude was adjusted each time on site and measurements were carried out. At the same time, “Kaiko” maintained a desired altitude as much as possible while navigating at a low and constant speed of less than 1 knot.

In this test, during the process of “Kaiko” diving, we conducted technology verification to generate long-distance ranging and high-resolution images (maximum horizontal resolution: 8000 pixels or more) using the "Green Laser Demonstrator". . As a result, we confirmed a distance measurement range of approximately 30-40m (preliminary figures). It was also confirmed that the maximum horizontal resolution when visualizing the ocean floor was over 8,000 pixels.

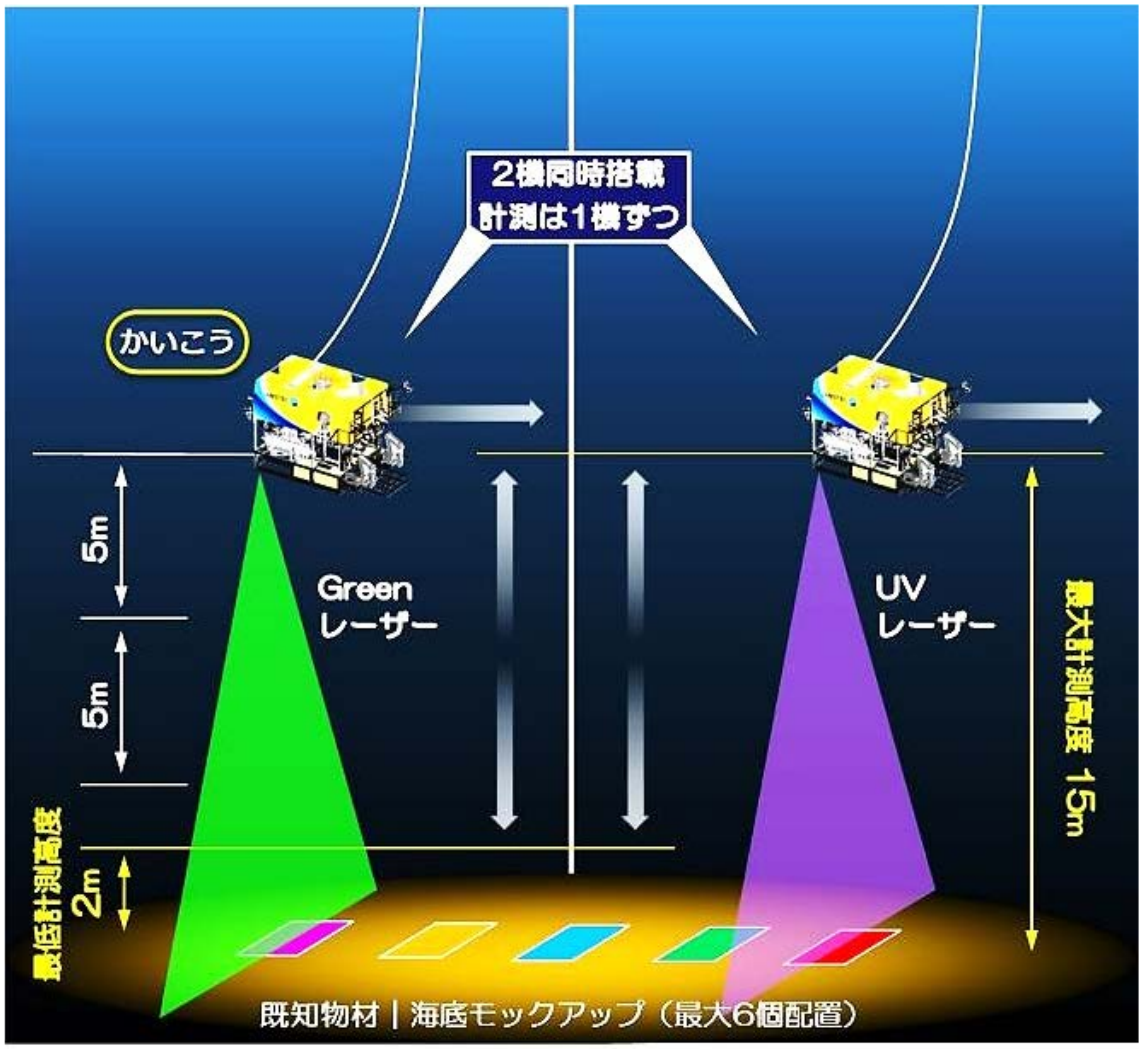
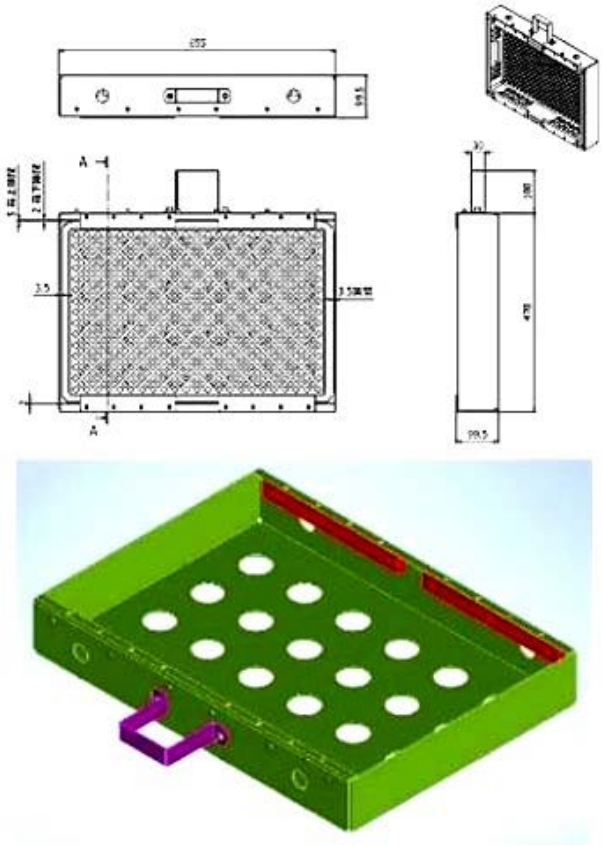


Fig. 1　Overview of the “Physical property estimation test”.

Size	645x420x95mm
Weight (air)	20-40kg
Working Depth	1,000m

Fig. 2　Seabed-mockups.



Size	655x570x100mm
Weight (air)	< 15kg
Working Depth	1,000m

Fig. 3　Storage-cases.

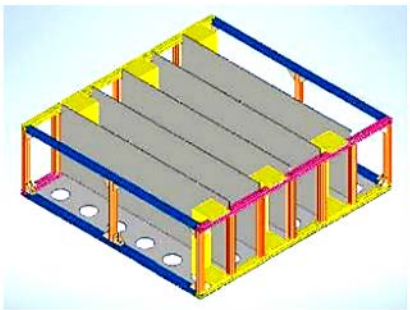
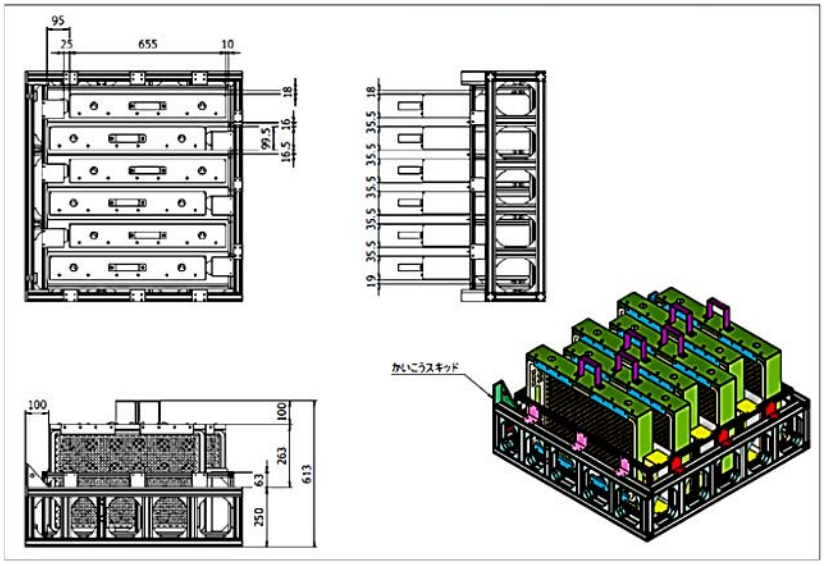


Fig. 4　Rack-frame.

Size	655x570x100mm
Weight (air)	< 15kg
Working Depth	1,000m



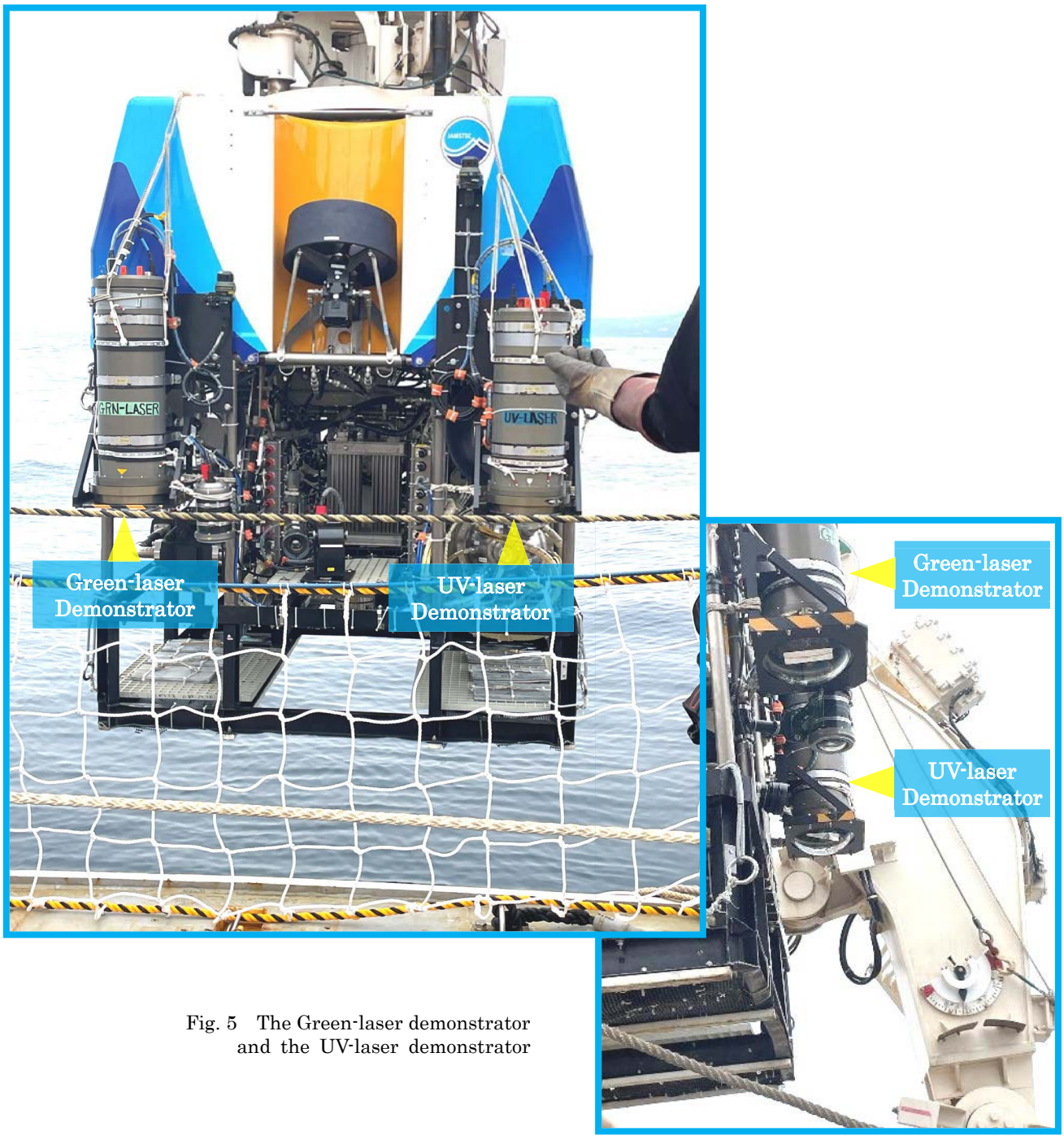


Fig. 5 The Green-laser demonstrator and the UV-laser demonstrator

< (2) Basic performance test of Doppler demonstrator >

This test was conducted to detect the speed of a moving object by extracting the Doppler shift of reflected laser in an underwater environment, and to evaluate the basic performance of combined navigation technology with an inertial navigation system (INS) that applies the speed. Based on the results of this test, improvements to the Doppler demonstrator will be extracted in preparation for the tests next year (the final year of this project). Fig. 6 shows an overview of this test. The premise for realizing this technology is to "detect the Doppler shift of a laser reflected from underwater objects." In other words, it means detection of "velocity relative to suspended matter ≒ velocity relative to water". Regarding the relative velocity of the laser emitted by an underwater vehicle in the minute time it takes for it to be reflected by the underwater suspended objects and received, the speed of the moving object (underwater vehicle) can be calculated by assuming that the underwater suspended object is an instantaneous stationary target. Define the relativity of the relative speed detected by this is input as an observation term to the INS's complex navigation calculation process (13th-order Kalman filter) to improve navigation performance. Therefore, the laser was irradiated in the direction of movement of the underwater vehicle, aiming several meters (2m to 5m) in front of the underwater vehicle, and the measurement target was the underwater suspended objects existing in the area.

In this test, the ideal conditions were for the underwater vehicle (Kaiko) to cruise at the slow and constant speed possible, without making any major attitude changes (roll/pitch changes), and with no vertical component. The action to suppress movement as much as possible determines the results of this test (accuracy of detected speed values). Also, at that time, it is important to maintain the heading (bow direction). Therefore, we believe that the use of ``Kaiko", which is equipped with an INS incorporating a high-performance optical gyro and has an autonomous navigation function based on this, is optimal for this test.

The ideal sea area for this test is a deep-sea area where there are many underwater suspended objects and where sunlight does not reach. Therefore, we decided to base our research on depths of 300 m or deeper in sea areas with sufficient water depth. At the same time, it was stipulated that the “Kaiko” must keep at a constant depth, maintaining an altitude of 200 m or more, taking into consideration a sufficient distance (altitude) that would not be affected by seafloor objects (such as flying up sediment). Under the test environment and conditions, multiple tests were conducted in which the “Kaiko” maintained a low speed of 1 knot or less and a constant depth, and navigated in one direction for as long as possible (60 minutes or more).

In this test, the Doppler demonstrator was equipped with a dedicated auxiliary equipment stand and the Doppler demonstrator installed inside the sample basket that "Kaiko" always has. The Doppler demonstrator was installed facing toward the bow of the “Kaiko” (≒ the direction of travel), and the laser was also emitted in the same direction. Therefore, the speed detected by the Doppler demonstrator (velocity relative to suspended objects) was the bow direction speed, which was strictly different from the forward direction speed. Fig. 7 shows the appearance of the Doppler demonstrator when it was installed on “Kaiko”.

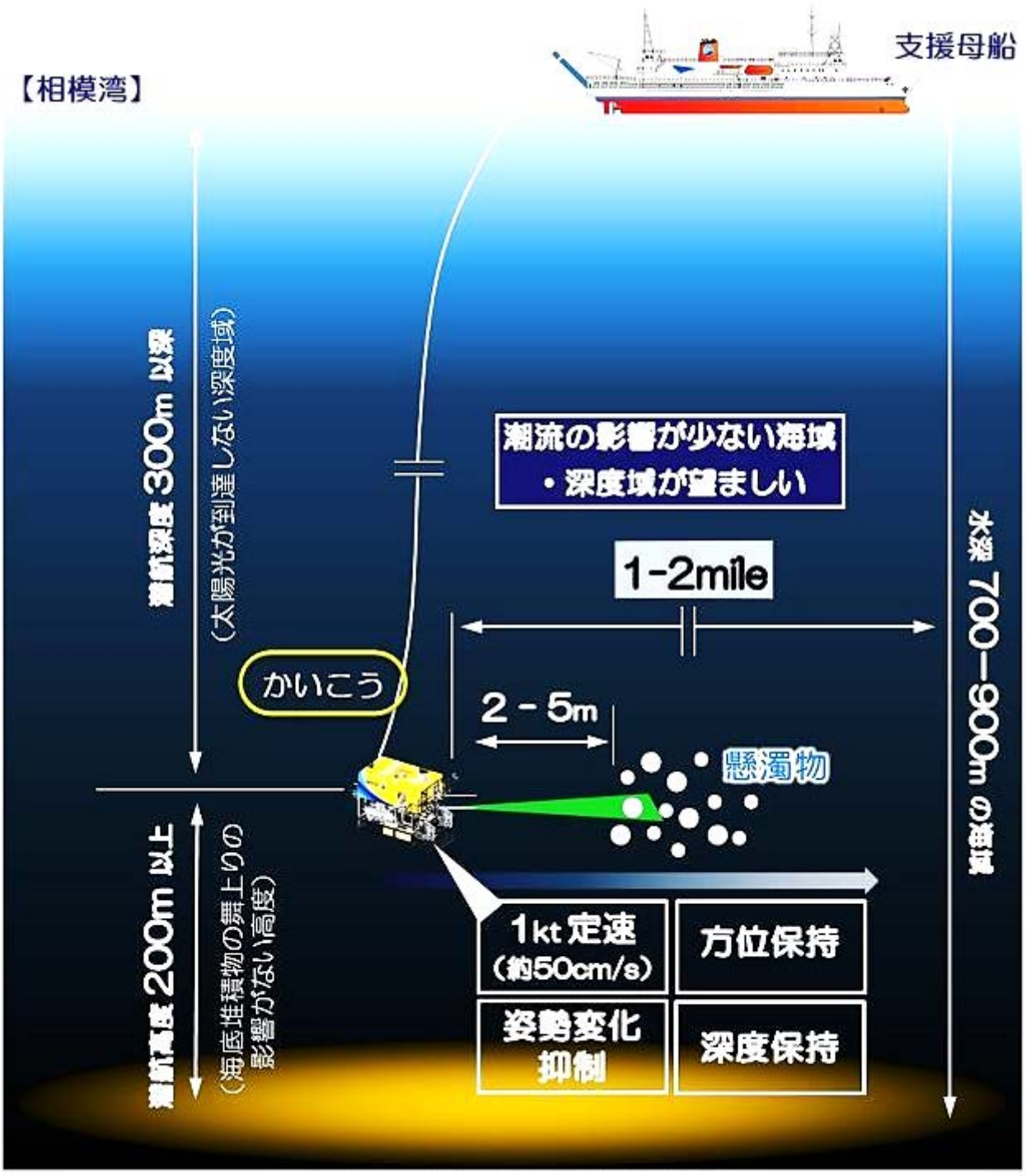


Fig. 6　verview of the “Basic performance test of Doppler demonstrator”.

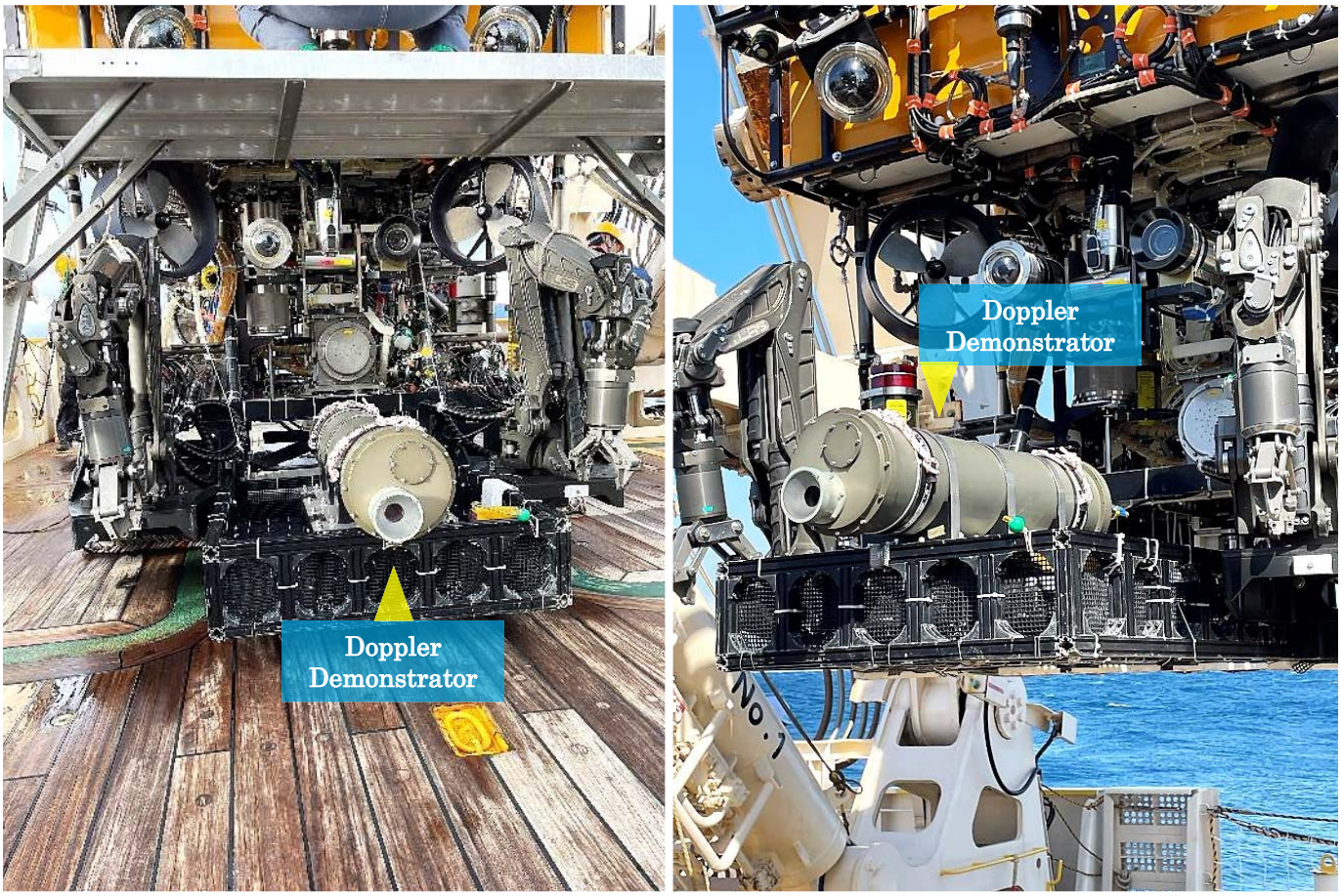


Fig. 7　The Doppler demonstrator.

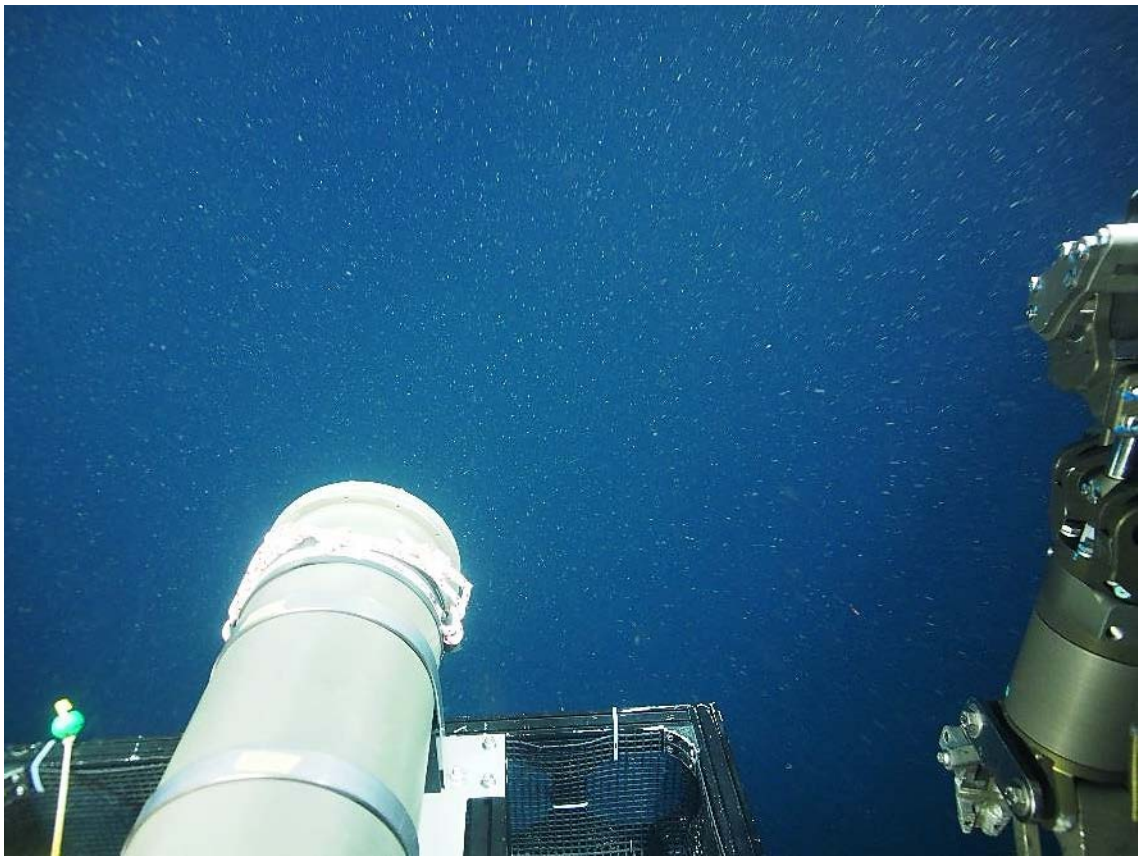
- Results

- Dive #905

Date : 02/03/2024
Sea area : Sagami-Bay
Payload : Green-demonstrator / UV demonstrator / Doppler demonstrator
Sampling : no

<Log>

1. 09:18 D= 650m | Measurement (Doppler test0) start (35-00.9545N 139-13.3472E)
2. 09:50 D= 650m | Measurement (Doppler test0) finish (35-00.9537N 139-13.3389E)
3. 09:50 D= 650m | Measurement (Doppler test1) start (35-00.9537N 139-13.3389E)
4. 10:55 D= 654m | Measurement (Doppler test1) finish (35-01.2309N 139-13.7318E)
5. 12:12 D=1013m | Landing (35-01.0696N 139-13.5206E)
6. 12:16 | Alignment for INS start
7. 12:26 | Alignment for INS finish
8. 12:37 D= 978m | Measurement (Doppler test2) start (35-01.0549N 139-13.5079E)
9. 12:43 D= 837m | Measurement (Doppler test2) finish (35-00.9331N 139-13.2934E)
10. 13:46 D= 832m | Measurement (Doppler test3) start (35-00.9409N 139-13.3006E)
11. 14:57 D=1002m | Measurement (Doppler test3) finish (35-01.2602N 139-13.6019E)
12. 15:05 D=1033m | Measurement (Doppler test4) start (35-01.2453N 139-13.6093E)
13. 15:20 D=1017m | Measurement (Doppler test4) finish (35-01.3152N 139-13.6492E)
14. 15:20 | |Rise up
15. 16:04 | Surfacing



- Dive #906

Date : 04/03/2024
Sea area : Sagami-Bay
Payload : Green-demonstrator / UV demonstrator / Doppler demonstrator
Sampling : no

<Log>

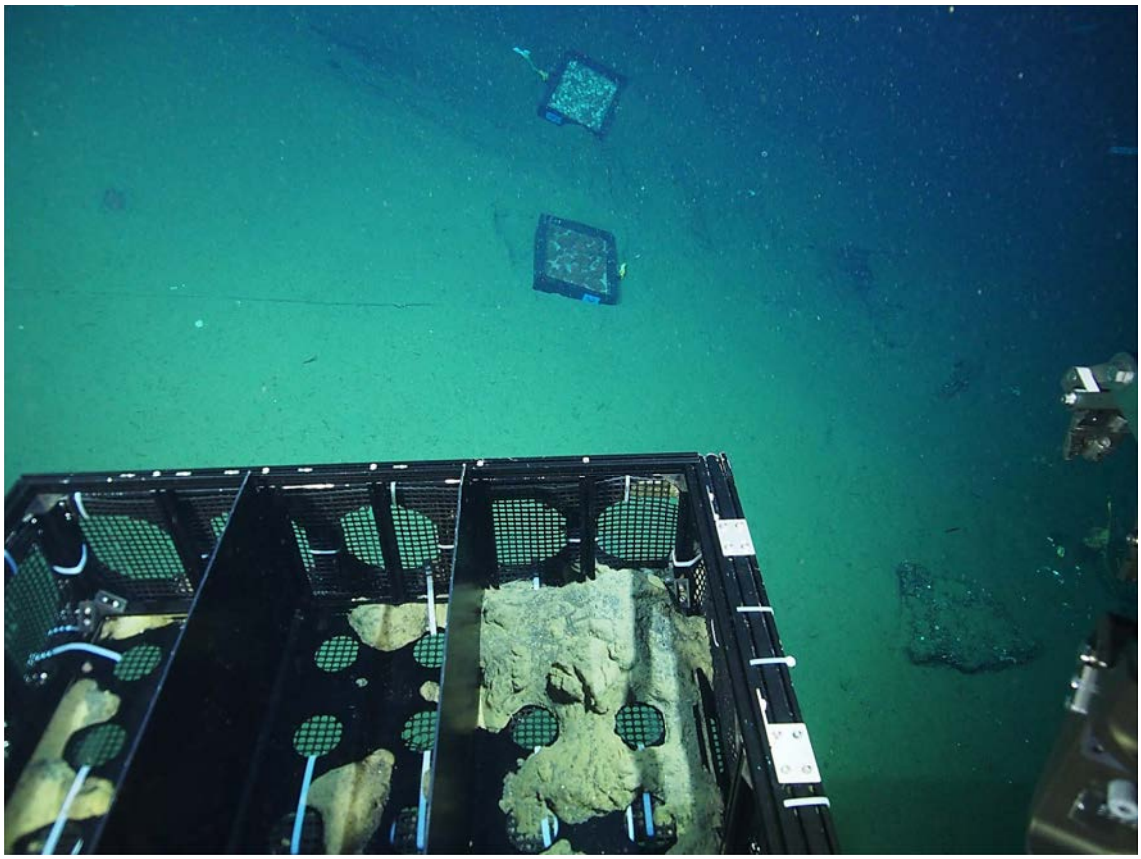
1. 14:04 D= 217m | Measurement (Green-Laser test1) start (35-02.5129N 139-12.8513E)
2. 15:00 D= 337m | Measurement (Green-Laser test1) finish (35-02.2666N 139-12.6556E)
3. 15:06 D= 343m | Measurement (Green-Laser test2) start (35-02.2694N 139-12.6523E)
4. 15:42 D= 356m | Measurement (Green-Laser test2) finish (35-02.2694N 139-12.6523E)
5. 15:42 D= 358m | Measurement (Doppler test1) start (35-02.2694N 139-12.6523E)
6. 16:01 D= 346m | Measurement (Doppler test1) finish (35-02.3707N 139-12.7208E)
7. 16:01 D= 346m | Real-up start
8. 15:20 | |Rise up
9. 16:16 | Surfacing

- Dive #907

Date : 05/03/2024
Sea area : Sagami-Bay
Payload : Green-demonstrator / UV demonstrator / Doppler demonstrator
Sampling : no

<Log>

1. 09:00 D= 900m | Landing (35-00.9431N 139-13.4020E)
2. 09:48 D= 898m | Measurement (Green+UV test1) start (35-00.9407N 139-13.3784E)
3. 10:27 D= 894m | Measurement (Green+UV test1) finish (35-00.9421N 139-13.3762E)
4. 11:38 D= 852m | Setting seabed-mockups (35-00.9576N 139-13.3216E)
5. 12:00 D= 847m | Measurement (Green+UV test2) start (35-00.9565N 139-13.3266E)
6. 12:47 D= 848m | Measurement (Green+UV test2) finish (35-00.9506N 139-13.3190E)
7. 12:52 D= 849m | Measurement (Green+UV test3) start
8. 14:01 D= 847m | Measurement (Green+UV test3) finish
9. 14:08 D= 838m | Measurement (Green-laser test1) start (35-00.9538N 139-13.3224E)
10. 14:54 D= 826m | Measurement (Green-laser test1) finish
11. 15:50 D= 852m | Recovering seabed-mockups
12. 15:50 D= 852m | Rise up
13. 16:21 | Surfacing



○ 4. Cruise Log

Date & Time	Description	Weather / Wind / Sea Condition
2024/02/29 Thu.	**Noon Position: 35-19.1N, 139-39.0E (JAMSTEC)**	**- / --- / -**
12:00	Science party came on board	
13:00	Research meeting for LASER operation	
14:00	Let go all shore lines & left JAMSTEC for Off Hatsushima	
14:30	Carried out education & training for scientists	
17:20	Arrived at research area	
17:23	Release XBT	
17:40	Scientist meeting	
	(blank)	
2024/03/01 Fri.	**Noon Position: 34-59.6N, 139-07.0E (Outside ITO port)**	**bc / SW-3 / 2**
7:00	Pending ROV operation due to rough sea condition	
10:00	Canceled todays operation	
10:15	Commenced proceeding to west ward	
11:30	Arrived at outside ITO port	
18:00-19:00	Scientist meeting	
	(blank)	
2024/03/02 Sat.	**Noon Position: 35-01.1N, 139-13.5E (Sagami Bay)**	**c / ENE-3 / 2**
8:11	Hoisted up "KAIKO"	
8:15	Launched	
8:26	"KAIKO Mk-IV" dove & com'ced her operation KK905	
12:12	Landed on the sea floor (D=1,013m)	
15:20	Left the sea bottom (D=1,017m)	
15:57	Refloated	
16:10	Recovered "KAIKO"	
18:00-18:30	Scientist meeting	
2024/03/03 Sun.	**Noon Position: 35-00.2N, 139-08.3E (Outside ITO port)**	**bc / SE-2 / 2**
08:15-08:30	Used work boat for picking up electrical element, important parts of Green Laser	
18:00-18:30	Scientist meeting	
2024/03/04 Mon.	**Noon Position: 35-02.7N, 139-13.0E (Sagami Bay)**	**bc / West-5 / 4**
9:30	Pending ROV operation due to rough sea condition	
13:17	Hoisted up "KAIKO"	
13:22	Launched	
13:33	"KAIKO Mk-IV" dove & com'ced her operation KK906	
16:16	Refloated	
16:31	Recovered "KAIKO"	
18:45-19:15	Scientist meeting	
	(blank)	
2024/03/05 Tue.	**Noon Position: 35-00.1N, 139-13.3E (Sagami Bay)**	**o / North-3 / 2**
8:07	Hoisted up "KAIKO"	
8:11	Launched	
8:21	"KAIKO Mk-IV" dove & com'ced her operation KK907	
9:00	Landed on the sea floor (D=900m)	
15:50	Left the sea bottom (D=852m)	
16:21	Refloated	
16:35	Recovered "KAIKO"	
17:00	Commenced proceeding to YOKOSUKA port due to avoiding rough sea	
18:00-18:45	Scientist meeting	
21:00	Arrived at YOKOSUKA port Section No. 4	

Date & Time	Description	Weather / Wind / Sea Condition
2024/03/06 Wed.	Noon Position: 35-19.7N, 139-40.5E (YKOSUKA port Sec. No.4)	r / North-6 / 4
15:30-17:00	Scientist meeting	
2024/03/07 Thu.	Noon Position: 35-19.1N, 139-39.0E (JAMSTEC)	- / --- / -
10:00	Sent out 1st shore line, arrived at JAMSTEC, then completed voy. No. KS-24-J02C	

● 5. Notice on Using

This cruise report is a preliminary documentation as of the end of cruise.
This report is not necessarily corrected even if there is any inaccurate description (i.e. taxonomic classifications). This report is subject to be revised without notice. Some data on this report may be raw or unprocessed. If you are going to use or refer the data on this report, it is recommended to ask the Chief Scientist for latest status.
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