Autonomous Control of Seafloor Data Transfer from Lander *Edokko Mark-I* to AUV *Hobalin*

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***Abstract*— In this study, a long-term, wide-area seafloor monitoring method was tested in coastal sea area by combining a seafloor landing probe (lander) and a hovering AUV (H-AUV). The lander and the H-AUV performed direct acoustic communication and acoustic positioning on the seafloor autonomously, and the H-AUV approached the lander in a horizontally opposed position for the underwater optical wireless communication. This established underwater high-speed LAN communication and enabled the transfer of large-capacity video data on the lander to the research vessel via the H-AUV.**

Keywords—seafloor, monitoring, optical communication, Lander Edokko Mark-I, AUV Hobalin

I. Introduction

Both a seafloor landing probe (lander) and a hovering AUV (H-AUV) are used for seafloor survey as cable-less seafloor probes [1, 2]. Although the operation procedures of both probes on the research vessel are similar, the lander is effective for long-term fixed-point observation, while the H-AUV is effective for immediate wide-area observation. Therefore, combining the two is considered to be an effective seafloor survey method [3]. In addition, simultaneous monitoring of the same seafloor means that the distance between them will be closer. If this is actively used, advanced cooperative surveys of the seafloor can be expected.

It is known that the underwater optical wireless communication is possible in the deep-sea environments within a distance of several tens of meters [4-6]. We are planning a high-speed communication system established between a lander and a H-AUV to transfer data on the seafloor and bring them back to the research vessel. Once this system is established, landers will exert the long-term seafloor monitoring platforms for more than a year with the function of immediate data providing. Additionally, H-AUVs can use the lander as an underwater acoustic lighthouses for self-positioning correction on the seafloor for their moving observations. The concept of this system is shown in Fig. 1.

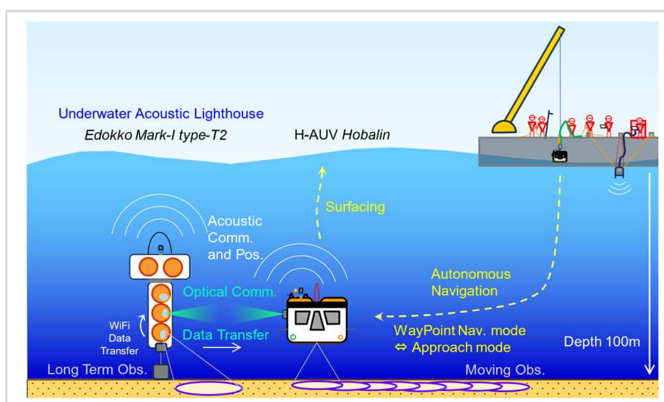

Fig. 1. Concept of the cooperative observation by Lander and H-AUV.

II. System and Devices

A. Lander "Edokko Mark-I"

The lander *Edokko Mark-I type-T2* owned by Japan Agency for Marine-Earth Science and Technology (JAMSTEC) was used for seafloor observations. It consists of five glass spheres, and the depth range is up to 8,000 m for all of spheres. The seafloor video shooting was set to an interval of 10 minutes once an hour. The video camera, lights, and the control unit of the communication device are installed in each of a separate glass sphere. The video image transfer is performed by WiFi wireless radio wave communication from the camera sphere to the communication sphere through glasses. The photo of the lander *Edokko Mark-I* is shown in Fig. 2.

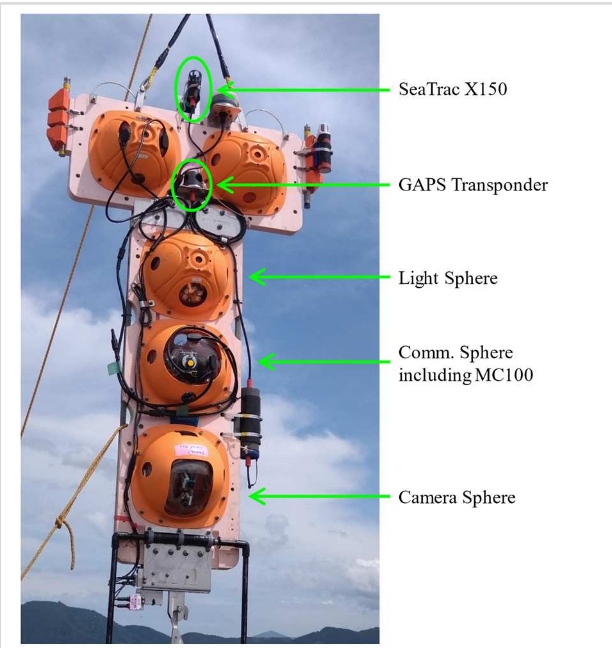

Fig. 2. Photo of the lander "*Edokko Mark-I type T2*" on May 29.

B. H-AUV "Hobalin"

The H-AUV *Hobalin* owned by National Maritime Research Institute (NMRI) was used for seafloor observations. The depth range is up to 2,000 m, and it is capable of maintaining altitude from the seafloor, heading, and horizontal position (hovering control) near the seafloor using six thruster controls. The camera imaging during the seafloor survey was set to shoot every 4 s (every 0.8 m horizontal movement) at a seed of 0.2 m/s.

In addition to the waypoint navigation mode for the seafloor photography survey, the approach mode was prepared for approaching *Edokko Mark-I* and transferring video data from *Edokko Mark-I* to *Hobalin*. Although the H-AUV *Hobalin 2* was also used in this sea trials, the discussion in this paper is limited to *Hobalin*. The photo of *Hobalin* is shown in Fig. 3.

C. Direct Acoustic Communication and Ultra-Short-Base-Line(USBL) Positioning Device "SeaTrac X150"

The SeaTrac X150s manufactured by Blueprint Subsea [7] were used as devices for direct acoustic communication and positioning between *Edokko Mark-I* and *Hobalin*. These devices are lightweight and compact, with a maximum pressure depth of 2,000 m and a maximum communication range of 1,000 m. Past tests of direct acoustic positioning between *Edokko Mark-I* and *Hobalin* showed a positioning error of about 1.7 m over a horizontal distance of 5 to 10 m [8].

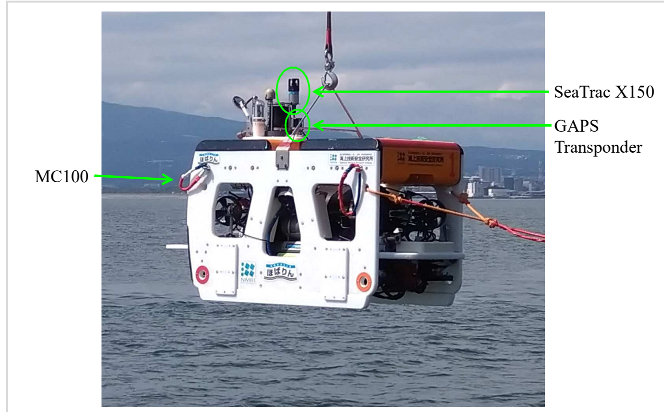

Fig. 3. Photo of the H-AUV "*Hobalin*" on May 29.

D. Direct Optical Communication Device "MC100"

The MC100s manufactured by Shimadzu Corporation [9] were used as optical wireless communication devices between *Edokko Mark-I* and *Hobalin*. These devices have maximum communication distance of 10 m underwater and a maximum communication speed of approximately 10 MB/s. The specifications of these devices have been modified for installation on the lander and the H-AUV, and the depth range for H-AUV is 1,000 m. The green lasers with a wavelength of 520 nm were used in both of the two communication devices, and the horizontal spread angle is about 8° at half angle. The half-duplex optical communication is established underwater with H-AUV side as the parent unit and *Edokko Mark-I* side as the child unit.

E. Acoustic USBL Positioning Device "Exail GAPS" from the Vessel

During the sea trials, it is necessary to identify positions of *Edokko Mark-I* and *Hobalin* on the seafloor from the vessel. SeaTrac X150 is used for direct communication and positioning between *Edokko Mark-I* and *Hobalin*, but the positioning accuracy of this device is not sufficient for use between *Edokko Mark-I* and vessel, or between *Hobalin* and vessel. Therefore, we used GAPS manufactured by Exail to perform positioning of the *Edokko Mark-I* and *Hobalin* from the vessel.

F. Data Transfer

The seafloor moving survey data are stored in *Hobalin*. The seafloor long-term survey data are stored in the camera sphere of *Edokko Mark-I*. For the data transfer test, camera images are transferred to and stored in the adjacent communication sphere via WiFi. These files can be accessed via LAN in the communication sphere and can be copied from outside via FTP. Since the communication sphere is connected to the optical communication device, once optical communication is established, it is possible to get data files in *Edokko Mark-I* from outside via FTP.

III. SEA TRIALS

The sea trials of a simultaneous operational test of *Edokko Mark-I* and *Hobalin* was conducted in the 100 m depth area of Suruga Bay during May 29-30, 2024. After the deployment of *Edokko Mark-I* and the start of seafloor observations, *Hobalin* was launched, and grid navigation was conducted to photograph a 50 m x 25 m seafloor area in the first half of the test. In the second half of the sea trial, after *Hobalin* reached the waypoint at a distance of approximately 30 m to *Edokko Mark-I*, It changed to the approach mode, and maintained its position horizontal distances of 10 m, 7 m, and 4 m relative to *Edokko Mark-I* while directly communicating and positioning, and also maintained altitude and heading to attempt optical communication with *Edokko Mark-I*. The table of observation periods are shown in Table 1. The depth, altitude, and seafloor position of *Hobalin* on May 29 are shown in Fig. 4 and 5.

TABLE I. SEA TRIALS 2024 IN SURUGA-BAY

	Edokko Mark-I type-T2		***Hobalin***		***Simultaneous Obsavation***
	Launch	Recovery	Launch	Recovery	
May 29	10:24	15:18	11:26	14:25	2h59m
May 30	09:55	13:53	10:45	13:28	2h43m

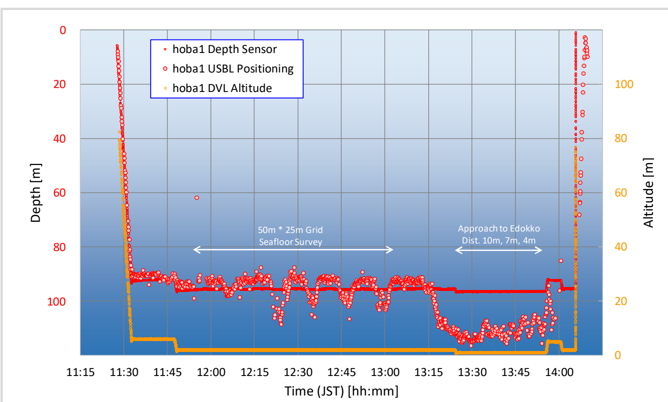

Fig. 4. -AUV *Hobalin* Depth and Altitude on May 29.

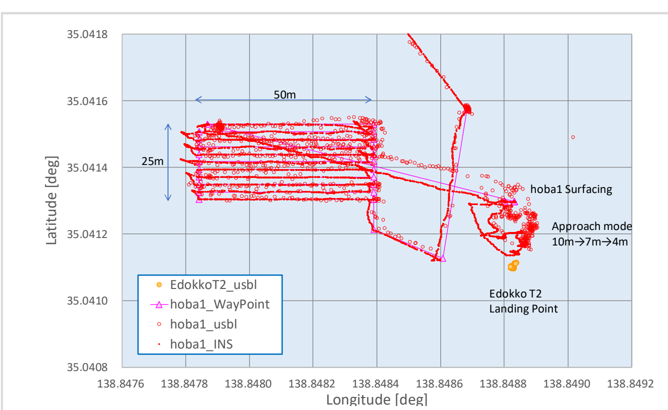

Fig. 5. *Hobalin* Seafloor Tracks on May 29.

Hobalin photographed the seafloor for 11 survey lines of 50 m long at an altitude of 2 m (about 0.6 km), as per the mission before launch. It then moved to the waypoint at a distance of about 30 m to *Edokko Mark-I*. After reaching the waypoint, *Hobalin* entered approach mode, turned on the optical communication device MC100, and irradiated a green laser. In addition, acoustic positioning of *Edokko Mark-I* by SeaTrac X150 was repeated every 24 seconds, and confirmation of relative heading by acoustic communication with *Edokko Mark-I* was repeated every 24 seconds. The position and heading were maintained at a horizontal distance of 10 m, 7 m, and 4 m, respectively for 10 minutes, on the front side where optical communication with *Edokko Mark-I* was possible.

During the sea trials, in addition to *Hobalin*, *Edokko Mark-I* was also launched and recovered daily. Therefore, heading of *Edokko Mark-I* at the seafloor was changed on May 29 and 30. The estimated heading of *Edokko Mark-I* for each day by the acoustic positioning of *Hobalin* in the approach mode is shown in Fig. 6.

A small ROV was used to confirm the underwater situation of *Edokko Mark-I* and *Hobalin*. It had rained the day before sea trials, and the underwater conditions were turbid and full of marine snow. Although the underwater conditions were not suitable for underwater photography, the ROV and *Edokko Mark-I* camera succeeded in obtaining images of *Hobalin*. Additionally, the ROV and *Hobalin* camera succeeded in obtaining the images of *Edokko Mark-I*. Examples of these underwater images are shown in Fig. 7.

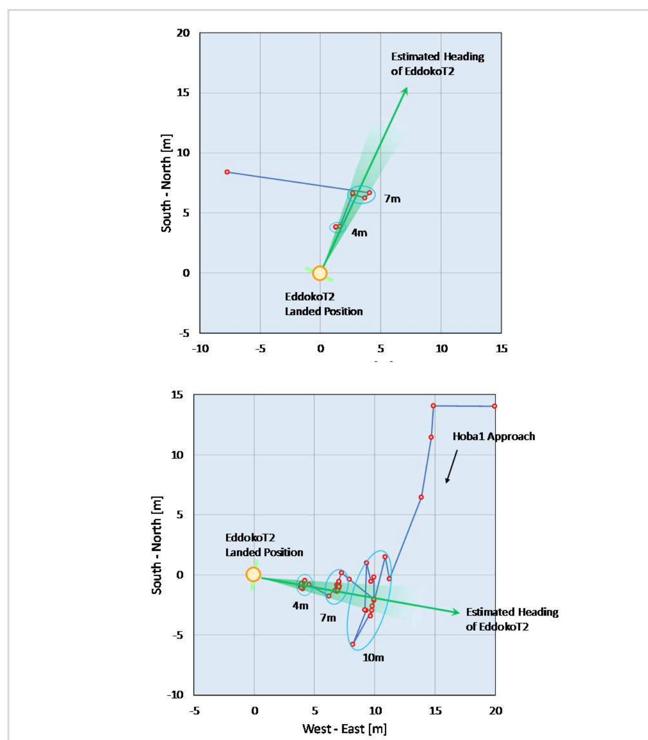

Fig. 6. USBL Positioning from *Edokko Mark-I* to *Hobalin* (Up: May 29, Down: May 30).

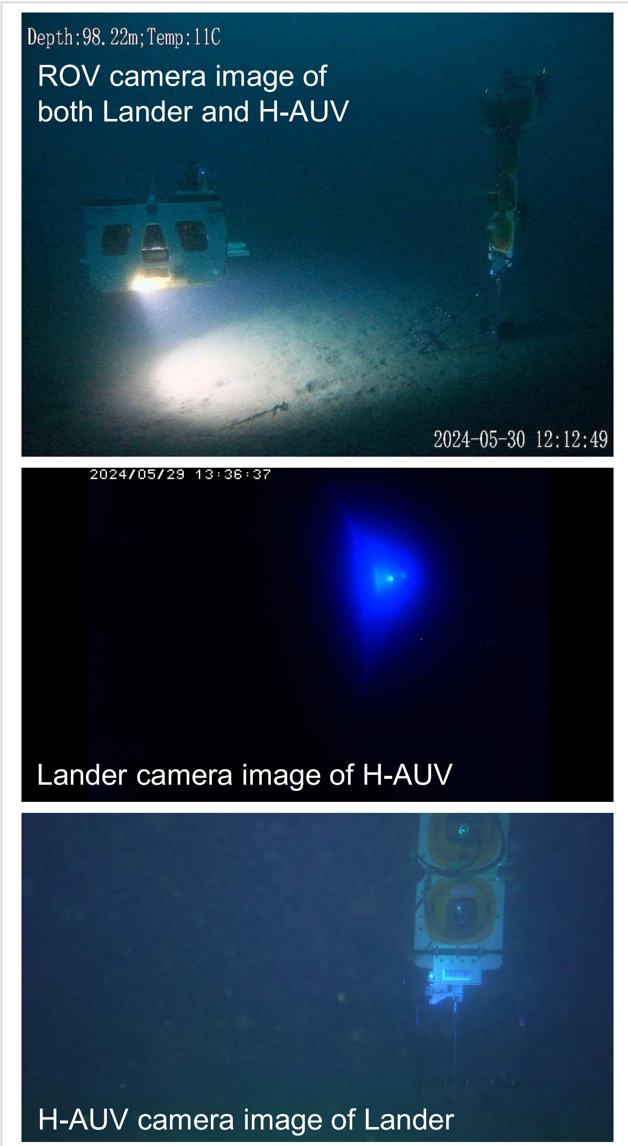

Fig. 7. Image samples near seabottom on May 29 and 30 (Top:ROV camera view, Middle: *Edokko Mark-I* camera view, Bottom: *Hobalin* camera view).

IV. Obtained Data

In this sea trials, 4,596 seafloor photographs were obtained including the survey area (50 m x 25 m) on May 29. This allowed us to confirm benthic fishes, shellfish, sea urchins, etc. Examples of these photos are shown in Fig. 8.

34 files (3.0 GB) of video data stored in *Edokko Mark-I* were transferred to *Hobalin* through underwater optical wireless communication, and brought back to the vessel. In these video data, the seafloor images on May 29 were included. The example of the video files are shown in Fig. 9. The duplication of video files by optical communication on May 29 was successful only for 20 minutes at distances of 7 m and 4 m. The 10 minutes optical communication at a distance of 10 m was not successful. This may be due to the fact that direct acoustic positioning between the lander and the H-AUV was not successful.

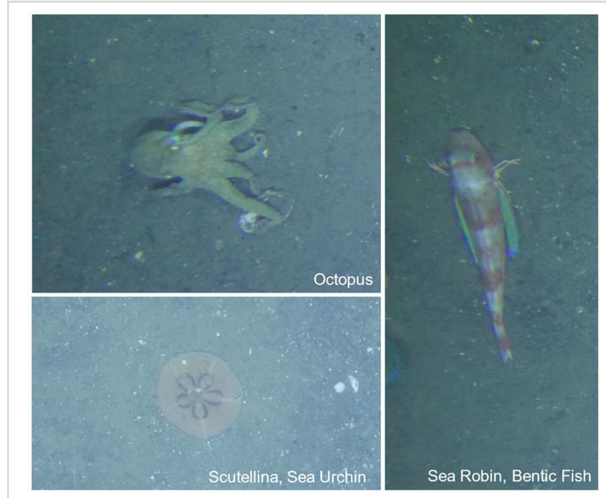

Fig. 8. Photo samples shot by still cameras on *Hobalin* on May 29.

Fig. 9. Image sample of transferred data from *Edokko Mark-I* to *Hobalin* on May 29.

V. Summary

We have successfully conducted a simultaneous seafloor observation test of *Edokko Mark-I* and *Hobalin*. The lander is effective for long-term observation and the H-AUV is effective for wide-area observation, opening up the possibility of simultaneous seafloor observation by combining the two methods.

In addition, we succeeded in transferring a large-capacity video files from the lander, which was designed for long-term monitoring of the landing point, to the H-AUV using underwater optical communication, and brought those files back to the vessel. The possibility was demonstrated to check the accumulated data in landers using H-AUVs during the long-term seafloor observation.

Acknowledgment

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