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R/V Kaiyo “Cruise Report” KY13-14_leg2

A sea trial for a performance test of AUVs <Leg2>

“The tele-operation test of an underwater vehicle applying an Internet Satellite

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

1. Cruise Information

- Cruise ID KY13-14_leg2
- Name of vessel KAIYO
- Title of the cruise A seat trial for a performance test of AUVs <Leg2>
- Chief scientist Shojiro Ishibashi [JAMSTEC]
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- Cruise period Oct. 4, 2013 – Oct. 7, 2013
- Ports of departure / arrival The Pier of JAMSTEC-HQ - The Pier of JAMSTEC-HQ
- Research area Sagami-Bay
- Research map

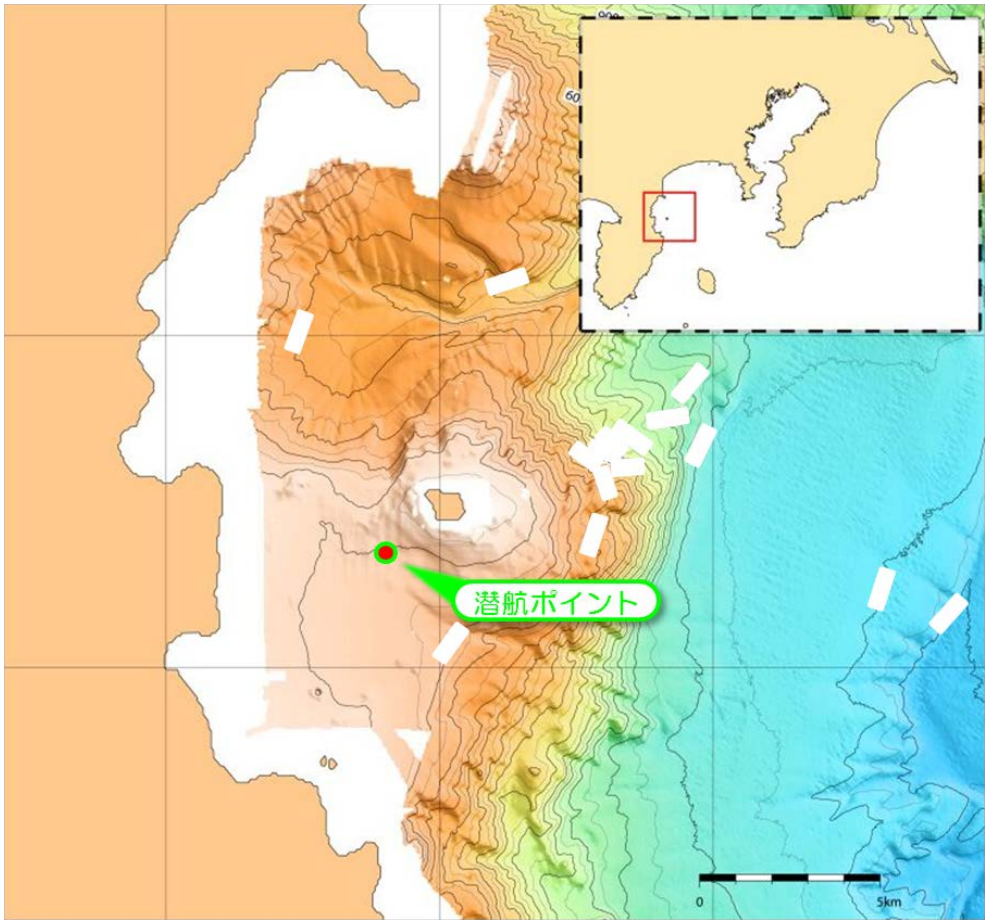

Fig. 1 The research area in the sea trial.

2. Observation

1) Purpose

In order to improve the operability of underwater vehicles, the underwater vehicle “OTOHIME” is remotely operated in real time through the ultra-high speed internet satellite “KIZUNA” (WINDS) from the ground base which is located at JAMSTEC HQ, Yokosuka. There is not a necessary that researchers and operators have to get on the support ship and actually go to a research area if such the remotely control system will be usual realized in near future.

In this sea trial, two kinds of remotely operations are conducted. One is that the “OTOHIME” is controlled from the onshore base station so that it cruises freely. The other is that it is controlled from the land base so that it works a simple mission using a manipulator on the seabed. In these operation tests, operators, who are at the onshore base station, uses each control tool for cruising and working, watching movies shown in real time.

2) Configuration

In this sea trial, two communication base stations are set. One is the onshore base station which is set at the JAMSTEC HQ located at Yokosuka. And the other is the onboard base station which is set on the support ship “KAIYO”. The satellite communication between the onshore base and the onboard base stations is established by the ultra-high speed internet satellite “KIZUNA” (WINDS) via ether-network. The onboard base station is connected to the relay operation console, which can control directly “OTOHIME”, via ether-network. “OTOHIME” is physically connected to the relay operation console by a very thin optical fiber cable whose diameter is 1mm. And “OTOHIME” can transmit all its own information and movies taken by three types of TV cameras including a HDTV camera through the optical fiber cable communication. As the result, the onshore base station can observe all information about “OTOHIME” and the movies and transmit order commands to it. The system configuration in this sea trial is shown in the Fig. 2.

3) Systems

[OTOHIME]

“OTOHIME” was developed as a multi-mission underwater robot that can operated as either as a ROV or an AUV. Fig. 3 shows its appearance and equipment layout. Its weight in the air is between 800 kg to 900 kg, depending on the operational form, and it is neutrally buoyant in the sea. In addition, it is equipped with the buoyancy adjustment system which can increase its buoyancy by up to 5 kg. It has two thruster systems with a tilt mechanism. So they can generate the thrust force in the fore-aft direction and the up-down direction using the thruster systems. The heading angle of “OTOHIME” can be controlled at low speed because each thruster system can be rotated separately. Moreover, it is equipped with a vertical rudder and a horizontal wing to control its heading angle and pitch angle when

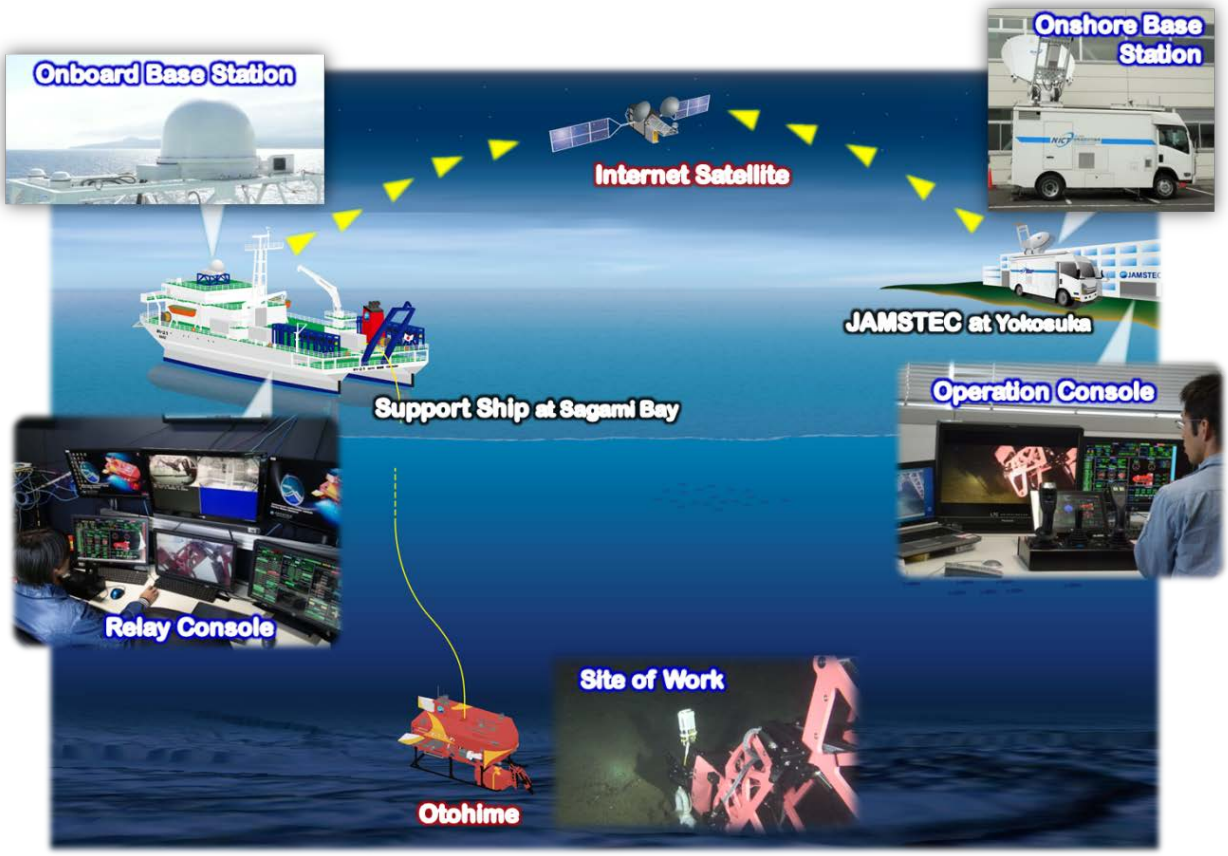

Fig. 2 System configuration in the sea trial.

cruising. The power supply unit is onboard, allowing it to cruise and work freely without the tether cable. The power supply unit consists of 32 Li-ion battery cells connected in series, its nominal voltage is 128V, the nominal capacity is 30Ah, and provides the vehicle with an endurance of about 6 hours.

"OTOHIME" is equipped with various types of camera systems. They are an HDTV camera, two NTSC TV cameras, a pan-tilt TV camera, a snapshot digital camera and a stereo vision system which is

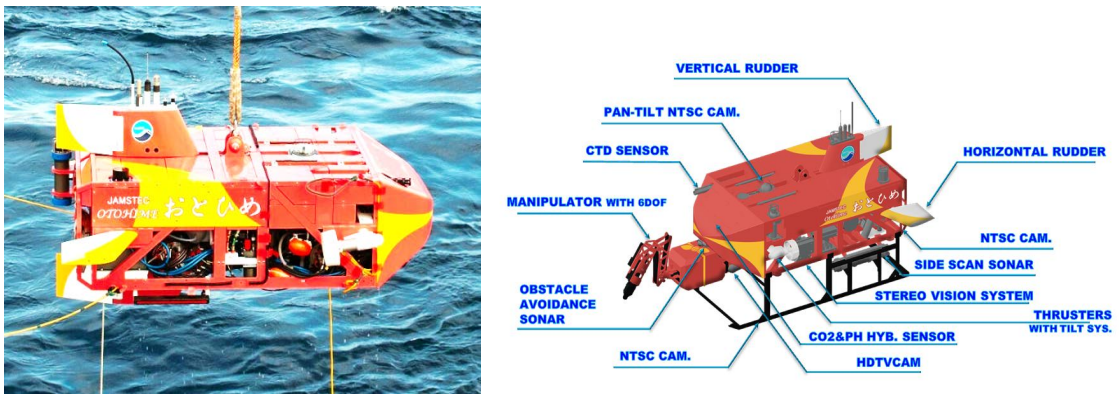

Fig. 3 Appearance and equipment layout of ""OTOHIME".

composed of two high resolution cameras. Each TV camera is used to observe the field circumstance and to take pictures of the seabed. A side scan sonar is also installed onboard in order to measure the seabed topography. In addition, the vehicle is equipped with some science sensors such as a CTD sensor, a fluorometer, a turbidimeter and a CO2-ph hybrid sensor. As such, it is a specialized multi-purpose vehicle for seabed scientific exploration.

"OTOHIME" is conceived to perform scientific exploration on the seabed. To that end, it must have high maneuverability and workability. So it has three operation forms in order to well use some particular kind of observation devices. Fig. 4 shows appearance of each from. They are the cruising form, the landing form and the working form.

[KIZUNA (WINDS)]

"KIZUNA" (WINDS) is the ultra-high speed internet satellite which was developed by the cooperation project between Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT). Weights of its shot case and orbit case are about 4.85 tons and 2.7 tons respectively. Its total length is about 21.5m when it opens the solar panel. "

"KIZUNA" (WINDS) has two kinds of antennas. One is two multi-beam antennas (MBAs) for Japan and nearby countries and south-eastern Asia area. The directivity angle of the MBAs is fixed. The other is the active phased array antenna (APAA) which can control and change arbitrarily the directivity angle and include whole Asia area and Pacific area. Fig. 5 shows the outline and main specifications of "KIZUNA" (WINDS). It can provide 155 Mbps communication line at maximum when a replay relay unit is applied. And also, it can provide 1.2 Gbps communication line when vent-pipe type relay mode, which has a 1.1 GHz bandwidth capability, is applied.

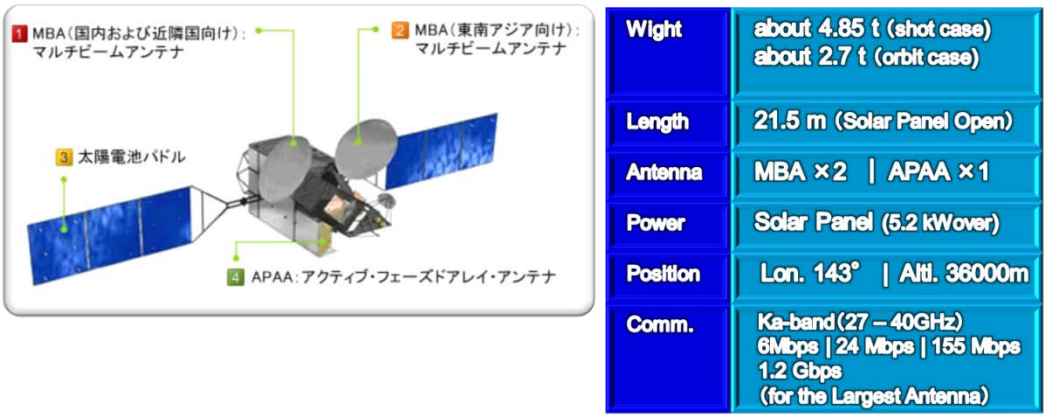

Fig. 5 The outline and main specifications “KIZUNA” (WINDS).

4) Schedule

This sea trial was carried out for four days. In the first day, we set up each system and the satellite communication link between the on-shore base station and onboard base station was established by “KIZUNA” (WINDS). And the health conditions of each system were confirmed. In addition, the parameters of each base station were adjusted.

In the second day, the satellite communication condition was confirmed. In this sea trial, the tracking system was applied to the onboard base station in order to track the “KIZUNA” (WINDS) at any time on the support ship “KAIYO” which usually moved with vacillation. So the operation test of the tracking system was also executed at that time. And moreover, the launch and recovery process for “OTOHIME” was tested and trained.

The third day was the mission day for the tele operation applying the ultra-high speed internet satellite “KIZUNA” (WINDS) and the underwater vehicle “OTOHIME”.

In the last day, the support ship went back to JAMSTEC HQ and fit off all systems and devices including the onboard base station, the relay operation console and “OTOHIME”.

Table 1 shows the schedule during the sea trial.

Table 1: Test Schedule

Date	Action/Place		Plans	Actuals
Oct. 4, Mon.	Pre-testing/ Departing	Yokosuka HQ	-Fitting Out -All system setting	←
Oct. 5, Tue.	Sea trial	Sagami-Bay	-Confirmation of the system conditions -Launch/Recovery -Test & Training for the underwater vehicle	←
Oct. 6, Wed.	Sea trial		-Mission Test a.m.: #1 | p.m.: #2	←
Oct.7, Thu.	Sea trial	Yokosuka HQ	-Fitting Off	←

5) Test Results

In the second day, we tested and trained the launch and recovery process after establishing the satellite communication link. Then the test was conducted in the working form. When “OTOHIME” was recovered helping the small boat, it clashed “OTOHIME” at a few times. This accident was caused by the faulty maintenance of it and the operator’s careless behavior and actions. As the result, its vertical rudder, parts of flame-work and buoyancy materials were broken out. So, on the same day, we did emergency repairs for all of them to conduct the objective tele-operation mission on the following day.

In the current day (third day), each tele-operation mission was executed. In a.m. the day, the tele-operation test for the manipulator was carried out. The operation form was the working form. And the operator, who was at the onshore base station, used the game controller as the mater arm to control the manipulator at that time. The operator could well control the manipulator watching movies sent from the onboard base station in about real time. And then the operator could also observe the status information of the manipulator via the satellite communication. Finally, the operator could perform the simple work which emulated the sensor setting work. Fig. 6 shows the scene of the tele-operation test.

In continuously p.m. the day, the tele-operation test for handling the vehicle was carried out. In the test, the operator uses the operation console unit. It can control the rotation speed of each thruster, the angle of the vertical rudder and the horizontal rudder, and the angle of the azimuth mechanism for thrusters respectively. The operator could control each actuator simultaneously or independently observing all status including thruster speeds and its position, heading and attitude of “OTOHIME” which was sent by the satellite communication in about real time, as shown in Fig. 6. And this test was tried by multiple

Fig. 6　Scenes of tele-operation tests for the manipulator and actuators.

people who do not have the special knowledge and experience. As the result, everyone could well operate "OTOHIME" from the onshore base station. Fig. 7 shows scenes of the tests.

These results can show the utility of the tele-operation of underwater vehicles applying the satellite communication.

3. Supplement

Fig. 8 shows appearances of the onshore base station and the onboard base station.

Fig. 9 shows appearances of the onshore operation console and the onboard relay console.

Fig. 7　Scenes of tele-operation tests carried out by multi people.

Fig. 8　Appearances of the onshore base station and the onboard base station.

Fig. 9　Appearances of the onshore operation console and the onboard relay console.