



KAIYO Cruise Report

KY13-05

Engineering test of autonomous underwater vehicles for
underwater resources exploration

Sagami-Bay

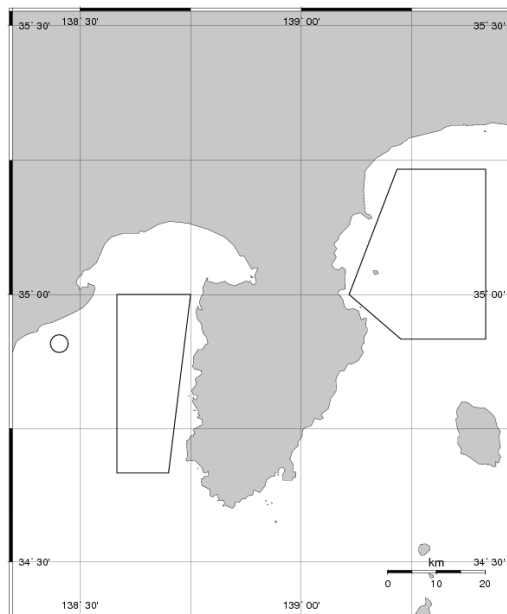
March 15,2013 – March 28,2013

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

1. Cruise Information

- ✓ Cruise ID KY13-05
- ✓ Name of vessel KAIYO
- ✓ Title of the cruise Engineering test of autonomous underwater vehicles for underwater resources exploration.
- ✓ RePresentative of Science Party : Hiroshi Yoshida, MARITEC, JAMSTEC
- ✓ Title of proposal Engineering test of autonomous underwater vehicles for underwater resources exploration
- ✓ Cruise period 2013/3/15~2013/3/28
- ✓ Ports of departure / call / arrival Pier of JAMSTEC ~ Sagami-Bay ~ Pier of JAMSTEC
- ✓ Research area Sagami-Bay (water depth of 80 m ~ 1,500m)
- ✓ Research Map

Sea-trial was carried out in the area bounded by (34°55.0'N,139°13.5'E), (35°00.0'N,139°06.5'E), (35°14.0'N,139°13.0'E), (35°14.0'N,139°25.0'E), (34°55.0'N,139°25.0'E)



2. Researchers

Name	Affiliation	Job Title
Hiroshi Yoshida	Maritec, JAMSTEC	Chief Scientist
Tadahiro Hyakudome	Maritec, JAMSTEC	Scientist
Shojiro Ishibashi	Maritec, JAMSTEC	Scientist
Makoto Sugawara	Maritec, JAMSTEC	Scientist
Takeshi Nakatani	Maritec, JAMSTEC	Scientist
Yutaka Ota	Maritec, JAMSTEC	Scientist
Hiroshi Ochi	Maritec, JAMSTEC	Scientist
Yoshitaka Watanabe	Maritec, JAMSTEC	Scientist
Takao Sawa	Maritec, JAMSTEC	Scientist
Yoshiyuki Nakano	Maritec, JAMSTEC	Scientist
Yoshiaki Yamauchi	Mitsubishi Heavy Industry	Chief Engineer
Hitoshi Noda	Mitsubishi Heavy Industry	Engineer
Kazuki Eguchi	Mitsubishi Heavy Industry	Engineer
Yoshimi Kanako	Mitsubishi Heavy Industry	Technician
Yasuo Yamakawa	Mitsubishi Heavy Industry	Technician
Yoshinobu Kanenaga	Mitsubishi Heavy Industry	Technician
Kazuhiro Kanayama	Mitsubishi Heavy Industry	Technician
Sho Mizumoto	Mitsubishi Heavy Industry	Technician
Mutsuo Takashima	Mitsubishi Heavy Industry	Technician
Hiroyuki Miyake	Ryoyu System Giken	Engineer
Kazunari Takahashi	Oki Seatech	Engineer

3. Engineering Test

1) Overview

The departing date was delayed because the ballast system of the Yumeiruka was troubled just before the leaving date planed first. Through the sea trial, the acoustic communication system was not working right, and all dives were thus done by the optical fiber communication. This means that the vehicle drops the surfacing ballast if the optical communication is lost despite autonomous control.

Table 1: List of results in the Leg #1.

Date	Plan	Place	Result
Mar. 16	Leaving the pier Training of launch & recovery System check on the board	Pier of JAMSTEC Sagami-Bay	
Mar. 17	Acoustic communication test	Sagami-Bay	Acoustic wave propagation characteristics were obtained.
Mar. 18	evacuating from rugged weather	Yokouska 4th destrict	
Mar. 19	System check on the board	Sagami-Bay	
Mar. 20	Acoustic communication test	Sagami-Bay	
Mar. 21	Test dive (Dive#3)	Sagami-Bay	Altitude control test
Mar. 22	replace the SAS to IFS evacuating from rugged weather	Sagami-Bay	
Mar. 23	System check on the board debugging	Sagami-Bay	
Mar. 24	Test dive (Dive#4)	Sagami-Bay	Altitude control test
Mar. 25	Test dive (Dive#5)	Sagami-Bay	Altitude control test
Mar. 26	debugging	Sagami-Bay	
Mar. 27	Test dive (Dive#6)	Sagami-Bay	Depth Control test. Achieving Full autonomous test
Mar. 28	Arrival in port Unloading the equipment	Pier of JAMSTEC	

2) Scenario control test (Altitude control)

In Dive#3~#5, Altitude control test was carried out by using the scenarios. In Dive#4, four types of scenarios were performed and checked. Figure 1 shows the result in scenario #2 in Dive #4. In this scenario, target pitch angle was 0°but real pitch controlled was $\pm 3^\circ$.

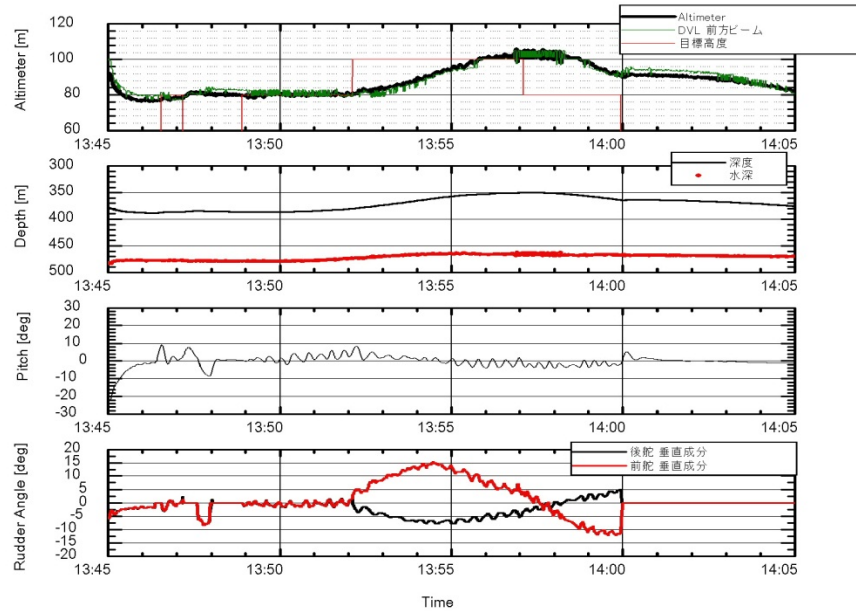


Figure 1: Pitch control test result.

3) Fully autonomous cruising

In Dive#6, the first autonomous cruising was achieved up to depth of 370 m. The vehicle status was monitored via acoustic communication. Two types of scenario: the standard depth control and the constant-pitch depth-control were performed.

Fig. 2 shows the cruising track and the depth trend of the vehicle obtained by the INS. Red cross-circles denote the preprogrammed way-points. The vehicle was first launched from the support ship, diving toward near the first start point of the scenario #1 by using the no-point cruising. Updates of the vehicle position were done with the data obtained by the SSBL to correct the error of the INS (you see sudden change of the position in the figure). After the position update, the vehicle entered in the scenario #1 and then it cruises toward the start point autonomously. The scenario #1 consists of a straight cruising using a course keeping control in horizontal plane and two changes of the vehicle depth with a depth keeping control of priority in vertical plane. The scenario #2 consists of a straight cruising using a course keeping control in horizontal plane and two changes of the vehicle depth with a pitch keeping control of priority in vertical plane. In each scenario, there are four way-points: the start point, the first and second depth change points, and the finish point. In the both scenarios, the vehicle successfully passed through the all way-points as shown in the figure.

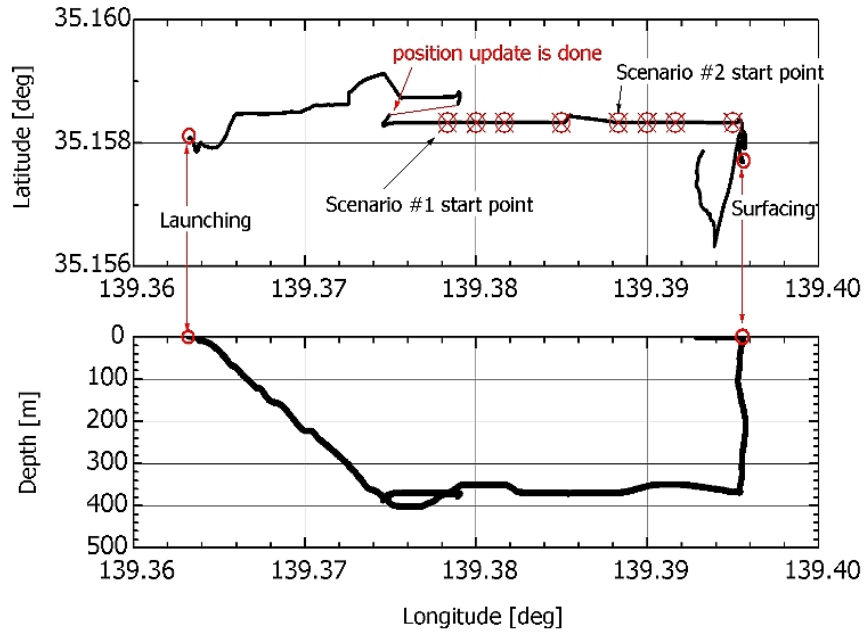


Figure. 2: The vehicle track (upper) and the depth trend (lower) in the dive # 6.

Figure 3 shows a depth trend and a vehicle attitude for performing the scenarios in dive #6. In all dives the auto stabilizing control of the roll was turned off to observe nature of roll change. Although the course keeping control was used (it means that its heading was not kept if external forces exist) and sea current was from 0.2 to 0.6 knots, the heading was in the angle between 87 degree and 94 degree when the target angle was 90 degree. In the scenario #2, the constant pitch control during depth change was successfully achieved as shown in the figure. The roll angle of the vehicle was varied between 0 and -1.5 degree during performing scenario.

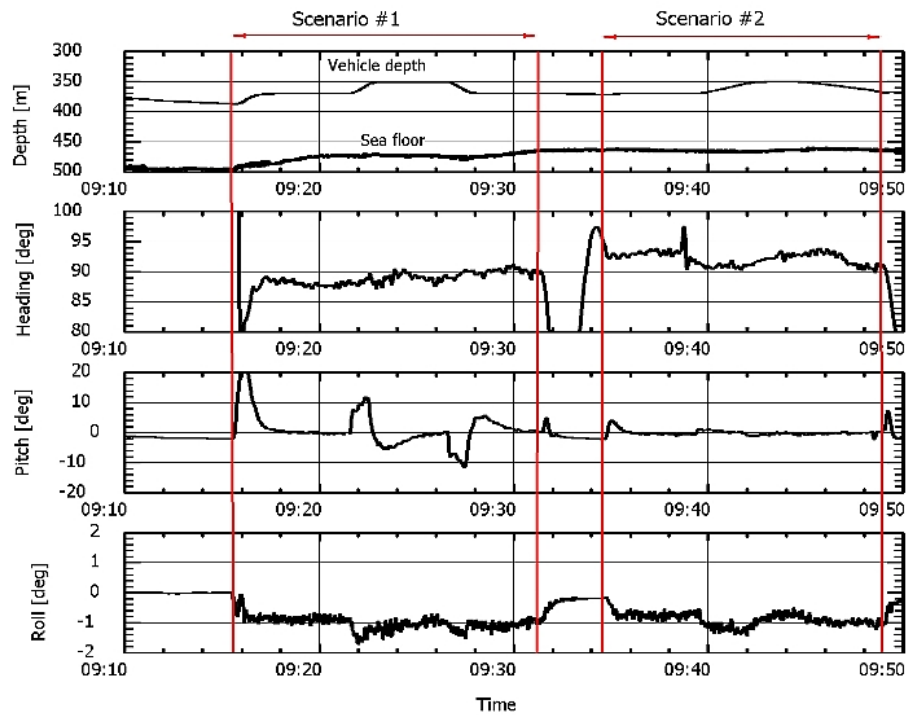


Fig. 3: Time trends of the vehicle attitude in the dive # 6. Upper: depth, second: heading of the vehicle, third: pitch angle, and lower: roll angle.

4) Sensors for observation

Sea-floor observations by tree sonars (Interferometry sonar, synthetic aperture sonar, and sub-bottom profiler) were carried out. In each recorded data, electrical noise was superimposed.

Obtained data from the CTD, the fluoro-turbidity meter and the ph sensor were good.

5) Modification of the recovery system.

Figure 4 shows the photographs of the recovery scene in the previous docking method and the docking system modified.

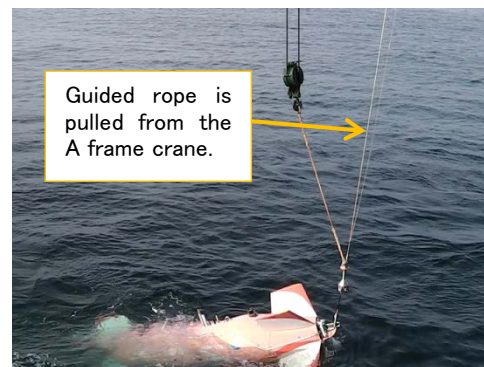
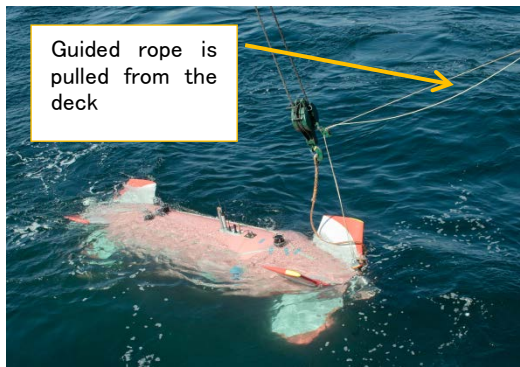


Figure 4 : Scene of docking: left) previous, right) modified.



Photo 1 : Recovering scene in Dive #6

6) Specifications of Yumeiruka

Yumeiruka is the AUV equipped with a canard-X rudder. The highly maneuverable AUV will be utilized for underwater resources exploration. Its constant motion control allows a magnetic sensor and/or synthetic aperture sonar to enhance performance. Table 2 shows its specifications.

Yumeiruka has a streamline shape to reduce hydro resistance. Its frame is made from aluminum alloy. The mechanically-formed syntactic forms attached into the frame make the vehicle buoyant. The

syntactic forms also form vehicle outer shape. Its whole surface is covered with separated thin fiber-reinforced plastics (FRPs). Cross arranged four 400 Watts direct drive thrusters at rear make propulsion. The thrusters generate maximum speed of 3 knots. Two X-rudders are mounted on the bow and the stern to control the vehicle highly maneuverable. Its controllable speed with the rudders is between 2 and 3 knots. The rudder area and aspect ratio were optimized by the balance between the control range of the simultaneous heading and course control and the rudder overhang length from the body. Fig. 1 shows the device arrangement of Yumeiruka. A buoyancy compensator adjusts the vehicle weight to near-neutral. The compensator consists of a pressure hull with capacity of 30 liters, an oil bladder, a pump and valves. Its buoyancy is adjusted by transferring the oil between the pressure hull and the bladder. It can be automatically controlled by a mission scenario. A small inertial navigation system (INS) consisting of three ring laser gyros developed by Japan Aviation Electronics Industry, Ltd. and JAMSTEC enables high accuracy positioning of the vehicle with a 300 kHz Doppler velocity log (DVL), a global positioning system (GPS) and acoustic navigation systems (ANSs). Its navigation modes, a DVL-INS hybrid mode and so on, are automatically or manually selected. The AUV system has a super short base-line (SSBL) acoustic positioning system. Other sensors for navigation are an altimeter and a depth meter. The vehicle is equipped with a depth meter, model 8B and a CTD, SBE49 but the vehicle system gives priority to the model 8B as depth data measured. Both the DVL and an altimeter measure altitude and the DVL has priority as well. These pair sensors constitute a redundancy system.

Table 2: Specifications of *Yumeiruka*

ITEMS	VALUES
Maximum depth rating	3,000 m
Cruising speed	2 knot
Length	5.0 m
Weight	2.7 tons
Endurance	16 hours
Scientific payload	70 liters (100 kg)
Observation items	IF sonar, Synthetic Aperture Sonar, SBP, CTD meter, Fluoro & turbidity meter, pH meter

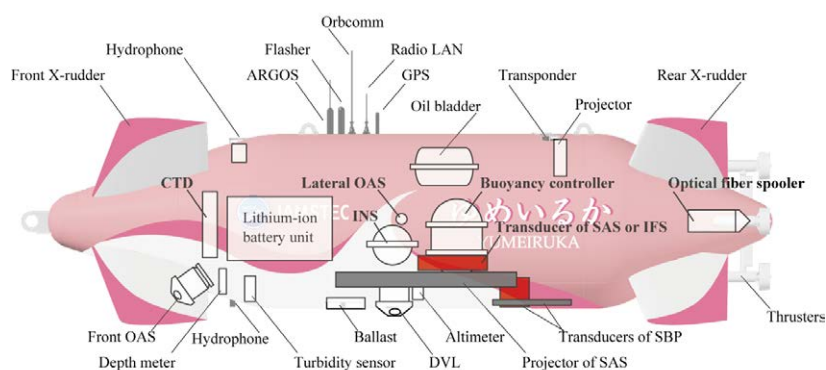


Fig. 5: System arrangement.

4. Notice on Using

Notice on using: Insert the following notice to users regarding the data and samples obtained.

This cruise report is a preliminary documentation as of the end of the cruise.

This report may not be corrected even if changes on contents (i.e. taxonomic classifications) may be found after its publication. This report may also be changed without notice. Data on this cruise report may be raw or unprocessed. If you are going to use or refer to the data written on this report, please ask the Chief Scientist for latest information.

Users of data or results on this cruise report are requested to submit their results to the Data Management Group of JAMSTEC.