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Yokosuka Cruise Report

YK10-02

Suruga Bay, Sagami Bay

25.February.2010 – 4.March.2010

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

Contents

1. Cruise Information

Cruise Number : YK10-02

Ship Name : "Yokosuka"

Title of the Cruise : Sea Trial of AUV "URASHIMA"

Title of Proposal : "Elemental Technology Tests for Deep & Long Cruising Range Autonomous Underwater Vehicle "URASHIMA""

Cruise Period : 25 February 2010 - 4 March 2010

Port Call : Shimizu port (Departure) – JAMSTEC (Back)

Experiment Area :
A) Suruga Trough (Depth: 700 -3,500m)
34° 00.0′ N, 138° 15.0′ E, 34° 45.0′ N, 138° 45.0′ E
B) Suruga Bay (Depth: 500 -1,400m)
34° 45.0′ N, 138° 15.0′ E, 34° 05.0′ N, 138° 45.0′ E

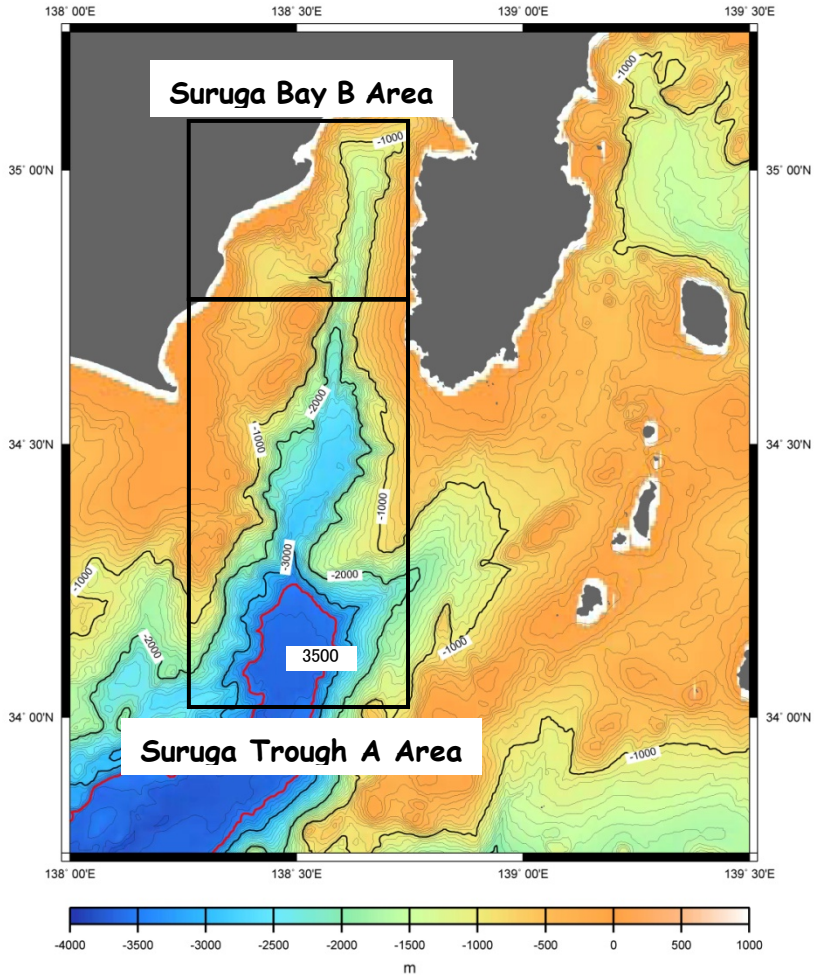

Fig.1 Experimental Diving Area in the Suruga Trough &Bay

C) Sagami Bay (Depth: 200 -1,500m)

34.92Lat. 139.26Long. , 35.00Lat. 139.12Long.
35.25Lat. 139.25Long. , 35.25Lat. 139.42Long.
34.92Lat. 139.417Long.

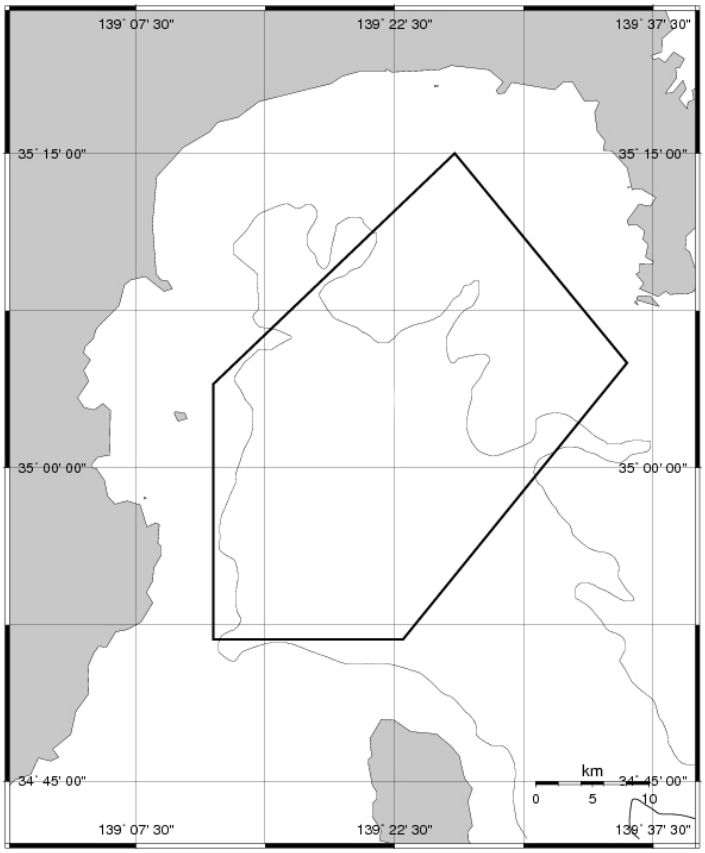

Fig.2 Experimental Diving Area in the Sagami Bay

2. Reseachers

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[JAMSTEC - Marine Technology Center]

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3. Experiment

Background :

In late years, deep-sea investigation becomes important for a study about the global warming and study about ocean earthquake. Recently the vehicle has begun to undertake cruises for scientific applications. These applications require precise maneuvering of the vehicle for detailed investigations. For high performance maneuvering of the vehicle, it is necessary to design a control system based on a mathematical model for the vehicle. Since the vehicle was built, PI control has been adopted. In order to improve control performance, the motion controller can be design by means of a model-based approach. An accurate mathematical model based on vehicle dynamics is needed for design of the high-performance controller. It is necessary for the mathematical model to express the actual motions of the vehicle precisely.

Outline :

The sea trial of maneuverability of the vehicle was carried out to improve the precision of the model. The items of performance test are accelerate test, transient response test, controller performance test, step response test and floor tracking test.

Experiment items :

1) Accelerate Test

The initial condition of the vehicle is inaction. Trim is 0 degree, elevator

deflection is 0 degree, rudder deflection is 0 degree and speed is 0 m/s. The vehicle is commanded with the number of revolutions of the thruster. The motion data of the vehicle until terminal velocity is measured.

2) Transient Response Test

The initial condition of the vehicle is constant speed, zero deflection of elevator and rudder. The motion data of the vehicle when elevator or rudder deflection is changed is measured.

3) Controller Performance Test

The motion of the vehicle when the vehicle keeps position controlled by depth controller or altitude controller is measured during sampling period. Control gain is tuned up to optimize the controller of the vehicle.

4) Step Response Test

The response to step command input of the vehicle when cruising by depth control or altitude control is measured.

5) Seafloor Tracking Test

The tracking performance of the vehicle against for the flat bottom seafloor or seafloor with ups and downs is tested.

URASHIMA

Fig.3 Overview of Deep & Long Cruising Range AUV "URASHIMA"

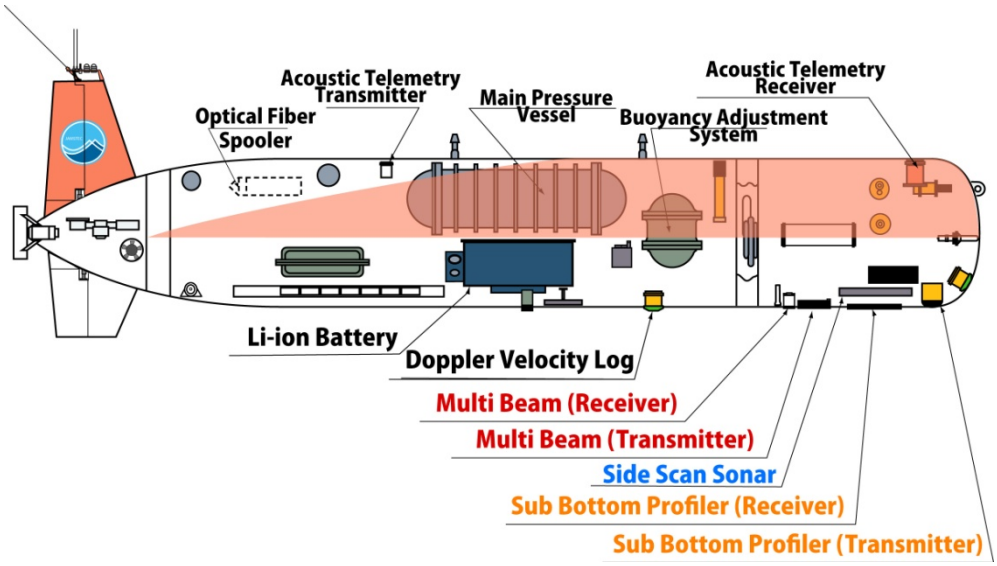

Fig.4 General Arrangement of "URASHIMA"

Specifications of the vehicle

Weight in the air	:	6,700kg
Size	:	10.6 (L) x 1.3 (W) x 1.5 (H)
Maximum Depth	:	3,500m
Cruising Speed	:	3 knots
Operation Mode	:	Autonomous / Remote Control / UROV
Navigation Devices	:	Inertial Navigation System, Depth meter Doppler Velocity Log, Altimeter
Observation Devices	:	Side Scan Soner, Multi Beam Echo Sounder, Sub-bottom Plofiler, CTD-DO sensor

Cruise Log

YK10-02 Schedule

Date 2010	"YOKOSUKA"	Test Area	Contents
25, February (Thursday)	Departure Experiment1	Shimizu port – Suruga Bay	1) Accelerate Test 2) Transient Response Test
26, February (Friday)	Experiment 2	Suruga Bay	3) Controller Performance Test 4) Step Response Test
27, February (Saturday)	Experiment 3	Suruga Bay near by Yaizu port	5) Seafloor Tracking Test The earthquake trace investigation with SSS and MBES
28, February (Sunday)	Canceled	Suruga Bay	To shunt by tsunami occurred in Peru
1, March (Monday)	Experiment 4	Suruga Bay near by Yaizu port	5) Seafloor Tracking Test The earthquake trace investigation with SSS and MBES
2, March (Tuesday)	Experiment5	Sagami Bay near by Hatsushima	5) Seafloor Tracking Test The earthquake trace investigation with SSS and MBES
3, March (Wednesday)	Experiment 6	Sagami Bay near by Hatsushima	5) Seafloor Tracking Test The Seafloor investigation with SSS and MBES
4, March (Thursday)	Return to Port	JAMSTEC	Remove fittings

Experiment results

2010 February 25

Test Point: 35° 3.0986′ N 138° 36.5527′ E 1,000m Depth

The vehicle dived to 700m in depth, and it was measured motion from 0 m/s to terminal velocity at three phase number of revolutions, and difference of the motion by rudder and elevator operation. The following things were confirmed on the acceleration test.

Figure 5 shows an experimental result of acceleration test. The velocity is indicated by green, The thruster number of revolutions is indicated by blue. The case of thruster number of revolutions was 440 rpm, the vehicle reached the terminal velocity in 390 seconds, and the terminal velocity was 2.6 knots. The case of thruster number of revolutions was 280 rpm, the vehicle reached the terminal velocity in 290 seconds, and the terminal velocity was 1.8knots. The case of thruster number of revolutions was 150 rpm, the vehicle reached the terminal velocity in 340 seconds, and the terminal velocity was 0.9 knots.

Figure 6 shows an experimental result of elevator performance test at 1.9 knots. The upper graph shows depth deviation, the lower graph shows pitch angle. The case of 5 degrees elevator deflection is indicated by blue, 10 degrees is indicated by green and 15 degrees is indicated by red. In the case of elevator deflections is 5 degrees, the vehicle went ahead 260m while raised 15m.

Figure 7 shows an experimental result of rudder performance test at 1.8 knots. The case of -5 degrees rudder deflection is indicated by blue, -10 degrees is indicated by green and -15 degrees is indicated by red. The turning radius of the vehicle in each rudder deflection was 115m, 61m and 50m. It was confirmed that the turning performance of the vehicle did not depend on the speed.

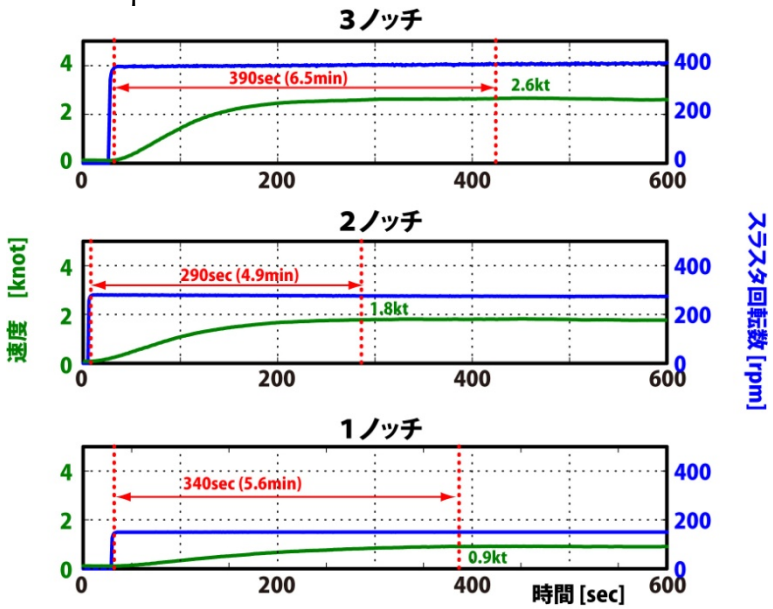

Fig.5 The Experimental result of acceleration test

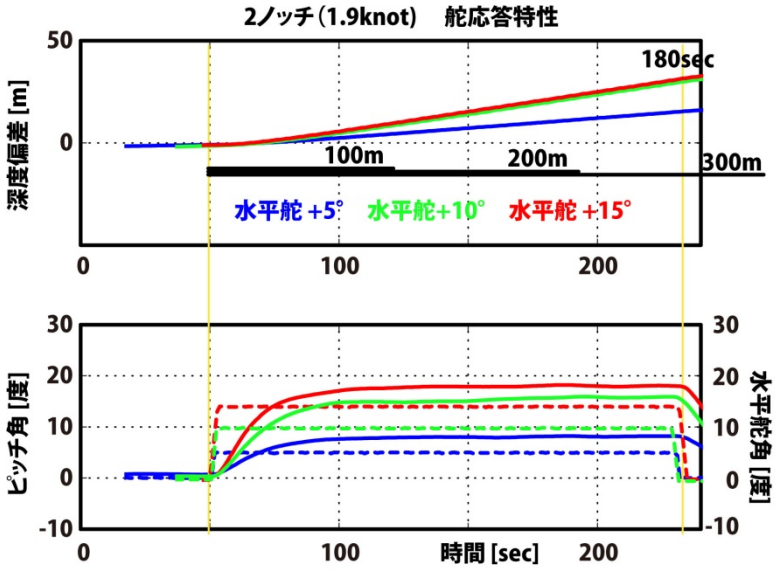

Fig.6 The experimental result of elevator performance test

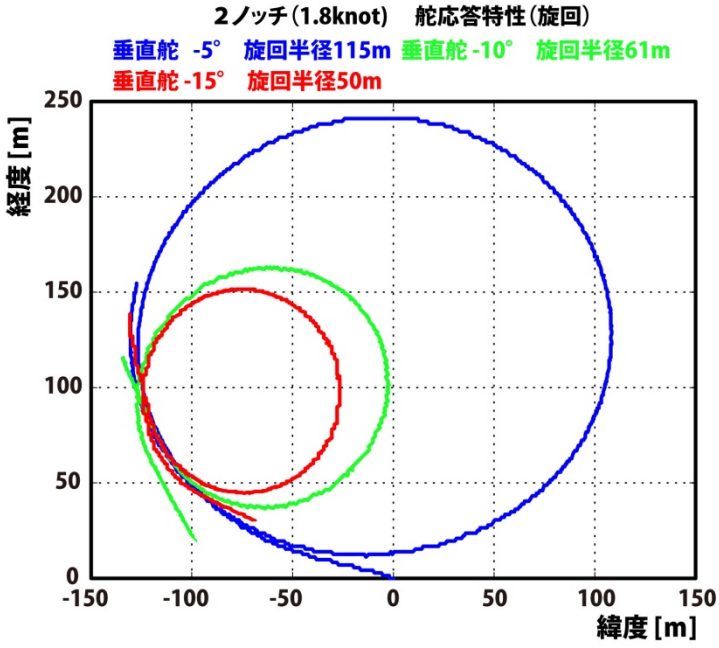

Fig.7 The experimental result of rudder performance test

2010 February 26

Test Point: 35° 3.2127′ N 138° 43.1068′ E 1,000m Depth

The vehicle dived to 900m in depth, and it was measured motion controlled by depth controller or altitude controller.

Figure 8 shows the experimental result of step response of the vehicle controlled by depth controller. The figure expresses the time series of depth, speed, pitch angle and elevator deflection. The step input for depth controller is 10m dive and the speed of the vehicle is 2.7 knots. The command for the vehicle is indicated by red, the case of control gain 1.8 is indicated by blue and control gain 2.0 is indicated green. The performance of two control gain was approximately equal. An angle of pitch deviation is smaller control gain 2.0 than gain 1.8.

Figure 9 shows the experimental result of step response of the vehicle controlled by altitude controller. The figure expresses the time series of altitude, speed, pitch angle and elevator deflection. The step input for altitude controller is 10m dive or 10m rise and the speed of the vehicle is 2.7 knots. The command for the vehicle is indicated by red, the case of control gain 1.56 is indicated by blue and control gain 2.0 is indicated green. The performance of two control gain was approximately equal. An angle of pitch deviation is smaller control gain 2.0 than gain 1.56.

It was confirmed that an angle of pitch change shrank if a control gain was large value from these experiments.

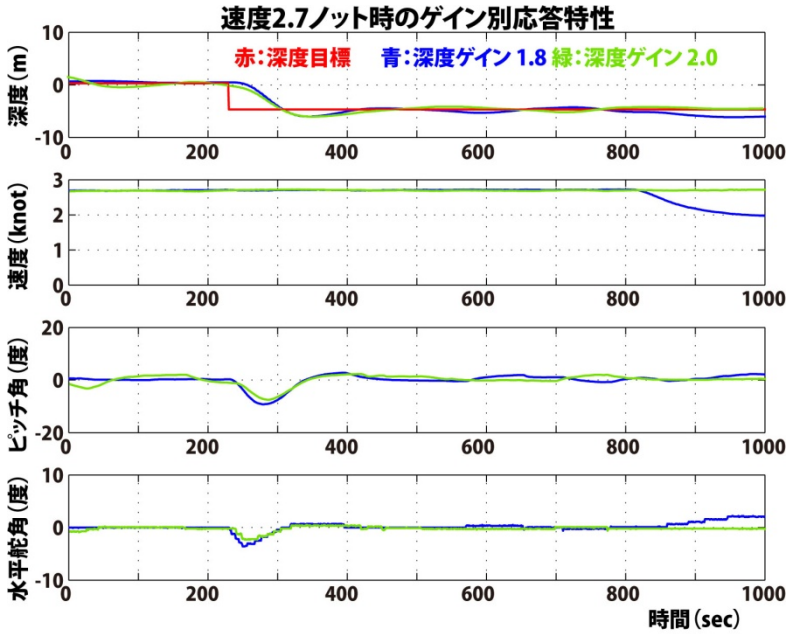

Fig.8 The Experimental Result of Step Response of The Vehicle Controlled by Depth Controller

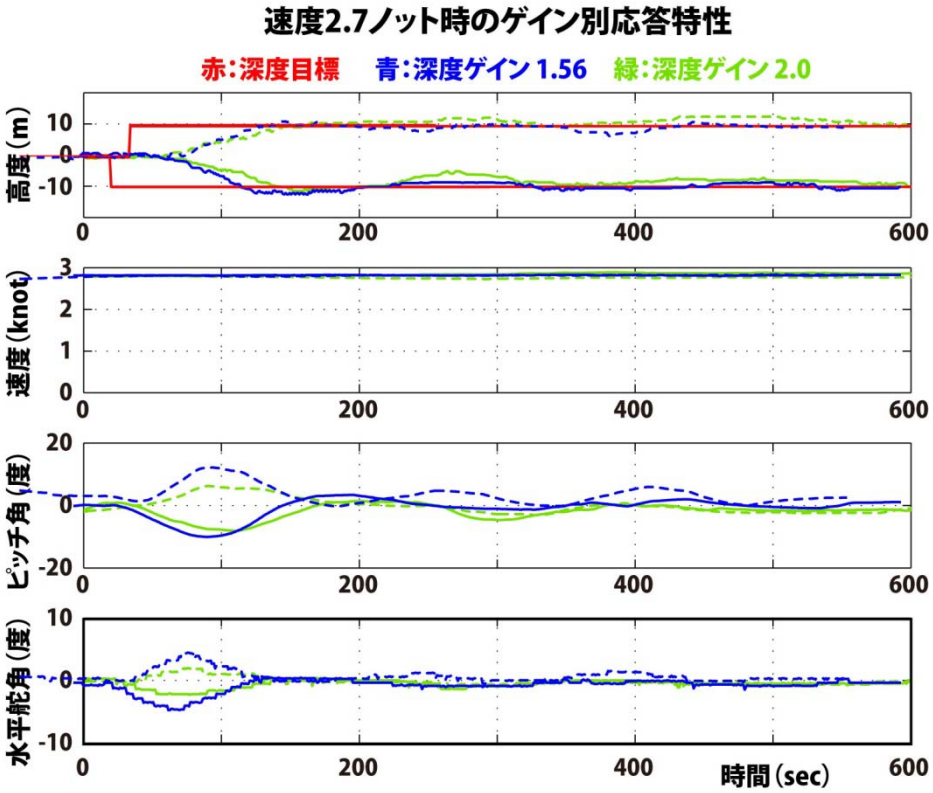

Fig.9 The Experimental Result of Step Response of The Vehicle Controlled by Altitude Controller

2010 February 27

Test Point: 34° 50.6912′ N 138° 24.6175′ E 500-700m Depth

Morning: undulation high. Measured the depth sounding by ship.

Afternoon: The vehicle was carried out seafloor tracking test. The earthquake trace investigation with Side Scan Sonar (SSS) and Multi Beam Echo Sounder (MBES) at off Yaizu. Figure 10 shows track of the vehicle. The track of the vehicle obtained by acoustic navigation is indicated by red dots, the tack of the vehicle obtained by inertial navigation system built in the vehicle is indicated by blue line. The vehicle kept 80m altitude above from seafloor by altitude controller during cruising. The cruising speed was 2.8 knots. The vehicle can cruise along survey line. The vehicle cruised approximately 15km in half day. Figure 11 shows a part of the acoustic image of the seafloor obtained by MBES. Because the vehicle could approach the seafloor, a detailed image was obtained.

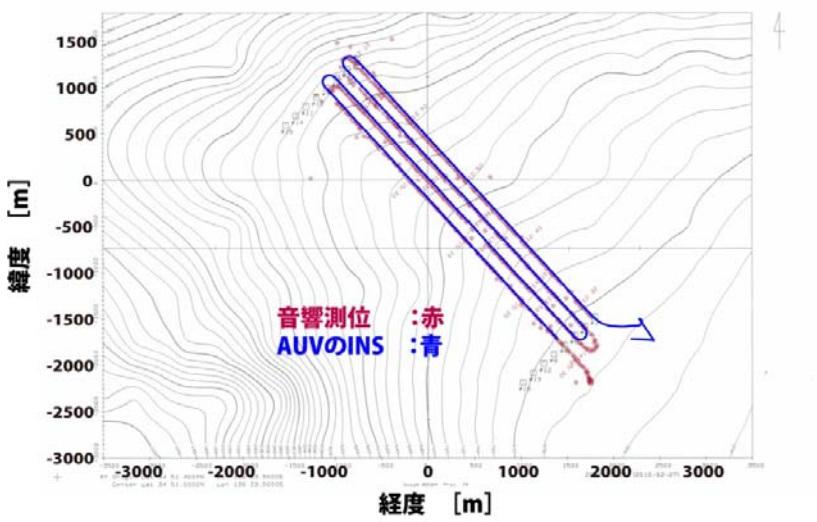

Fig.10 The Track of The Vehicle at Seafloor Tracking Test

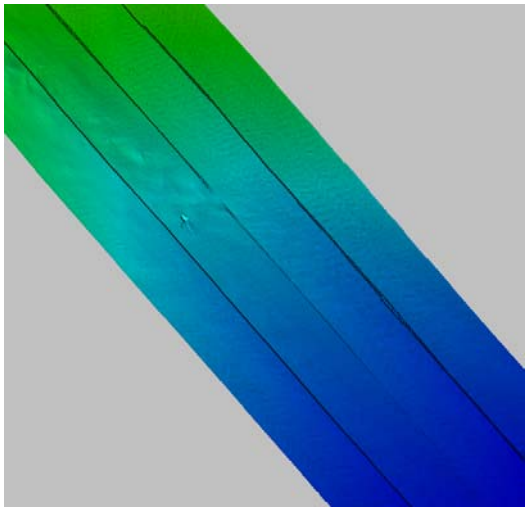

Fig11 The Acoustic Image Obtained By MBES

2010 March 1

Test Point: 34° 50.3156′ N 138° 24.4311′ E 1,200m Depth

The vehicle was carried out seafloor tracking test. The earthquake trace investigation with Side Scan Sonar (SSS) and Multi Beam Echo Sounder (MBES) at off Yaizu in the same way as the day before yesterday. Figure 12 shows track of the vehicle. The track of the vehicle obtained by acoustic navigation is indicated by red dots, the tack of the vehicle obtained by inertial navigation system built in the vehicle is indicated by blue line. The vehicle kept 80m altitude above from seafloor by altitude controller during cruising. The cruising speed was 2.8 knots. The vehicle can cruise along survey line. The vehicle cruised approximately 30km in day.

Fig.12 The Track of The Vehicle at Seafloor Tracking Test

2010 March 2

Test Point: 34° 59.5842′ N 139° 13.1445′ E 1,200m Depth

The vehicle was carried out seafloor tracking test. The earthquake trace investigation with Side Scan Sonar (SSS) and Multi Beam Echo Sounder (MBES) near Hatsushima island there is slant place with ups and downs. Figure 13 shows track of the vehicle. The track of the vehicle is obtained by acoustic navigation. The vehicle kept 80m altitude above from seafloor by altitude controller during cruising. The cruising speed was 2.8 knots. It was confirmed that the vehicle difficult to cruise with keeping altitude at the place where ups and downs were too big.

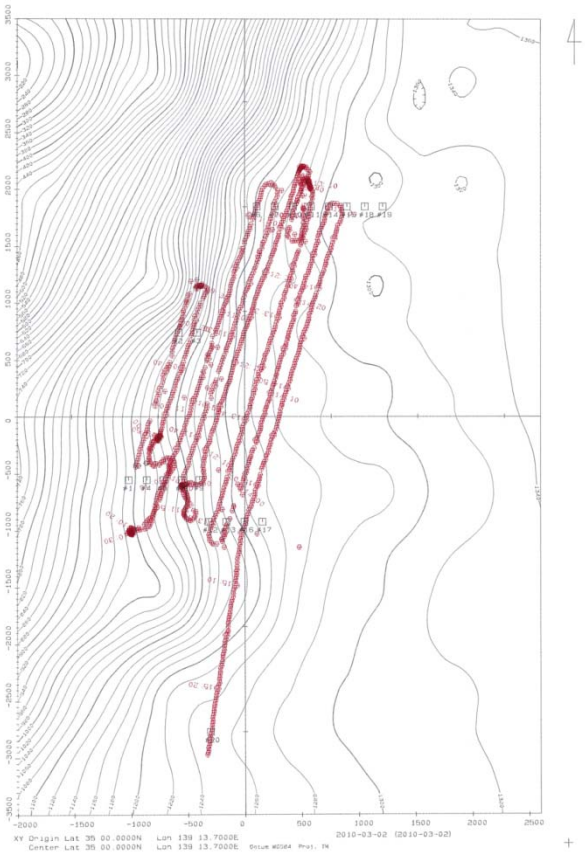

Fig.13 The Track of The Vehicle at Seafloor Tracking Test

2010 March 2

Test Point: 34° 57.3954′ N 139° 12.1646′ E 1,200m Depth

The vehicle was carried out seafloor tracking test. The seafloor there is slant place with ups and downs survey with Side Scan Sonar (SSS) and Multi Beam Echo Sounder (MBES). Figure 14 shows track of the vehicle. The track of the vehicle is obtained by acoustic navigation. The vehicle kept 80m altitude above from seafloor by altitude controller during cruising. The cruising speed was 2.8 knots. It was confirmed that the vehicle could cruise while maintaining altitude in such (see Fig.14) seafloor.

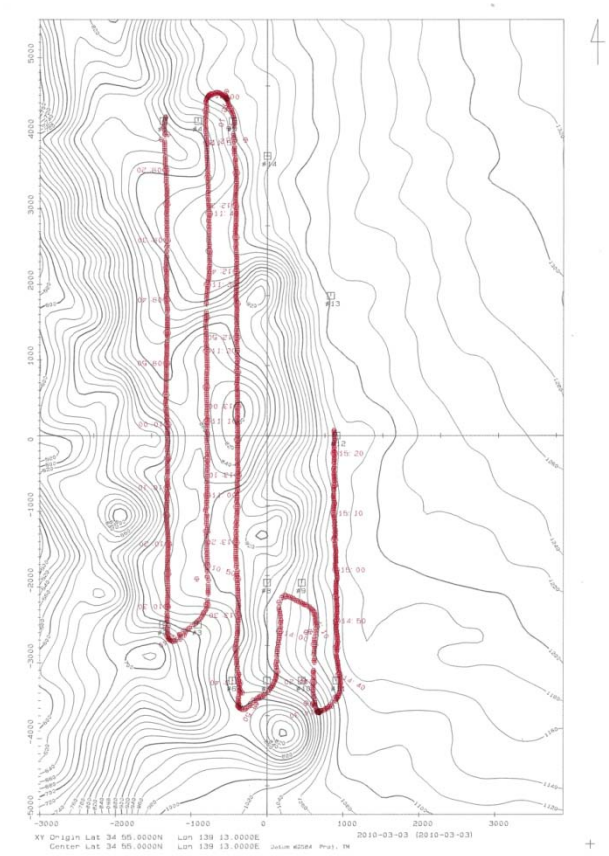

Fig.14 The Track of The Vehicle at Seafloor Tracking Test

4. Notice on using

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