doi : 10.17596/0003334

Natsushima Cruise Report
NT10-02

JAMSTEC~Beppu Bay~JAMSTEC

January 22, 2010 ~ February 9, 2010

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

Contents

1. Cruise information

- ✓ **Cruise number:** NT10-02
- ✓ **Ship name:** Natsushima
- ✓ **Title of the cruise:** Engineering tests using "MR-X1", a working type AUV and its applications for oceanographic, plate dynamics and biological researches.
- ✓ **Title of proposal:** Development of the next generation underwater vehicle, A laser stick, PICASSO, and Development of the advanced marine technology
- ✓ **Cruise period:** January 22, 2010 ~ February 9, 2010
- ✓ **Port call:** Jamstec ~ Beppu Bay ~ Jamstec
- ✓ **Research Area:** Beppu Bay, Sagami Bay, and Suruga Bay
- ✓ **Research Map:**

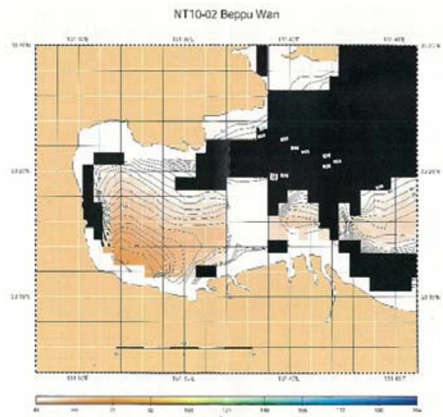


Fig. 1. A diving point in Beppu Bay

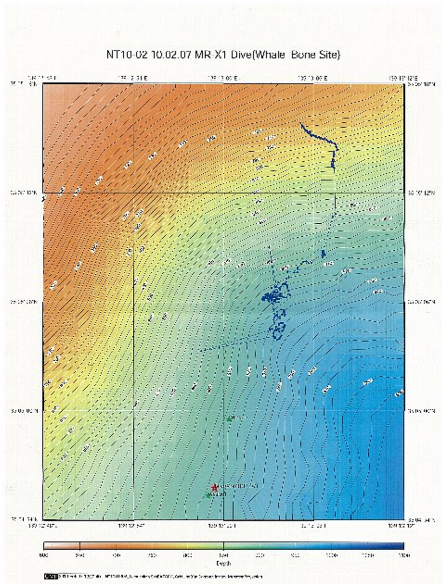


Fig. 2 : A MR-X1 track in Sagami Bay

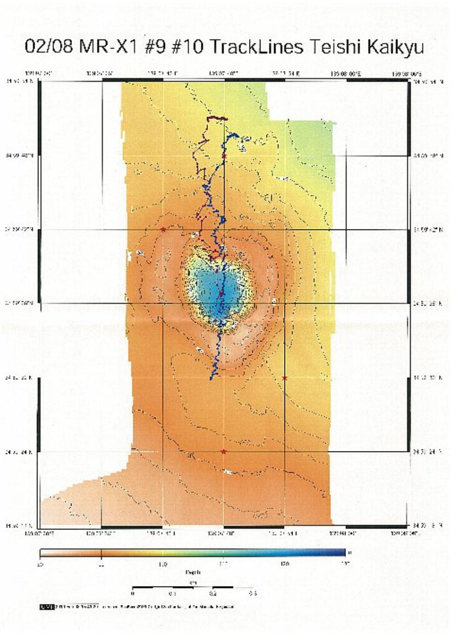


Fig.3 : MR-X1 tracks at the Teishi Knoll.

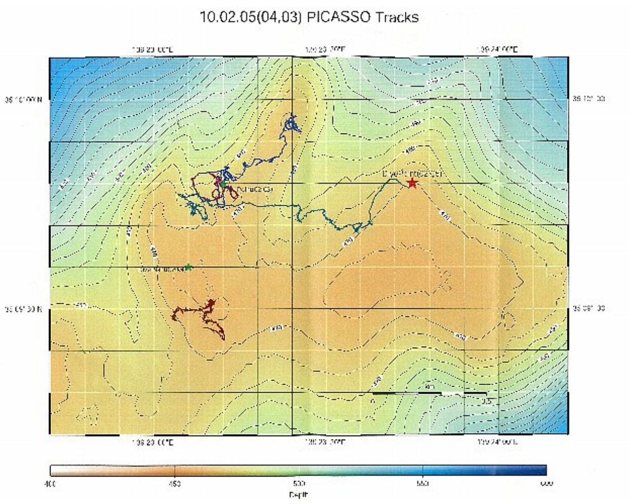


Fig.4: Picasso tracks at the Sagami Knoll.

2. Researchers

Name	**Affiliation**	**Assignment**	**Remarks**
Hiroshi Yoshida	Maritec, JAMSTEC	General management	Chief Scientist
Tadahiro Hyakudome	Maritec, JAMSTEC	Vehicle engineering	Science party
Shojiro Ishibashi	Maritec, JAMSTEC	Vehicle engineering	
Takao Sawa	Maritec, JAMSTEC	Vehicle engineering	
Yoshiyuki Nakano	Maritec, JAMSTEC	Satellite communications	
Takafumi Kasaya	IFREE, JAMSTEC	Magnetometer	
Nomi Harada	RIGC, JAMSTEC	Sediment samplings	
Kana Nagashima	RIGC, JAMSTEC	Sediment samplings	
Dhugal Lindsay	Biogeos, JAMSTEC	Plankton observations	
Hiroyuki Yamamoto	Biogeos, JAMSTEC	Plankton observations	
Kei Sunagawa	JAXA	Satellite communications	
Akihiko Shinozaki	SED	Satellite communications	
Makoto Hohashi	ARIB	Satellite communications	
Takashi Saito	Mitsubishi Tokki Systems	Laser engineering	
Takashi Gunji	Mitsubishi Tokki Systems	Laser engineering	
Shogo Okamoto	Mitsubishi Tokki Systems	Laser engineering	
Tsuyoshi Kumagai	SAS	Vehicle engineering	
Yoshiyuki Uemura	Kowa	Vehicle engineering	
Tetsuya Katsumi	Communication Technology	Vehicle engineering	
Masahiro Aota	Fujitsu Wireless Systems	Satellite communications	
Nobuhiro Tanaka	Ai-ichi Industry	Vehicle engineering	
Suehiro Nitta	Seacam	Video camera operator	
Junichiro Takizawa	Takizawa Casting Industry	Vehicle engineering	
Tae-hwan Joung	Flinders University	Observer	
Andren Keith Lammas	Flinders University	Observer	
Mary Grossman	Biogeos, JAMSTEC	Plankton observations	
James Reimer	Biogeos, JAMSTEC	Plankton observations	
Jun Nishikawa	ORI, The University of Tokyo	Plankton observations	
Teruki Tanaka	Graduate student of Yokohama National University	Observer	

3. Sea-Trial

3.1 Background and objectives

JAMSTEC is currently conducting a research and development project for a next generation autonomous underwater vehicle (AUV) as a part of "Key Technologies of National Importance" since 2006. The goal of the project is to develop an AUV with the ability to cruise long range over 3,000 km and carry large payloads for surveys of natural resources, improvement of earthquake predictions, and for environmental research. In the initial-five year period, we have concentrated on the improvement of power sources, navigation systems, control systems, acoustic communications, and sonars. On the other hand, science communities need these technological applications to develop new scientific tools.

In this trial, we had two main purposes: engineering evaluations of the developed systems in the project, and scientific applications of our technological capabilities. We had tested a lithium-ion battery system, an inertial navigation system, a distributed CPU system, a synthetic-aperture sonar, a geostationary satellite communication system, and underwater laser propagation measuring system were tested using underwater test-beds as engineering tests. For palaeoenvironmental researches, a newly developed mud sampling tool was installed on the hybrid vehicle "MR-X1" and samplings were performed. Geomagnetic observations were also performed with a modified cesium magnetometer which was installed on the MR-X1. A small vehicle "PICASSO" was tested and used for plankton surveys.

3. 2 Vehicles and tools

1) The working type hybrid AUV, "MR-X1"

This vehicle is used as an underwater platform for engineering evaluations.

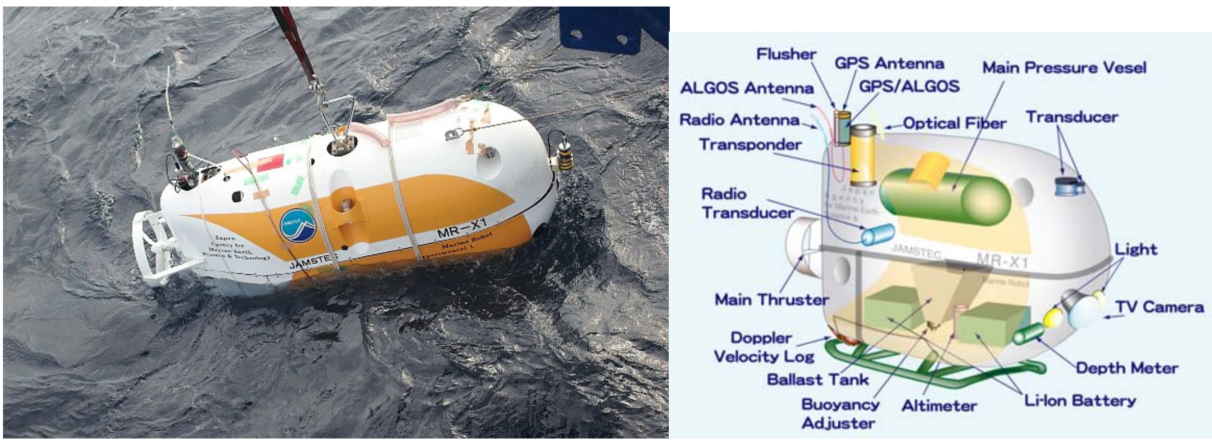


Fig. 5 : MR-X1

Weight :	800～900 kg
Dimension:	2.5 (L) x 0.8(W) x 1.2(H) m
Max. depth rating:	4,000 m
Operation mode:	UROV / AUV
Navigations:	INS, DVL, Depth meter, Altimeter
Observations:	TV camera, Side scan sonar (option)

2) The magnetometer and the sediment sampler

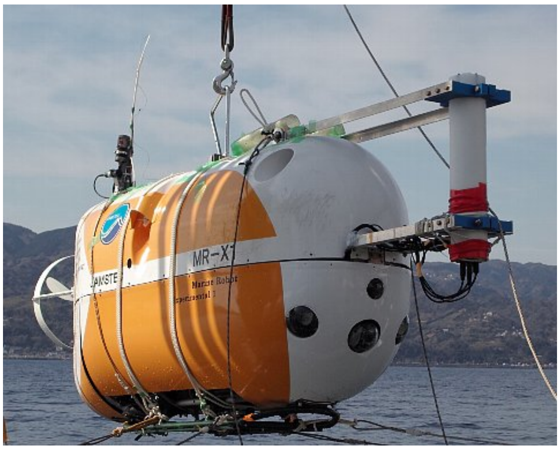



Fig. 6 : The MR-X1 with the mud sampler (left) and the cesium magnetometer (right).

3) The plankton survey robot "PICASSO"

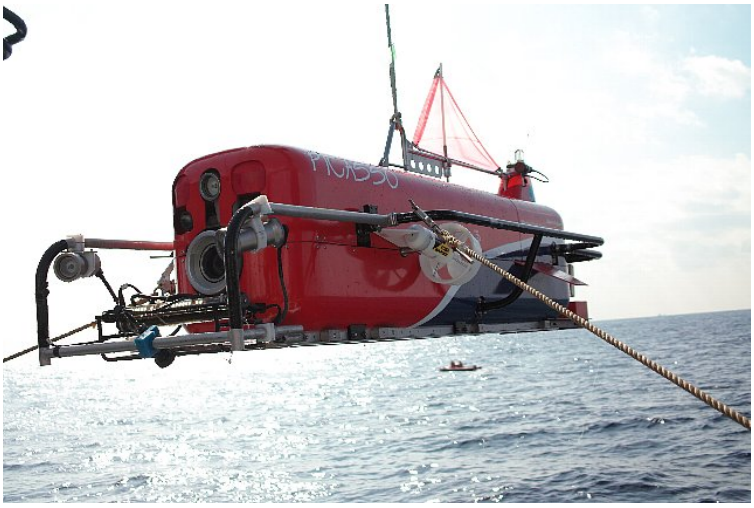


Fig. 7 : PICASSO

Weight :	200 kg
Dimension:	2(L) x 0.8(W) x 0.8(H) m
Max. depth rating:	1,000 m
Operation mode:	UROV
Navigations:	MEMS gyro, DVL, Depth meter
Observations:	HDTV camera, CTD-DO, Turbidity meter

4) A geostationary satellite communication system

We prepared two types of antenna systems for the satellite communication experiments. One is a small size antenna and tracking system for low rate communication (64 kbps). The other is a parabolic antenna and a commercial tracking system for high rate communication (384 kbps).

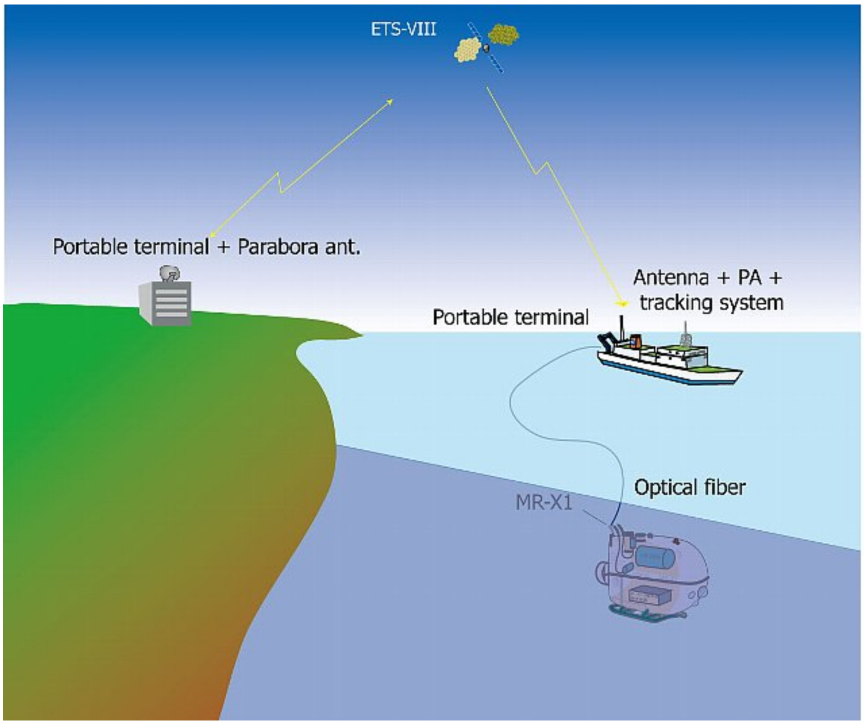


Fig. 8: An experimental configuration of the satellite communication tests.

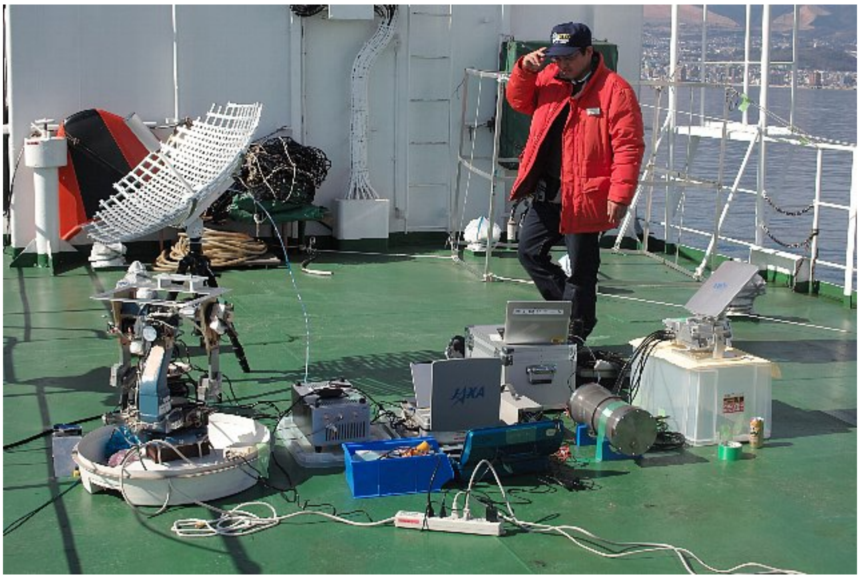


Fig. 9: Antennas, tracking systems, and transceivers on the top of the support ship.

5) The Laser Frame, an underwater laser propagation measuring system

The laser frame is deployed by a wire winch installed on the deck. The frame can measure propagation loss between the TX and the RX laser. To measure altitude from the sea-floor, it was equipped with a Doppler velocity log (DVL).

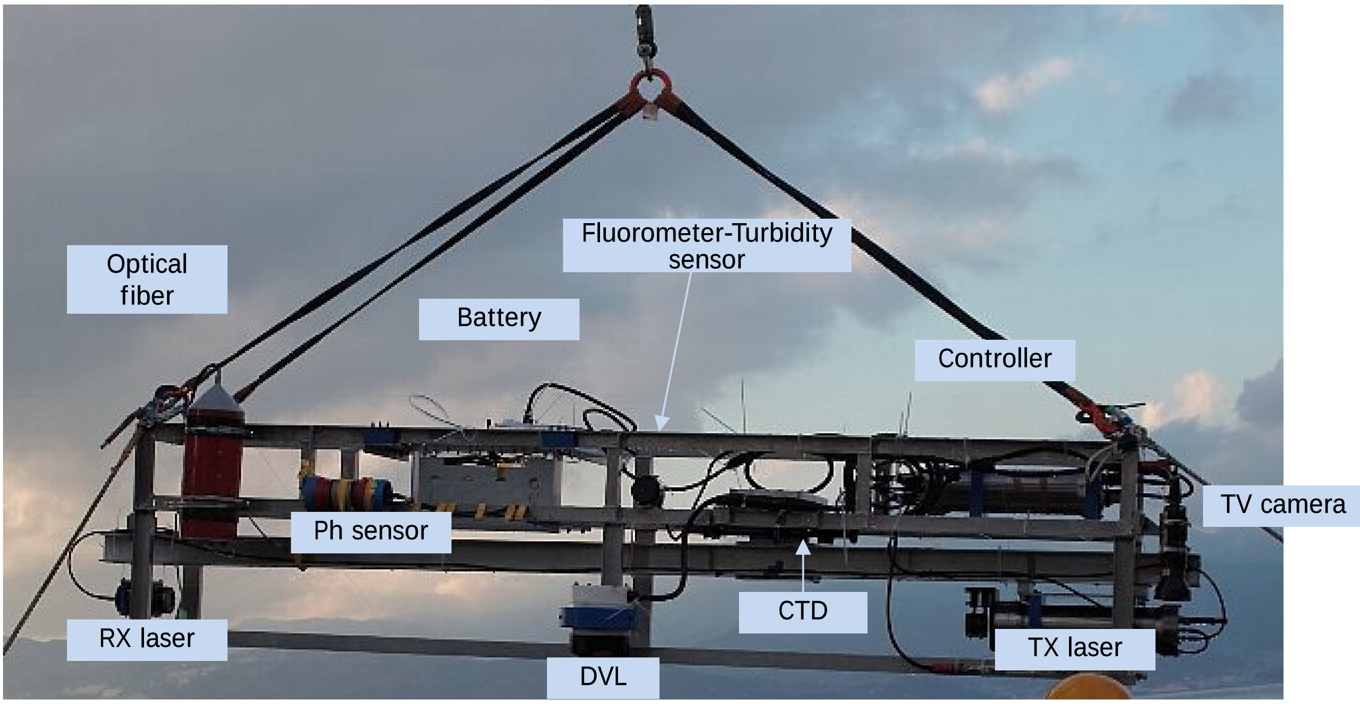


Fig. 10: The Laser Frame.

Weight : 85 kg
Dimension: 2.9(L) x 0.4(W) x 0.6(H) m
Max. depth rating: 700 m
Observations: Laser propagation loss meter, TV camera, CTD, Fluorometer-Turbidity sensor, Ph sensor, DVL.

(6) A small inertial navigation system

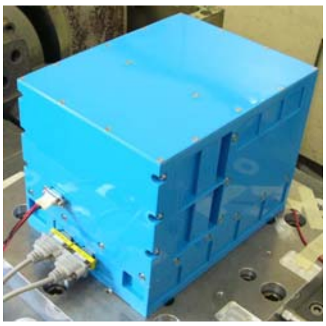


Fig. 11: An inertial navigation system developed in 2007

Weight : 10 kg
Dimension: 180 x 180 x 240 mm
Navigation error: 1.1 Nm/hr CEP

7) A beam-steering synthetic-aperture sonar (SAS)

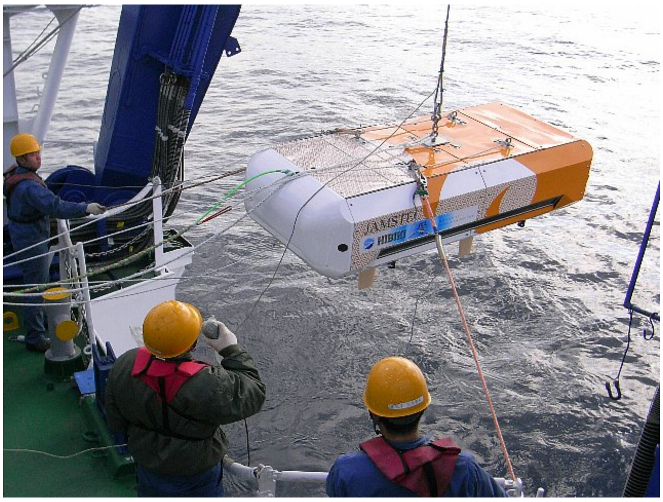


Fig.12: A deployment scene of the synthetic-aperture sonar.

Weight：	50 kg
Transducer:	1.56 m, 8 elements
Hydrophone:	0.35 m, 1 element
Frequency:	71.2 – 80 kHz
Resolution:	0.09 m
Range:	1,000 m

3.3. Results

1) Total number of tests and dives

MR-X1 dives	8 dives （including mud samplings and magnetometer tests）
PICASSO dives	5 dives
Underwater laser propagation test	4 times
SAS tests	2 times
INS test	1 time
Geostationary satellite communication tests	5 times
Total	**13 dives and 12 tests**

2) Major achievements

MR-X1

- Autonomous cruising by a classical theory and a modern theory.
- Distributed CPU system operation.
- Maximum diving depth of 884m.
- Mud samplings.
- Geomagnetic field measurement with a cesium magnetometer.

PICASSO

- Fine vehicle maneuverability

- Great sea life image capturing on and above Sagami knoll.
- Vehicle operation without dedicated operators.

Underwater laser propagation

- Propagation loss measurement near the sea bottom.
- Propagation loss measurement in different wavelength.
- Propagation loss dependence on laser beam diameter.

Satellite communications

- Underwater video image transmission with data rate of 384 kbps.
- Connection between the ship-side PC and the JAMSTEC local area network.
- Long time satellite tracking with a new tracking system which is based on a PID control.

3) Schedule

1/22	Pre-vehicle test before departure
1/23	SAS test in Sagami Bay, CPU system failures occurred in the MR-X1
1/24	Laser measurement (L. meas.) and satellite communication (Sat. com.) tests in Sagami Bay
1/25	MR-X1 dive (Dive #3) and Sat. com. tests in Sagami Bay
1/26	Cruising: Sagami Bay ~ Owase~ Beppu
1/27	Cruising: Sagami Bay ~ Owase~ Beppu INS and Sat. com. tests in Beppu Bay in early evening
1/28	MR-X1 dive (Dive #4, #5, #6) with the mud sampler in Beppu Bay
1/29	MR-X1 dive (Dive #7) with the mud sampler, SAS test, and Sat. com.test in Beppu Bay
1/30	Cruising: Beppu bay ~ Suruga Bay
1/31	Cruising: Beppu bay ~ Suruga Bay, operation tests of PICASSO
2/1	PICASSO dive (Dive#35), L. meas. test and Sat. com. test in Suruga Bay
2/2	Cruising: Suruga Bay ~ Sagami Bay
2/3	PICASSO dive (Dive#36~#37) at the Sagami Knoll
2/4	PICASSO dive (Dive#38) at the Sagami Knoll L. meas. test (#7) in Sagami Bay
2/5	PICASSO dive (Dive#39) at the Sagami Knoll Cruising to JAMSTEC
2/6	Cruising to Sagami Bay L. meas. test (#8) in Sagami Bay

2/7 MR-X1 dive (Dive #8) in Sagami Bay

2/8 MR-X1 dive (Dive #9-#10) with the magnetometer at the Teishi Knoll

2/9 Arrival in the JAMSTEC port

3) Test details

Elemental technology evaluations

Modern and classical control theory applications installed on the space distributed CPU system successfully controlled the MR-X1 which was powered by a high-energy lithium-ion battery system (120V, 30 Ah x 2).

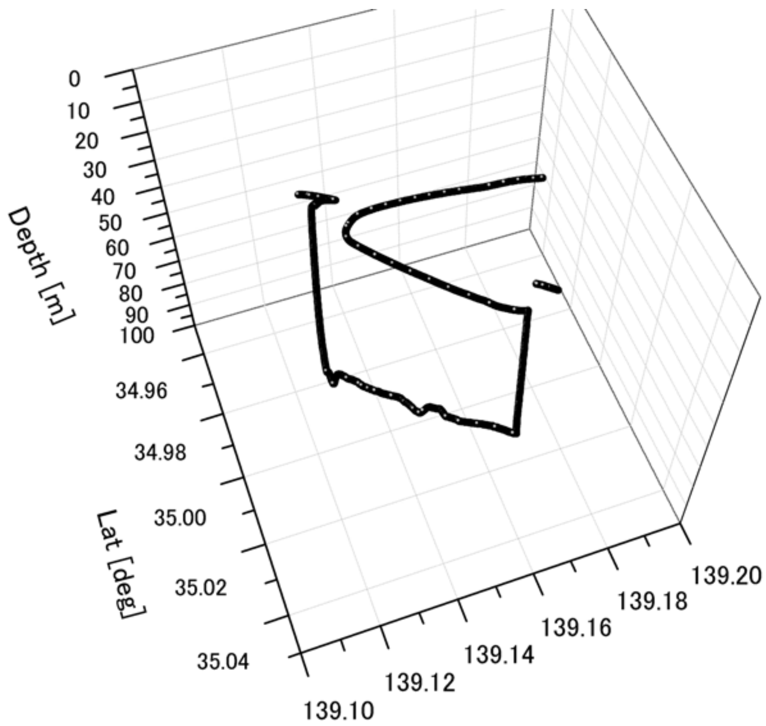
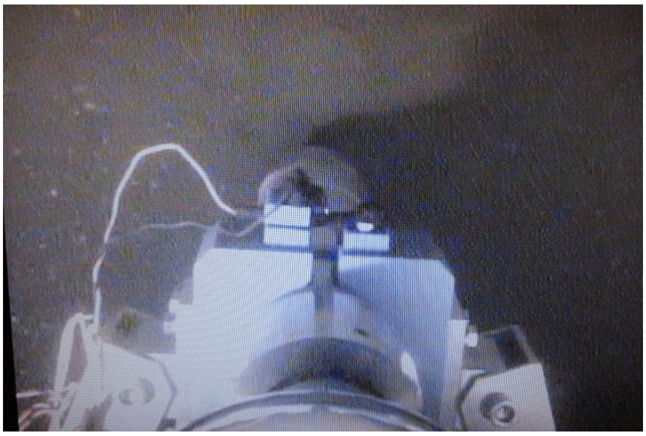


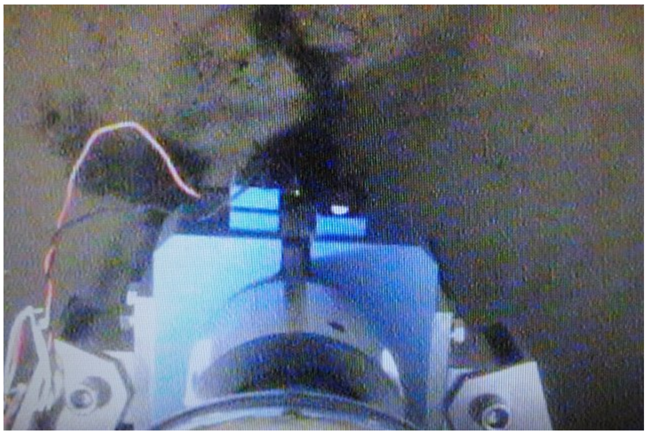
Fig. 13: An MR-X1 track obtained by the INS which was operated in the pure navigation mode. The vehicle cruised arouud the Teishi Knoll keeping the depth of 50 m.

The mud sampler and the magnetometer

The MR-X1 equipped with the mud sampler was tested in Beppu-bay. We carried out four dives of the MR-X1 for sampling. The first dive failed because of a vehicle-ship communication error. In the second dive, the core sampler was successfully inserted to the sea bottom as shown in Figure 14 (a) ~ (b). To insert the core sampler to the sediment, the force of the two vertical thrusters (150 N max.) only was used. The sampler was half-buried in the sediment. In the third and fourth dives, we used gravity force in addition to the thruster-generated force. In every dive the sampler was extracted by the thruster-generated force. The sampling operations were in the manual mode via a thin optical fiber cable.

(a) Before sticking the sampler in the bottom.





(b) The sampler edge just touched the sea-floor.   (c) The sampler stuck in the bottom.

Fig. 14: Photos of the sea-floor at the sampling point.

The vehicle equipped with the magnetometer was tested on Teish Knoll. Two dives were carried out with varying the depth of the vehicle. The vehicle cruised in a straight line (North to South).   The obtained geomagnetic data are still undergoing analysis.

<u>Satellite communication tests</u>

Using Engineering test satellite VIII, underwater video images were transmitted to the office of JAMSTEC in real time. The connection between a ship-side PC and JAMSTEC's local area network was tested.

<u>Laser propagation loss measurements</u>

A laser test frame developed was deployed from Natsushma. We obtained propagation data near the sea-floor at depth of about 350 m in Sagami Bay. These data are also undergoing analysis.

The synthetic-aperture sonar tests

A special towed system equipped with the SAS was deployed form Natushima in Sagami Bay and Suruga Bay.

The INS test

To evaluate the advantages of the bias-error canceling and gyro-drift canceling system developed, we measured whole errors of the INS system during ship-cruising.