

Kaiyo Cruise Report
KY10-11

Sea Trial for the Key Technologies of Underwater
Vehicles

JAMSTEC ~ Sagami-Bay ~ JAMSTEC

Aug 4, 2010 ~ Aug 13, 2010

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

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1. CRUISE INFORMATION

- ✓ Cruise number: KY10-11
- ✓ Ship name: R/V "KAIYO" 3,350 G/T
- ✓ Title of the cruise: Sea Trial for the Key Technologies of Underwater Vehicles.
- ✓ Title of proposal:
Development of the next generation underwater vehicle technology
- ✓ Cruise period: Aug. 4, 2010 ~ Aug 13, 2010
 - ✧ LEG1: 8/4 ~ 8/6
 - ✧ LEG2: 8/7 ~ 8/13
- ✓ Port call: JAMSTEC ~ Sagami-Bay ~ JAMSTEC
- ✓ Research Area: Sagami Bay
- ✓ Research Map:



Fig. 1. Sagami-Bay

(1) Sagami-Bay (Water depth: 80 m ~ 1,500 m)

34°55.0'N 139°13.5'E , 35°00.0'N 139°07.0'E
35°14.0'N 139°13.45'E , 35°14.0'N 139°25.0'E
34°55.0'N 139°25.0'E

(2) Suruga-Bay (Reserved area when Sagami-Bay is in bad weather.)

34°40.0'N 138°35.0'E , 35°00.0'N 138°35.0'E
35°00.0'N 138°45.0'E , 34°40.0'N 138°42.0'E

1.1 Background and objectives

JAMSTEC had conducted a research and development project of the next generation autonomous underwater vehicle (AUV) as the part of “Key Technologies of National Importance” for 5 years (FY2006 - FY2010). The goal of the project is to develop an AUV with the ability of long range over 3,000 km and large payload for surveys of natural resources, improvement of earthquake predictions, and environmental researches. In the initial-five year period, we had concentrated in the improvement of power sources, navigation systems, control systems, acoustic communications, and sonars. On the other hand, science communities need these technologies application 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 control system, a synthetic-aperture sonar, and an underwater stereo vision. As a new attempt for scientific observation, we performed a test of autonomous tool setting on the sea-floor. The MR-X1 had tried installation of a 3-axis magnetometer and a position maker.

We also performed tests of high-speed satellite communication using WINDS and carbon dioxide measurement using a Fourier transform spectrometer as a collaboration research with JAXA.

2. RESEARCHERS

<u>Name</u>	<u>Affiliation</u>	<u>Assignment</u>	<u>Remarks</u>
Hiroshi Yoshida	Maritec, JAMSTEC	General management	Chief Scientist
Tadahiro Hyakudome	Maritec, JAMSTEC	Management asistant	Science party
Ishibashi Shojiro	Maritec, JAMSTEC	System integrator	
Takao Sawa	Maritec, JAMSTEC	Researcher	
Yoshiyuki Nakano	Maritec, JAMSTEC	Researcher	
Masahiko Nakamura	Maritec, JAMSTEC	Researcher	
Takafumi Kasaya	IFREE, JAMSTEC	Researcher	
Takechika Kumagai	SAS	System Engineer	
Susumu Sato	SAS	Circuit Engineer	
Tatsuya Kono	SAS	Circuit Engineer	

Nobuhiro Tanaka	Ai-ichi Industries	Mechanical Engineer	
Akihito Ebina	Hitachi ICS	System Engineer	
Kazuaki Matsumoto	Hitachi ICS	System Engineer	
Naoya Tomii	JAXA	Satellite Researcher	Leader
Tomomi Suzuki	JAXA	Satellite Researcher	Sub leader
Shuji Kawakami	JAXA	Satellite Researcher	
Hiroshi Oyama	JAXA	Satellite Researcher	
Makoto Watanabe	SED	Satellite Engineer	
Shouichi Nasu	JAMSS	Satellite Engineer	
Osamu Hoshino	SNET	Satellite Engineer	
Kohei Otsu	Tokyo University of Marine Science and Technology	Satellite tracking	Professor
Naoki Okamura	Tokyo University of Marine Science and Technology	Satellite tracking	Student
Masamichi Nagayama	Tokyo University of Marine Science and Technology	AUV	Student
Naohito Mori	MWJ	Technical supporting	Technician

3. SYSTEMS UNDER THE TEST

3.1 The main test platform “MR-X1”

MR-X1 (Fig. 3.1) is an underwater working robot. This robot has 5 thrusters rather than ladders for improving its maneuverability. It was used as a main platform to evaluate new equipment.



Fig. 3.1 : MR-X1

Weight:	800 kg in air
Dimension:	2.5 (L) × 0.8(W) × 1.2(H) m
Depth rating:	4,000 m maximum
Operation mode:	Remote control/ Autonomous
Devices for Cruising:	Inertial Navigation System, Doppler Velocity Log, Depth meter, Altimeter
Devices for observation:	TV camera, Side Scan Sonar.

3.2 Newly developed Devices

(1) Inertial Navigation System (INS)

A small, high accuracy navigation system is needed for the next generation AUV. In this sea-trial, the first prototype of the small INS (Fig.3.2.1) developed by JAMSTEC was installed in the MR-X1. We carried out tests of the INS to confirm the INS system availability.

- Its dimension and weight are reduced to 60 % proportional to traditional one.
- The INS is controlled and operated from the CPU system (mentioned later).
- The new functions to compensate its error were developed.



Fig. 3.2.1 : High-spec INS

(2) Lithium Ion Battery System

We checked the operation capability of the battery system in the sea-trial.

- A newly developed pressure balanced lithium ion battery which gains power density of 1.7 times larger than later one.
- The battery system has an automatic cell voltage balancer to enlarge its endurance.



Figure 3.2.2: Lithium-ion battery unit.

(3) Space distributed CPU control system

Robustness, reliability, high speed, synchronization are important for a control system of underwater vehicles. A distributed CPUs system reduces concentration of processing load on a CPU and makes a system redundancy. The distributed CPUs system can be composed of printed circuit boards mounted an embedded CPU chip and an internal bus. In the distributed

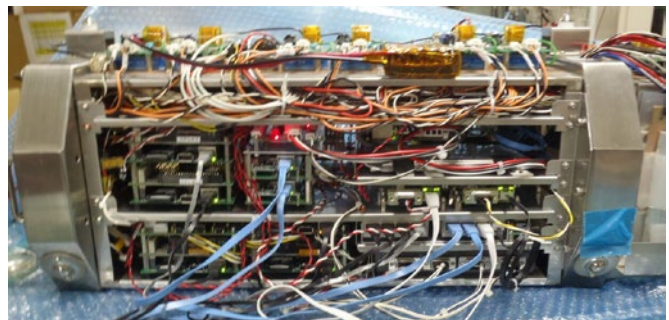


Figure 3.2.3 : Space distributed CPU.

real-time system, it is important which internal bus is the best for the system considered. We have developed the space distributed CPU system as shown in figure 3.2.3. Each board is connected with Ethernet. We implemented the basic control software on Linux 2.6.10 for control of the peripheral devices and communication between boards. Before implementing the software, real time processing test on Linux and the board synchronization test were performed.

In this sea trial, the MR-X1 was equipped with the space distributed CPU system and performed the tests below.

- Five CPU boards are interconnected with 100 Mbps Ethernet, sharing system data each other. This configuration would result in reducing CPU load, and making

higher redundancy. The CPUs control navigation devices, observation devices, communication device, and a safety system while diving. We checked the CPU system performance and practicality through the dives.

- We developed an algorithm for automatic install operation and then programmed it in the CPU system. The MR-X1 equipped with a device to be installed made two dives.

(4) Underwater Stereo Vision

We prepared a set of underwater stereo vision system as shown in Figure 3.2.4. This underwater camera system was tested.



Figure 3.2.4 : Stereo vision system

(5) Synthetic Aperture Sonar

We have developed the synthetic aperture sonar (SAS) applied motion compensation. In order to make wide area survey, an AUV keeps high altitude of several hundred meters from sea-floor. On the other hand footprint of obtained sonar data becomes large (i.e. resolution becomes lower) in higher altitude survey. The SAS is one of effective solution them.

The feature of the SAS is the function of real-time motion compensation. A prototype model was assembled as shown in Figure 3.2.5. This SAS installed in a deep tow has the specifications: frequency range of 71.2 ~ 80 kHz, resolution of 9 cm, and service range of about 1,000 m. The SAS was tested to investigate relation between degradation of the SAS performance and disturbance of the platform attitude.



Figure 3.2.5 : The deep tow equipped with the SAS.

3.3 Working Mission

We attempted automatic underwater installations by the AUV, MR-X1. This would be the first attempt in the world.

- 1) Ocean Bottom magnetometer (OBM) and
- 2) Sea-floor marker

were to be installed. Figure 3.3 shows the OBM mounted on the MR-X1.

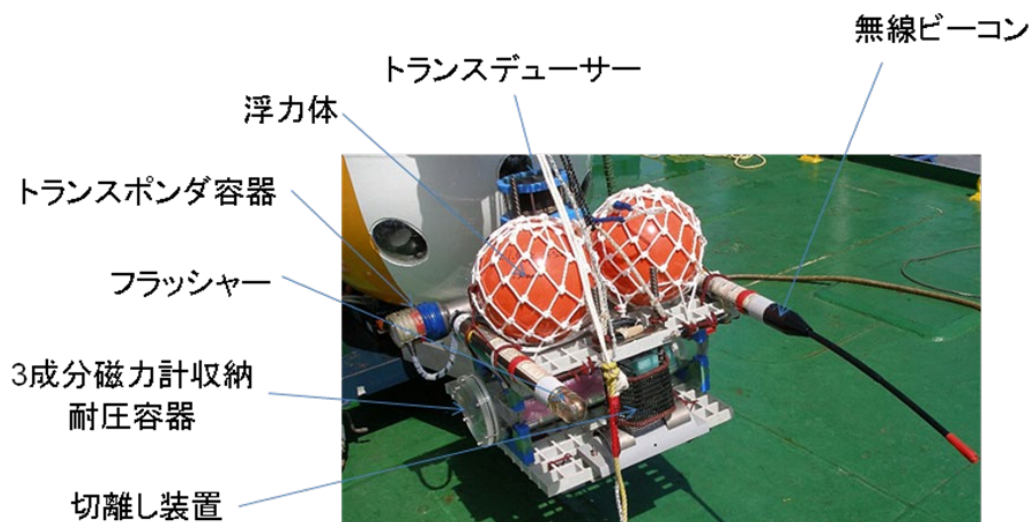


Figure 3.3 : The OBM is mounted on the MR-X1.

3.4 Wideband InterNetworking engineering test and Demonstration Satellite: WINDS

The WINDS can supply the communication environment with super high speed rate up to 150 Mbps. In cruise KH-09-E03, underwater HDTV image was transmitted from the ship, Hakuho to JAXA's land station with transmission rate of 13 Mbps. In this trial we

set the goal:

- network linking from the ship traveling,
- higher transmission rate of over 30 Mbps.

3.5 Fourier Transform Spectrometer (FTS)

This spectrometer prepared by JAXA measures atmospheric carbon dioxide level. Its measured values should be compared with the value obtained by the Greenhouse Gases Observing Satellite "IBUKI" which passed over the ship, Kaiyo. Figure 3.5 shows the FTS system to be loaded on the ship.

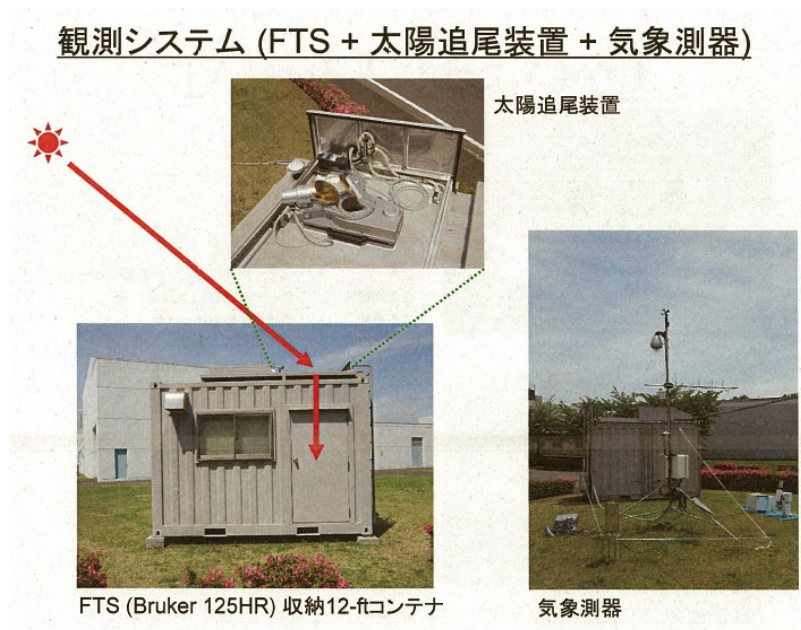


Figure 3.5 Fourier Transform Spectrometer

3.6 IN-SITU LASER PROPAGATION MEASURING SYSTEM (ILPMS)

To obtain practical underwater propagation data, we had developed the ILPMS. It was customized to approach seafloor closely, that is, an altimeter was added. The block diagram and a snapshot of the ILPMS customized are shown in Figures 3.6.1 and 3.6.2, respectively. The system consists of two main parts: a ship side controller and an underwater part. The latter consists of a main pressure hull, a pressure-balanced Lithium ion battery, an LED array light, two NTSC cameras, a turbidity meter and a chlorophyll-a meter, a CTD meter, a laser transmitter (TX) and a laser receiver (RX). The TX includes a milli-Watt class semiconductor laser, a controller and a data logger. The RX has a photo-diode, a preamp, and a level indicator. The TX and RX are mounted at both ends of a rigid straight boom. The boom is fixed at its weighted center to the laser frame. This configuration reduces deformations of the frame when external forces affect to the

frame and medium around the frame is changed. The TX is set about 2.5 m apart from the RX. Laser beam transmitted from the TX is adjusted to align with focal point of the RX using a tank filled the sea water before deployment. The modified ILPMS has the altimeter. When the underwater part approaches seafloor up to 20 m, the altimeter indicates its altitude. An operator on the support ship carefully controls a wire winch watching the altitude.

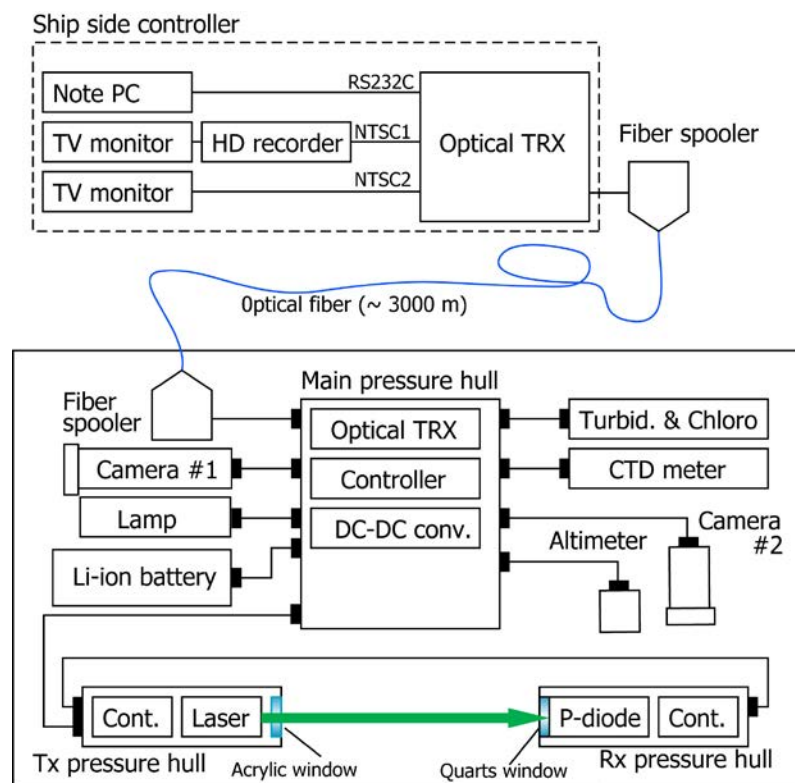


Fig. 3.6.1 : In-situ laser propagation measuring system.



Fig. 3.6.2 : A snapshot of the ILPMS.

4. SEA-TRIAL

4.1 Tests carried out

AUV "MR-X1" test	9 dives	(Dive#9 ~ Dive#17)
Laser propagation measurement	1 dives	
SAS test	2 dives	
Networking test using "WINDS"	5 trials	
CO ₂ measurement by the FTS	4 trials	

4.2 Results

We confirmed performance and practicality of the newly developed devices through the dives. Two missions were performed: the OBM installation and the marker installation. A release function was not normally operated in the OBM installation mission. Then the best release timing was gone. The OBM fell to the bottom from altitude of a few tens meters. In the second trial, we achieved automatic marker installation. This successful result was press released in Aug. 18, 2010. A snapshot of the MR-X1 equipped with the OBM is in Figure 4.2.1. A scene just the marker dropped is shown in Figure 4.2.2. Figure 4.2.3 shows the tracking record for the MR-X1 dive.

We achieved satellite communication between a land station and an underwater vehicle with higher transmission rate of 51 Mbps. The MR-X1 equipped with a HD-SDI camera was connected with the support ship via thin optical cable. A WINDS earth station was installed on the support ship. The land station in JAXA, Tsukuba received underwater image obtained by the HD-SDI camera. This result was also press released.

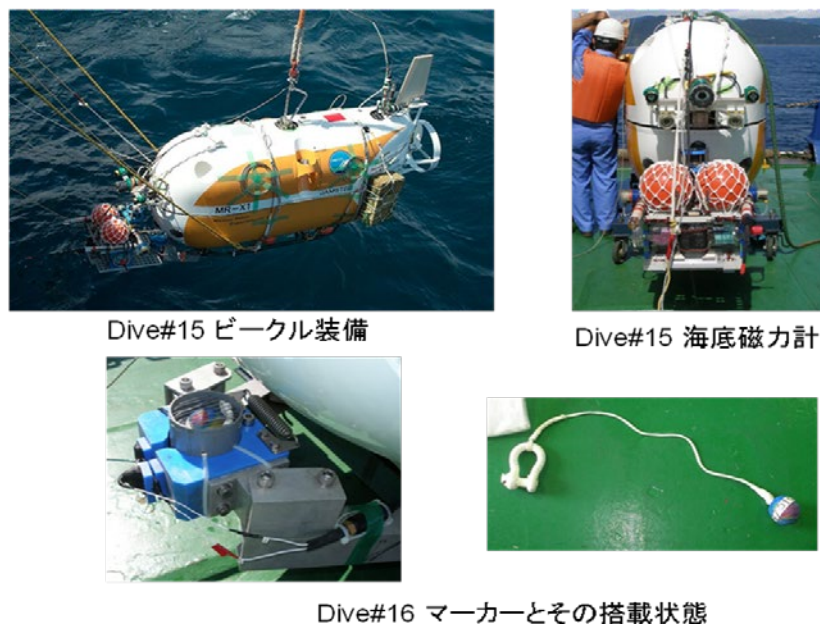


Figure 4.2.1: The MR-X1 (upper) equipped with OBM. The marker (lower)



Dive#16 マーカー設置場所



Dive#16 マーカー切離し

Figure 4.2.2: Photos of the place where the marker dropped (left) and the scene when just the marker was dropped (right).

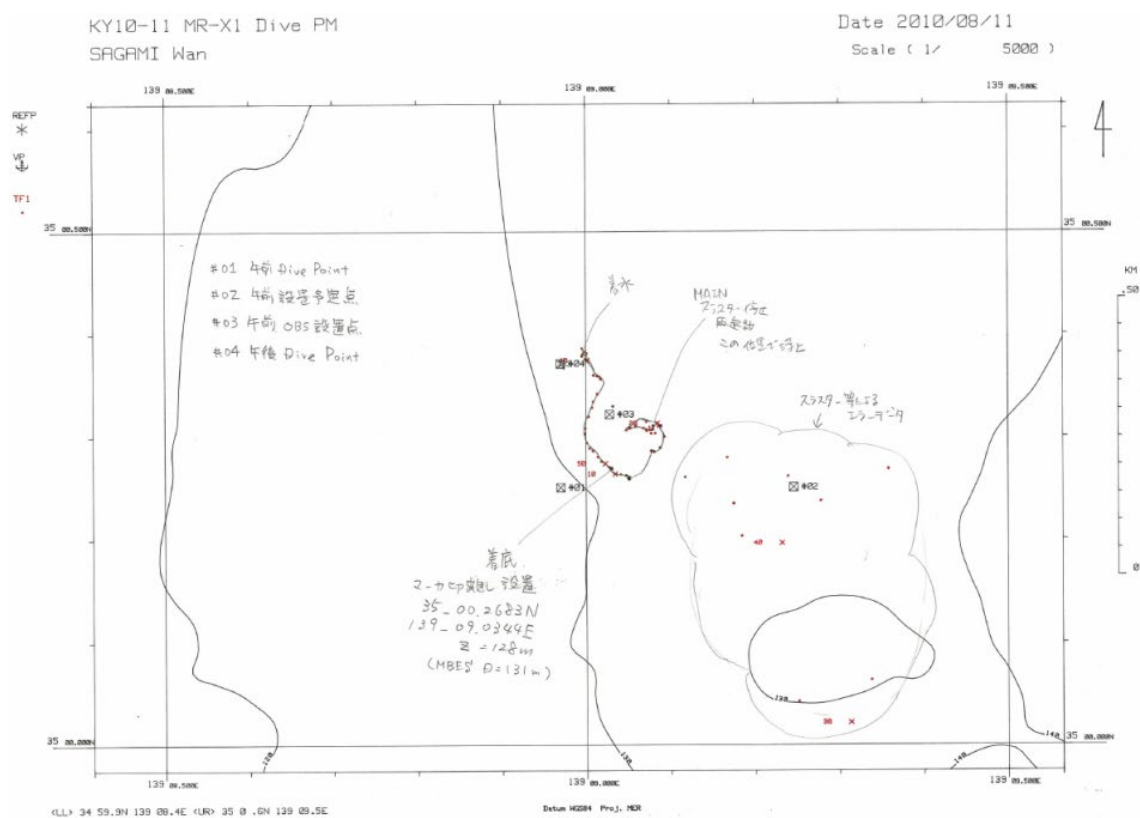


Figure 4.2.3: Tracking map in the automatic operation of the marker setting on the sea-floor in Teishi Knoll.

5. CONCLUDING REMARKS

In this sea-trial we obtained much data for each device and achieved the mission of the automatic installation. The author would like to thank the relevant parties for their support and assistance.