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JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY

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Deep Sea Cruising AUV *URASHIMA*

The deep-sea cruising vessel *URASHIMA* is an autonomous deep-sea exploration robot which was developed by JAMSTEC since 1998. The vehicle is able to determine its own location and follow predefined courses configured in its onboard computer. On February 28, 2005 *URASHIMA* succeeded to complete the world-record, 317-km continuous cruise.
URASHIMA is able to automatically collect oceanographic data (such as salinity, water temperature and dissolved oxygen) required to clarify the mechanisms of global warming over an extensive areas. The vehicle is also able to cruise along the seafloor in order to acquire extremely high-resolution seafloor topography and sub-bottom structure. The vessel is navigated by program put into its computer, which means that it can perform surveys over a particular fixed location or up and down a defined narrow path or range.

The need for Autonomous Underwater Vehicles (AUV)

Conventional exploration vehicles are connected to a support ship via a cable, therefore, have a limited movement and can move over only relatively small areas. This puts limitations on the extent to explore the vast and three-dimensional ocean.
In order to investigate the way in which CO_2, thought to be a cause of global warming, is absorbed and transported through the ocean, it is also necessary to efficiently and automatically acquire a wide range of seawater samples from various regions of the ocean. There are some difficult occasions, however, for example, support ships cannot reach, the seas are too rough and hazardous for seafaring crew, oceans are sealed over by ice, and regions are of the underwater volcanic activity. It is precisely these areas, however, that it should be seriously investigated.
This gives rise to the need for Autonomous Underwater Vehicles (AUV) that can perform automatic observational cruises on their own without being tethered by a cable. JAMSTEC is aiming to perform cruises beneath the ice in the Arctic Ocean, a region that greatly affects the rest of the ocean as well as the global environment. To do this survey, the capability to dive to the minimum depth of 6,000 m and to cruise continuously over a distance of

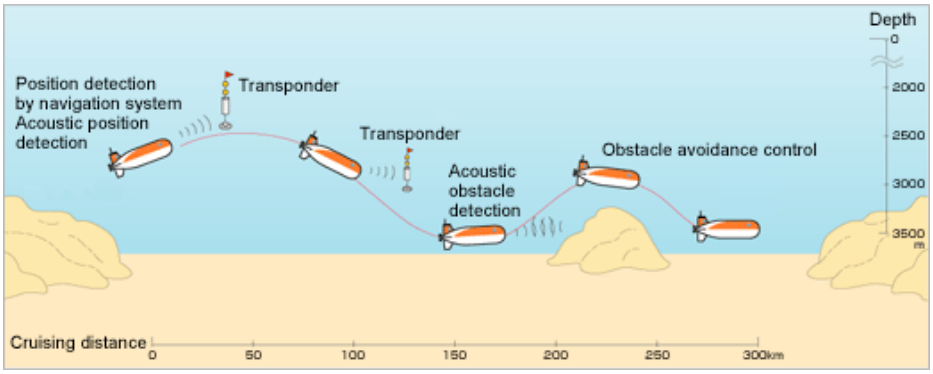
5,000 km is required.
It is hoped that *URASHIMA*, though it is a prototype, will provide the fundamental data required for the development of future full-fledged survey vehicles.

Systems

How does URASHIMA determine its position?

The high-precision ring-laser gyro at the core of the motion sensor. Three devices are equipped in tri-axes in the inertial navigation system.

In order to cruise autonomously, unmanned vehicles must be able to determine their position by themselves, and to calculate how far they have moved. GPS is available for personal or automobile navigation on land, but the radio waves used by GPS systems cannot propagate well underwater, making it impossible to use this type of navigation below the sea surface.
URASHIMA, therefore, uses a navigational system that combines the strengths of inertial navigation systems (INS) which measure inertial motion of the body with high precise ring laser gyros and motion sensors in tri-axes for time to time, and calculate moved distance based on the Newton's law of motion, and acoustic navigation which works by calculating distance based on round travel time of acoustic signals between the AUV and acoustic transponder deployed at known location before cruise.



A schematic underwater robot's navigation system, which combines inertial and acoustic navigation schemes.

Power source

URASHIMA uses either a lithium-ion battery or a fuel cell as its power source. Lithium-ion battery is a high-performance energy storing device that offer high energy density and long life, and is therefore used in mobile phones, electric cars and other applications. However, the size of the lithium-ion battery installed in *URASHIMA* only allows the vehicle to cruise for about 100 km. The fuel cell offers an even higher energy density and allows the vehicle to cruise for 300 km or more. The fuel cell is an energy converter that utilizes the energy produced when water is formed from hydrogen and oxygen. The energy produced by the extremely light hydrogen atoms is much greater than

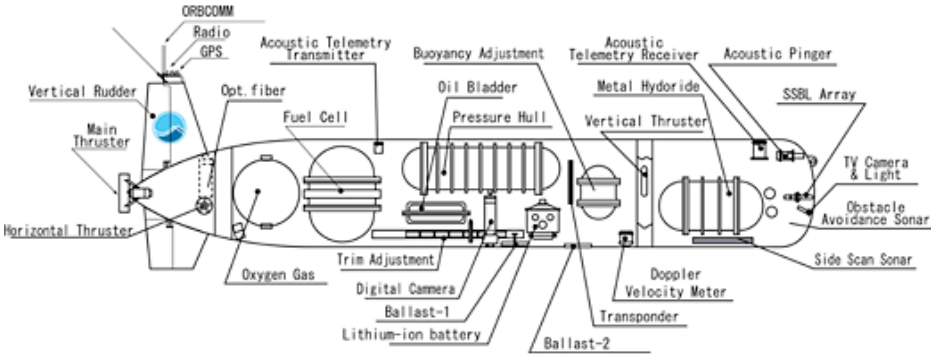
that which would be produced by a stored energy battery containing the same quantity of material.

Closed-cycle fuel cells

Fuel cell systems employed on land, such as those for automobiles, use hydrogen stored in a fuel tank and oxygen extracted from the air, and then expel the water produced back into the air. It is difficult to extract oxygen from seawater in the ocean, however. *URASHIMA* therefore also uses a tank of oxygen. Furthermore, the expelling water produced back into the high-pressure environment would require enormous amounts of energy, and would also have the disadvantage to inbalancing the vehicle's weight. The byproduct water is therefore also stored onboard in a pressure-resistant container. Because the fuel cell system on *URASHIMA* does not take anything from or emit anything into the external environment, it is known as a closed-cycle system. This type of system is indispensable for deep-sea exploration, and the technology used is significantly more advanced than that found in fuel cells used on land or in the atmosphere, such as mobile fuel cells for the cars and fixed fuel cells for plants.

Data on the Autonomous underwater vehicle, *URASHIMA*

Maximum depth capability	3,500 m
Cruising distance	More than 100 km (using a lithium-ion battery)
	More than 300 km (using a fuel cell)
Dimensions	10 m (L) × 1.3 m (W) × 1.5 m (H)
Weight	Approx. 8 tons (with a lithium-ion battery)
	Approx. 10 tons (with a fuel cell)
Speed	3 knots (4 knots maximum)
Power source	Lithium-ion battery or fuel cell
Operation	Autonomous or acoustic remote control (wireless, operated from the support ship)
Survey instruments	Physical measurement devices • Automatic water sampler (for measuring CO_2) • CTDO (salinity, water temperature, dissolved oxygen)
	Deep seafloor research (earthquake research, etc.) • High-sensitivity digital camera • Side scan sonar • Sub-bottom profiler • Multibeam echo sounder



Development History

Apr 1998 Development of the deep-sea cruising AUV *URASHIMA* began with the aim of commencing operations in 2005.

Dec 2000 Succeeded in the acoustic transmission of color images taken by the onboard camera at a depth of 1,753 m in Suruga Bay off Japan.

Aug 2001 Achieved the new world record for AUV 3,518m depth and tested the acoustic noise reduced propulsion system TV images through acoustic telemetry at this depth.

Jun 2003 Achieved the world-first, continuous 220 km cruise using a fuel cell.

Feb 2005 Achieved a new world record distance for cruising vehicles of 317 km.

Jun 2006 Succeeded in gathering evidence of submarine landslides and recording detailed seafloor typography of the eastern coast of Off Izu Peninsula.

Jul 2006 Detailed bathymetric survey of mud volcanoes in the Kumano Trough
- Contributing to research into large-scale earthquakes in ocean trenches as well as methane hydrate resources -

Dec 2006 Award for Excellence, The Robot Award 2006

Movies
Photo gallery
Autonomous Underwater Vehicle Technology Research Group