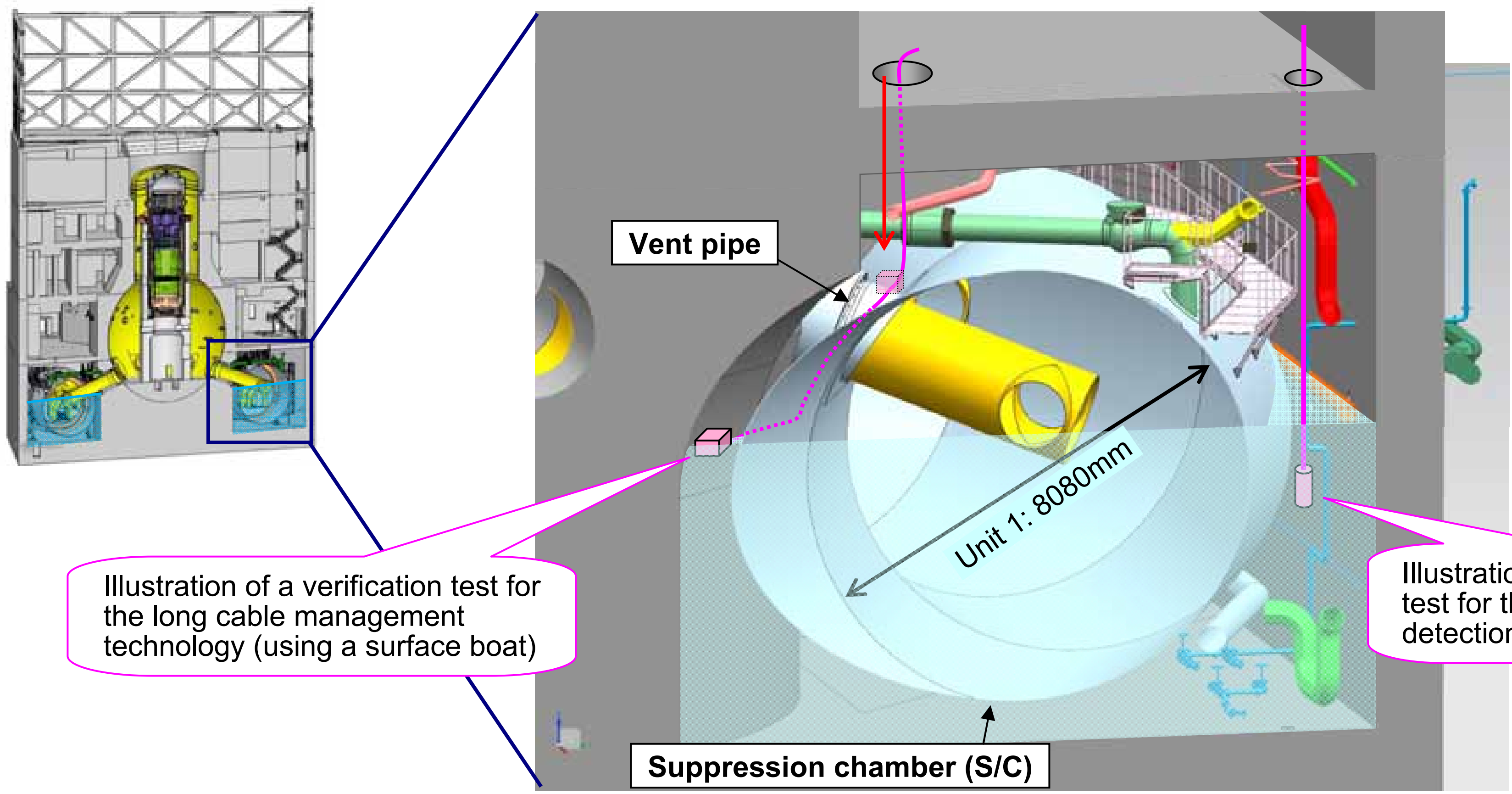
Verification Test in Development of Swimming Investigation Robot

October 24, 2013

［Remote Technology Task Force WG2］
Underwater Swimming Robot WG

1. Purpose

To verify, in the Unit 1 Reactor Building, a long cable handling technology and a self-position detection element technology, which have been developed in a **FY2012 technology platform establishment project subsidized by the Agency for Natural Resources and Energy for clearing the aftermath of a power nuclear reactor accident (swimming investigation robot technology development toward advancement of the remote technology platform)** with the support of "**Underwater Swimming Robot WG (Project Manager: Prof. Ura from Kyusyu Institute of Technology)**".



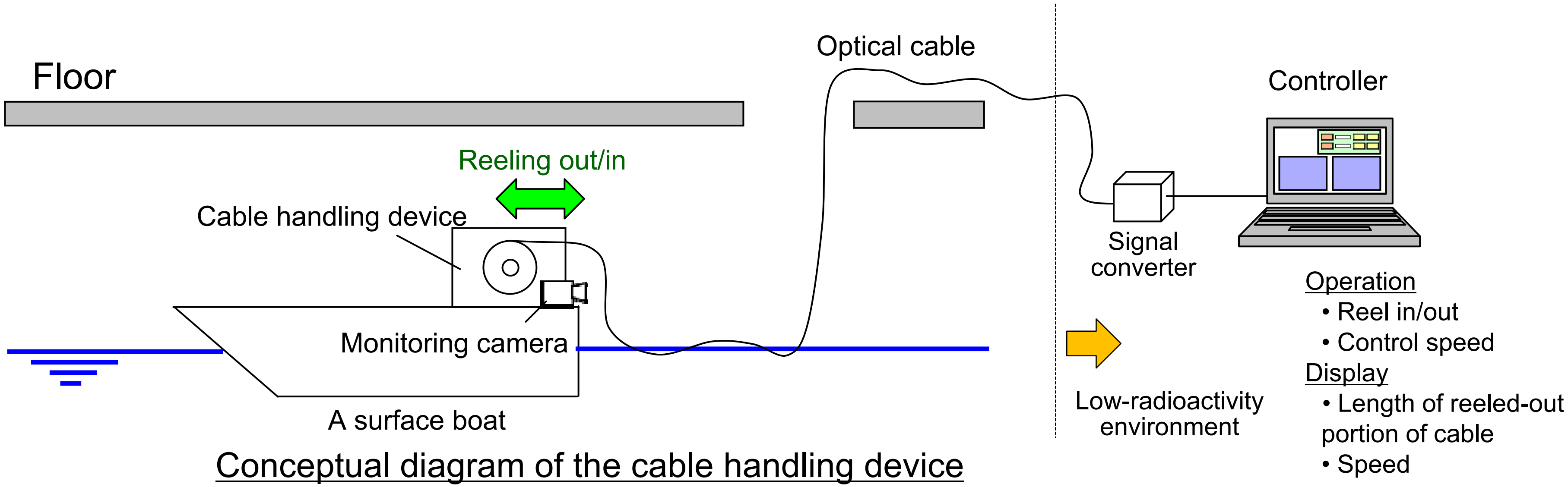
2. Long Cable Handling Technology: Overview of Technology under Development

■ Objective

To develop a long cable handling technology that enables a cabled water-surface investigation robot to swim for a long distance in order to make an investigation for water-leaking locations in the submerged parts possible in a situation requiring: use of a surface and underwater traveling machine requiring connection to a cable, etc. for signal transmission; and a technology to handle a long cable for an investigation under the narrow and adverse environment having complex structures.

Long cable handling technology

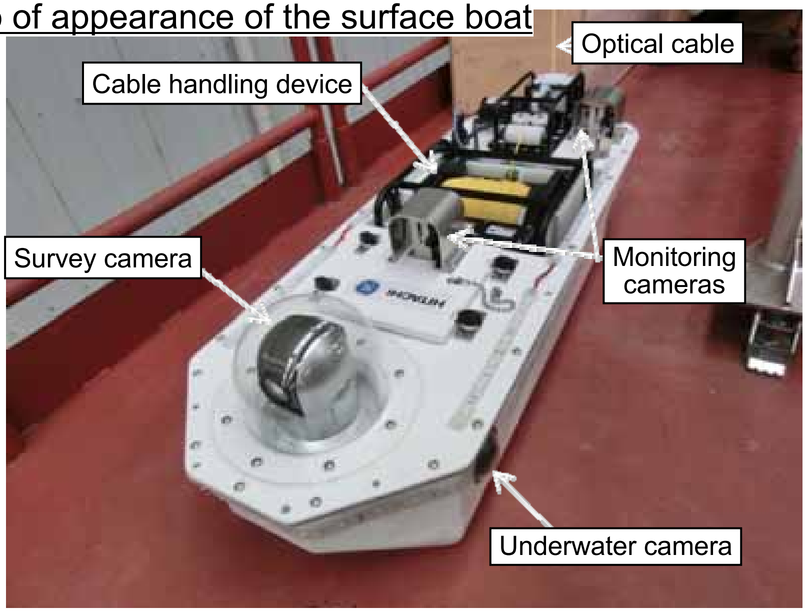
A cable handling device is mounted on a surface boat, and a cable is reeled out and in based on images captured by monitoring cameras.



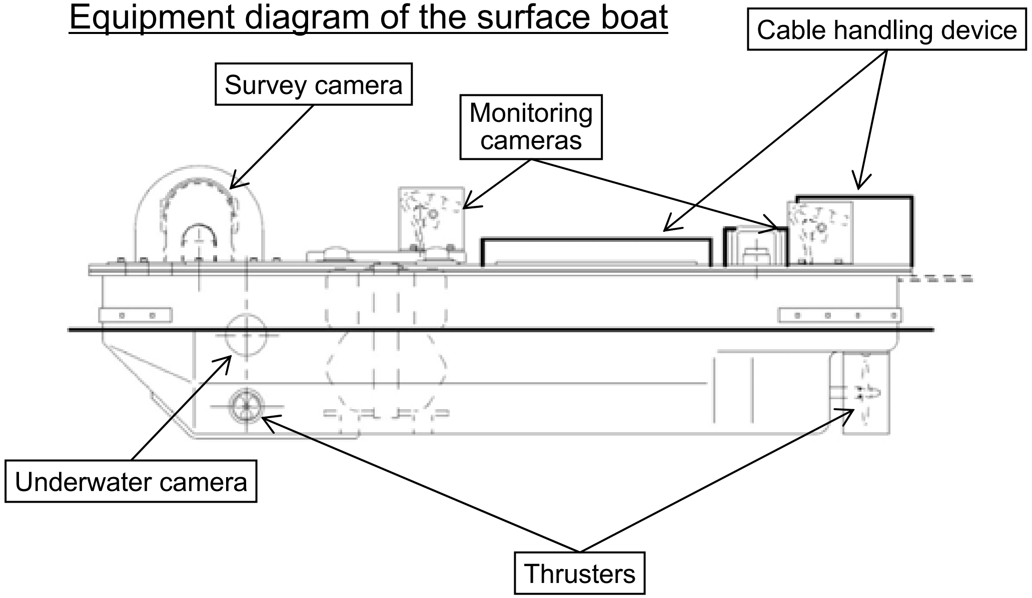
Conceptual diagram of the cable handling device

2. Long Cable Handling Technology: Device Specifications (Surface Boat)

Photo of appearance of the surface boat



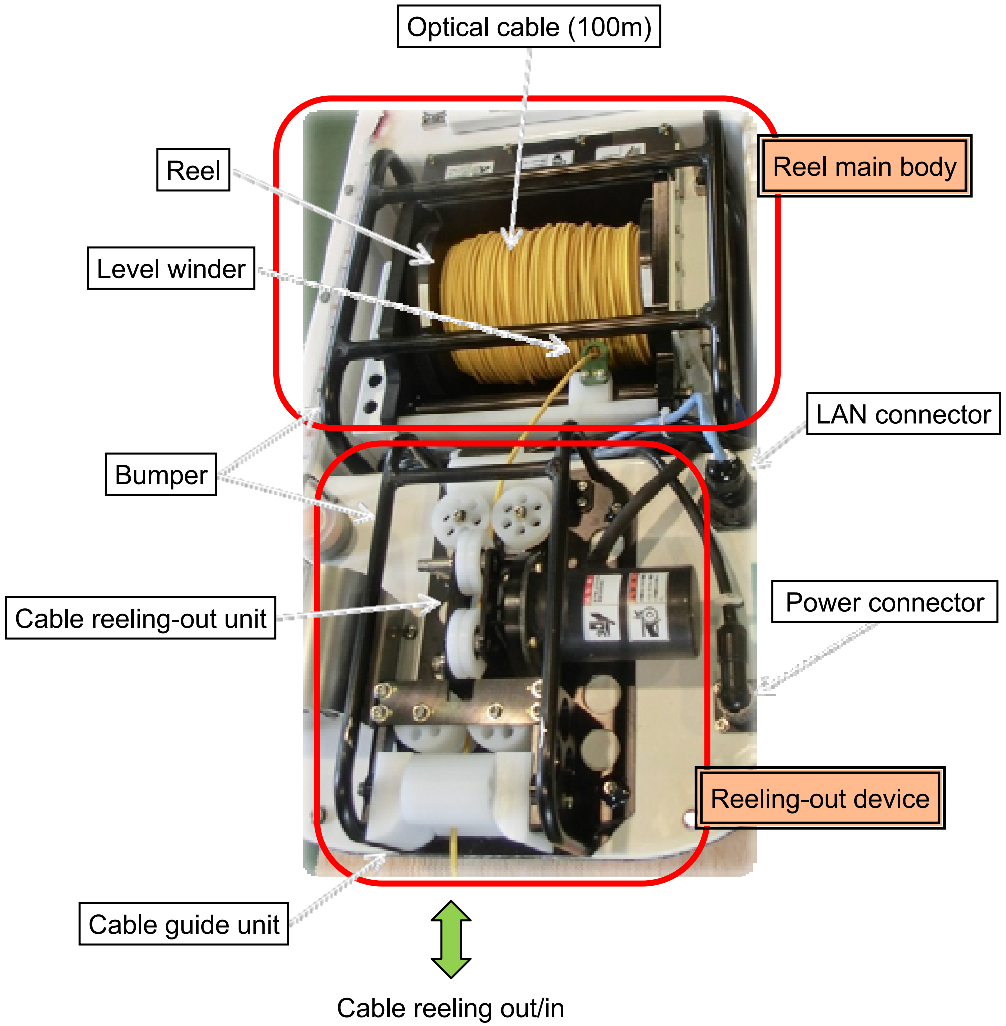
Equipment diagram of the surface boat



Device specifications	
External dimension	L 900mm × W 330mm × H 293mm
Weight	Approx. 27kg
Propulsion device	A forward-backward thruster, and a lateral thruster
Optical cable length	100m
On-board instrument	A survey camera, 2 underwater cameras, 2 monitoring cameras, and a radiation dose rate meter

2. Long Cable Handling Technology: Device Specifications (Cable Handling Device)

Photo of appearance of the cable handling device
(mounted on the surface boat)



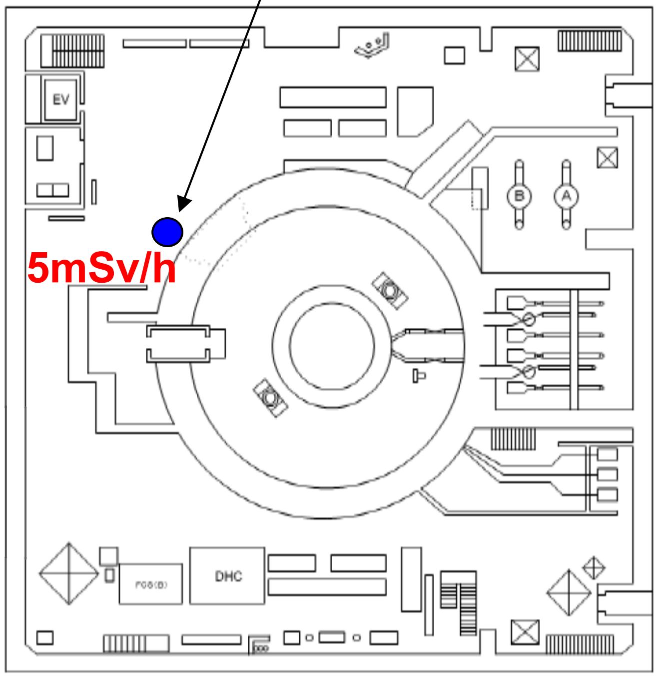
Device features	
External dimension	Reel main body: L 250mm × W 250mm × H 193mm Reeling-out device: L 204mm × W 153mm × H 83mm
Weight	Reel main body：Approx. 6kg Reeling-out device: Approx. 1kg
Features	• Small and light device for on-board use • Capability of handling an optical cable of up to 100m • Combined use of the level winder and the reeling-out unit, which enables smooth reeling-out/in actions that keep the cable from entangling

2. Long Cable Handling Technology: Verification Method

● How the surface boat will be thrown in

A hole (approx. 500mm in diameter) will be opened in the floor of the 1st floor's north west side of the Unit 1, where the dose rate is relatively low. The surface boat set inside a cage will be vertically thrown in through the hole, and then be let through an opening in the inside catwalk to be landed on the water.

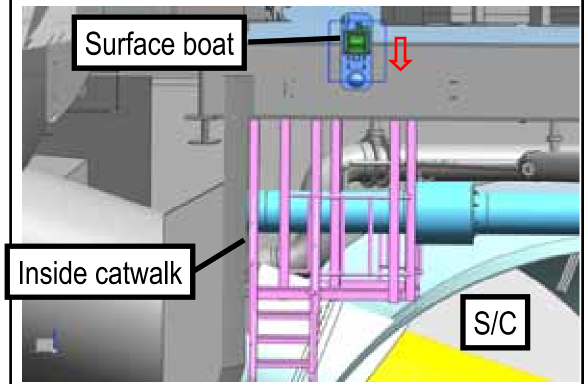
Spot through which to throw in the device (a hole to be newly drilled)



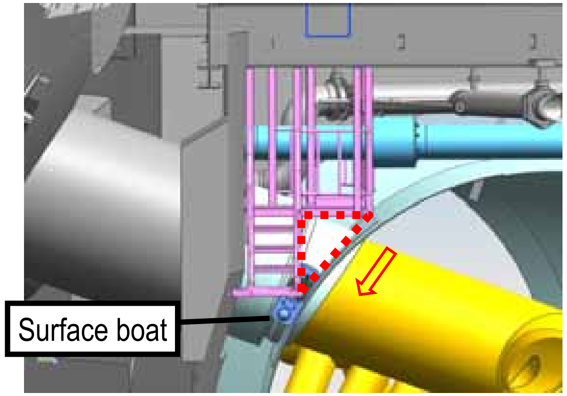
Verification test site
(1st floor of Unit 1 Reactor Building)

【Steps for throwing in the device】
① Throw the device in through a drilled hole.
② Let the device through a space between the outer surface of S/C and the inside catwalk.
③ Land the device on the surface of the accumulated water.

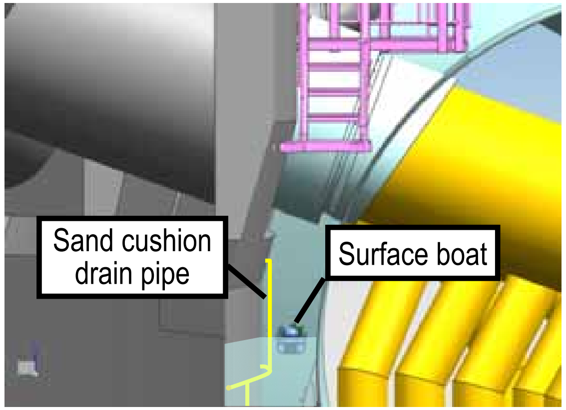
① Throw the device in.



② Let the device through the inside catwalk.

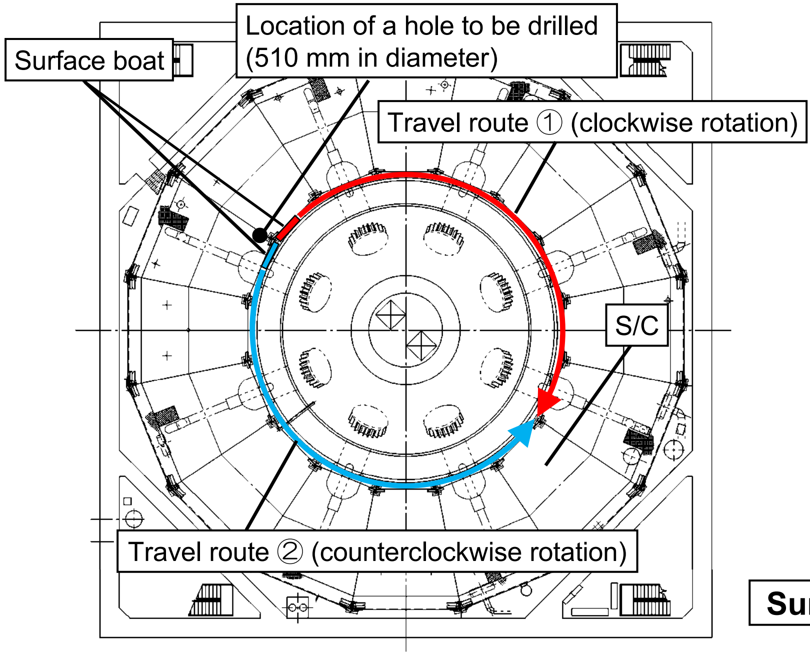


③ Land the device on the water.

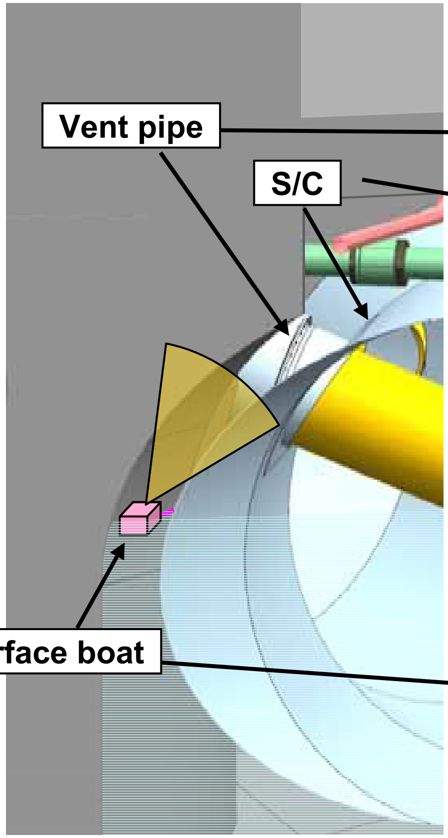


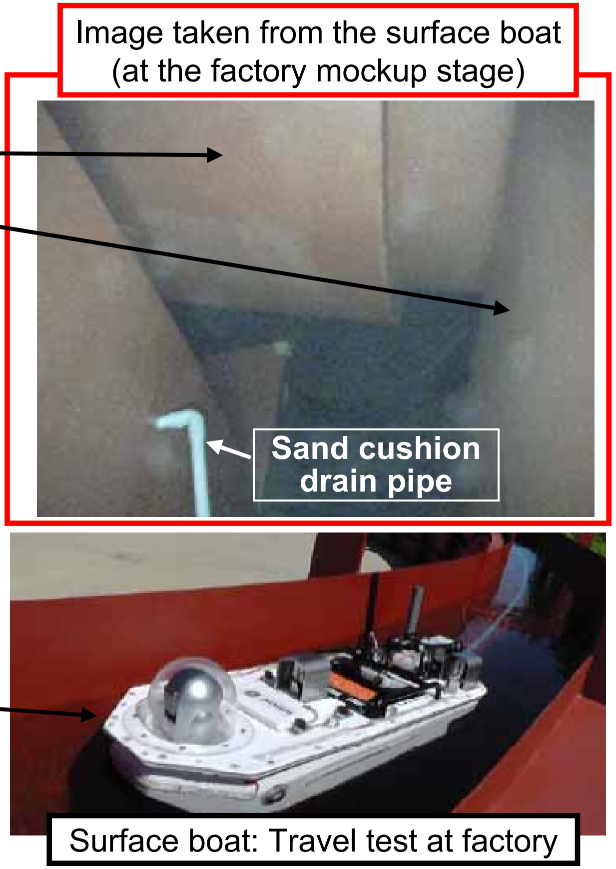
2. Long Cable Handling Technology: Verification Method

- The surface boat is caused to travel 180 degrees around a circle each time, and whether the long cable handling device is properly operating (reeling out and in) will be checked by the on-board monitoring cameras. At the same time, leakage around the lower side of the vent pipe and the condition of the sand cushion drain pipe (partly a vinyl chloride pipe) will be checked.



Surface boat travel routes





3. Self-position Detection Element Technology: Overview of Technology under Development

[Objective]
To develop, as a platform technology, a self-position detection element technology for detecting the self-position of an object such as a robot inside a space in a narrow, closed and muddy-water environment where the detection is difficult when it is merely based on optical camera images. The technology was designed to determine the current position based not only on optical camera images but also on geometry measurement results, obtained by a geometry measurement sensor (laser or ultrasonic), and map information so as to be usable for later investigations under various underwater environments.

Self-position detection method

Detection method	Description
Map matching method	**The current position is determined using geometry measurement results, obtained by a geometry measurement sensor (laser or ultrasonic) and map information**

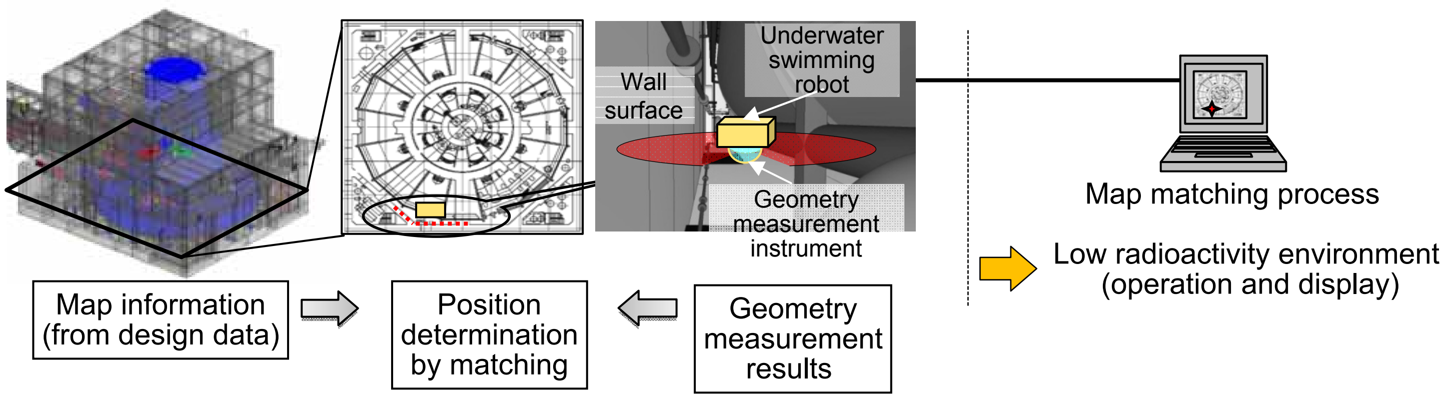
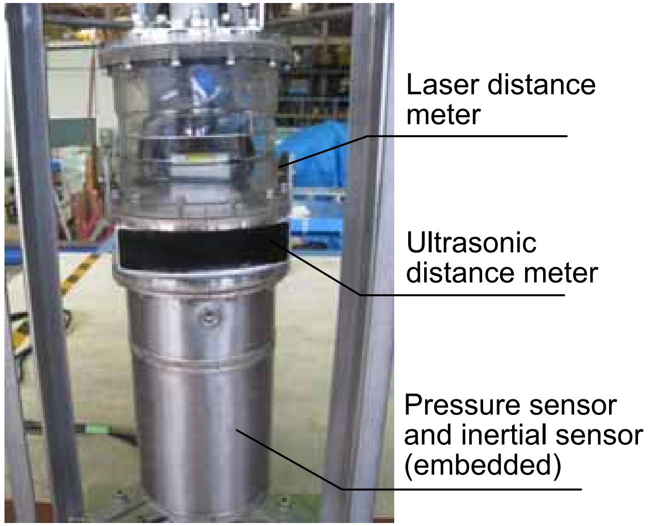


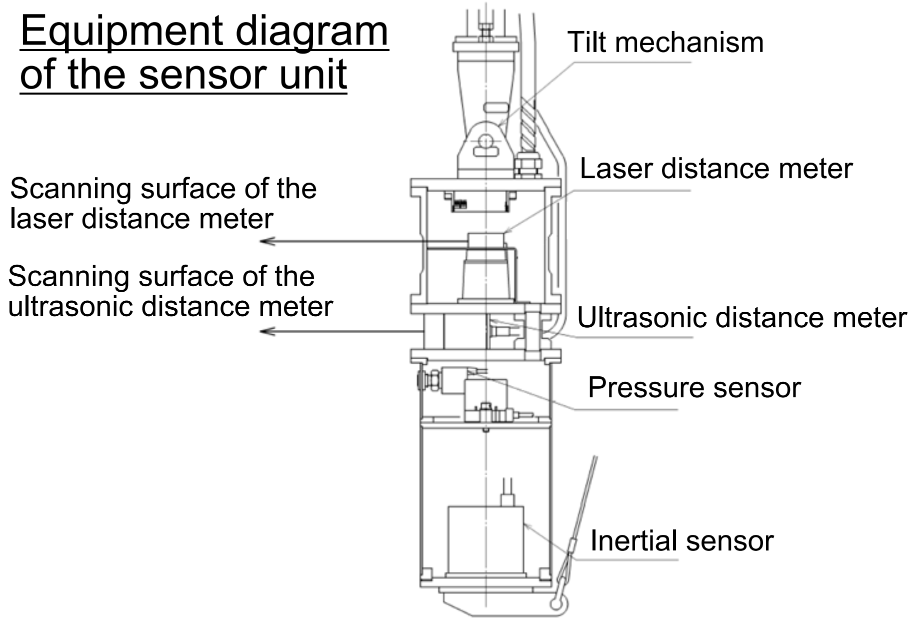
Illustration of the self-position detection element technology

3. Self-position Detection Element Technology: Device Specifications

Photo of appearance of the sensor unit



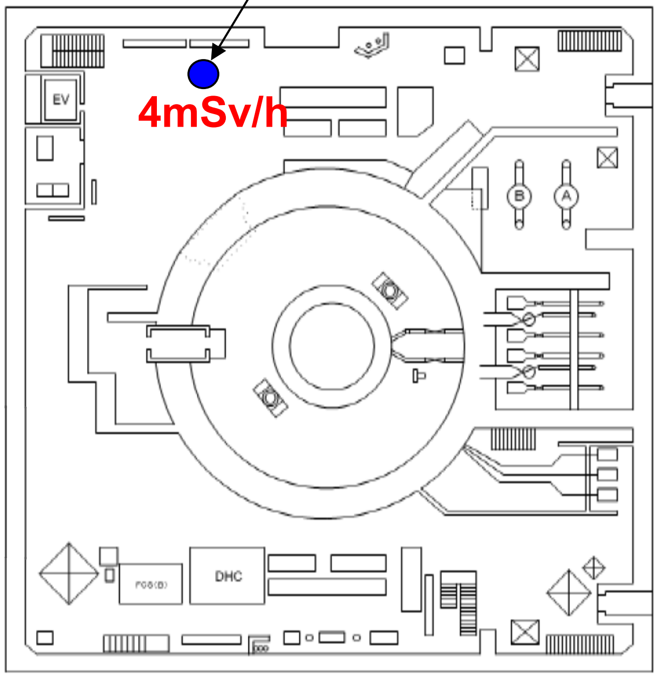
Equipment diagram of the sensor unit



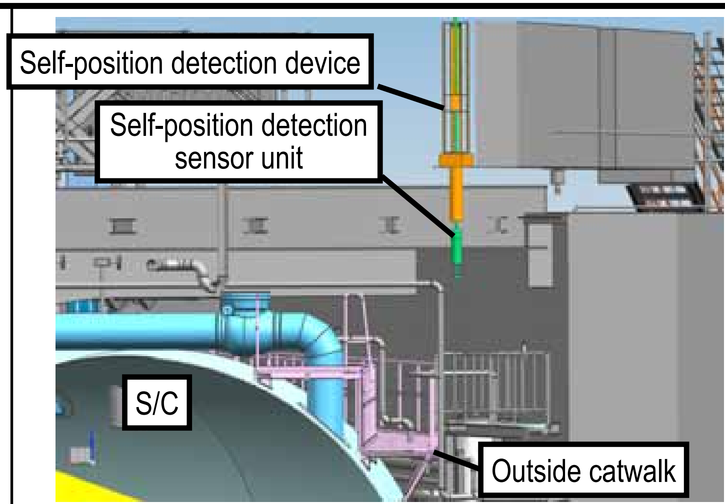
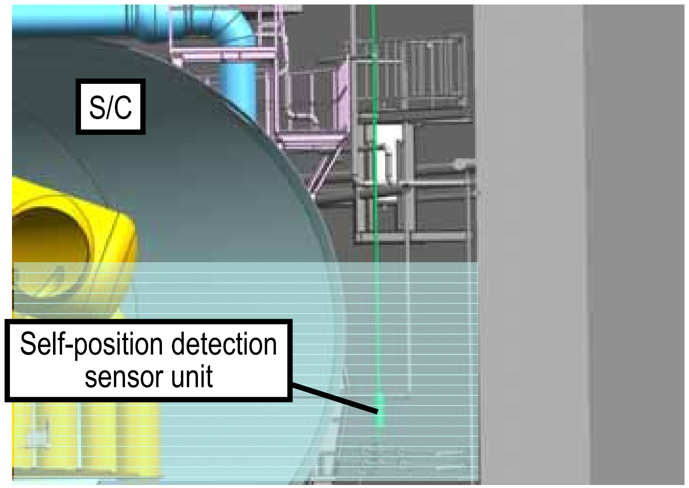
Device specifications	
External dimension	160mm in diameter ×H 435mm (Sensor unit)
Weight	Approx. 15 kg (Sensor unit)
On-board sensors	Distance: Laser distance meter and ultrasonic distance meter Water depth: Pressure sensor Orientation: Inertial sensor
Distances that can be measured	Ultrasonic: Up to10m Laser： Up to 2m

3. Self-position Detection Element Technology: Verification Method

- The device will be suspended and brought down through a hole (200mm in diameter) already drilled in the 1st floor of the Unit 1 Reactor Building. Then, the position detection performance in an actual device environment (such as muddy water) will be evaluated.



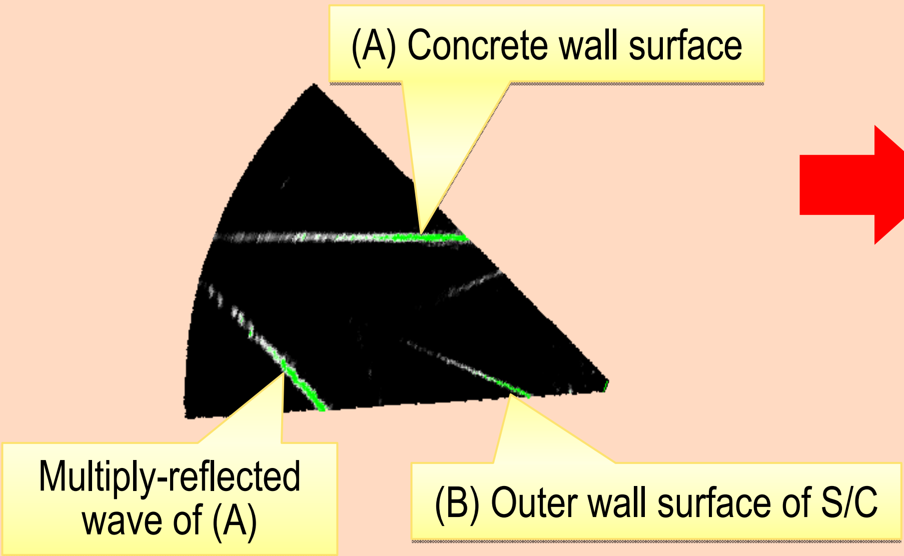
Verification test site
(1st floor of Unit 1 Reactor Building)

Throw in the device through an already drilled hole (200mm in diameter) into the torus room	
Bring down the device until it gets underwater, and conduct a verification test	

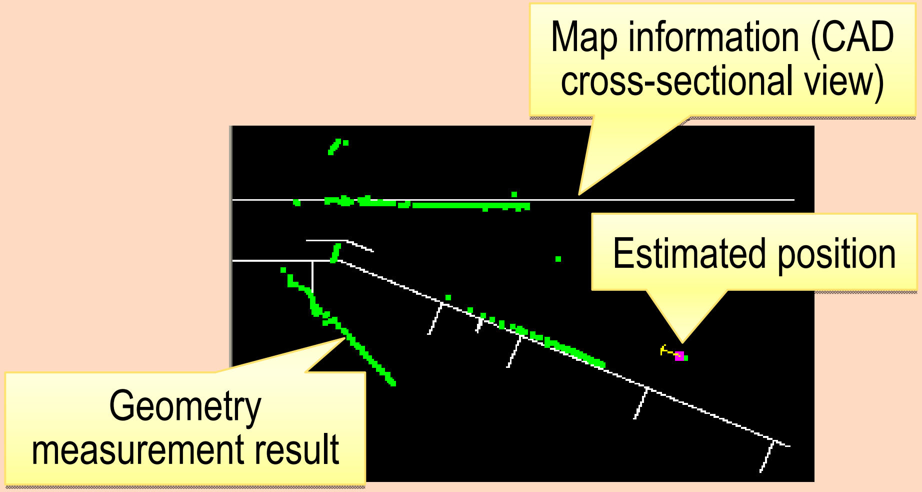
3. Self-position Detection Element Technology: Verification Method

- In an actual device verification to be conducted this time, we will verify whether the self-position detection sensor unit's function of estimating the self position operates properly, and will study how differences in environment affect the measurement results in comparison to results obtained in the plant test.

Geometry measurement result (Ultrasonic measurement result (example))



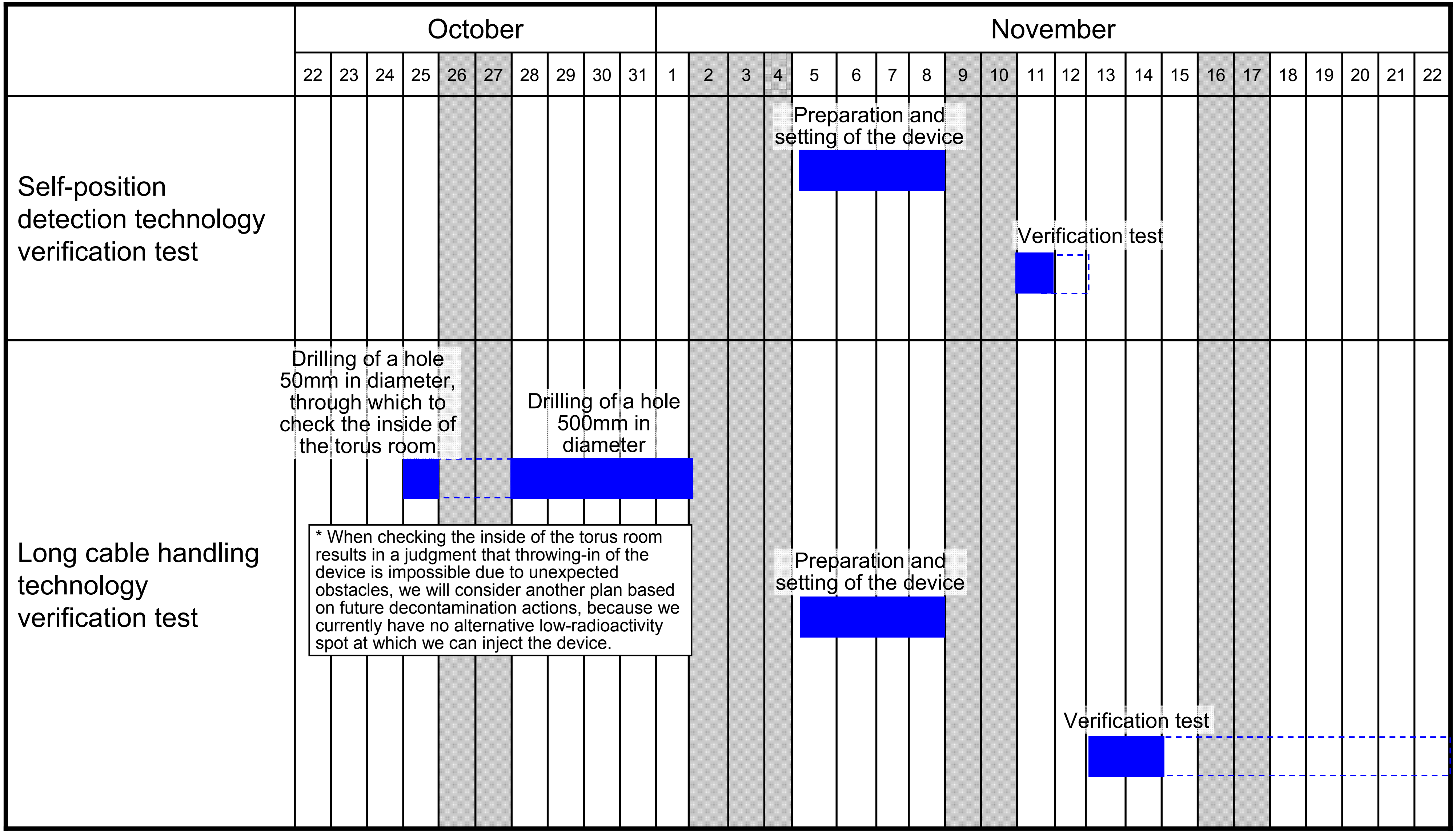
Self-position estimation result (example)



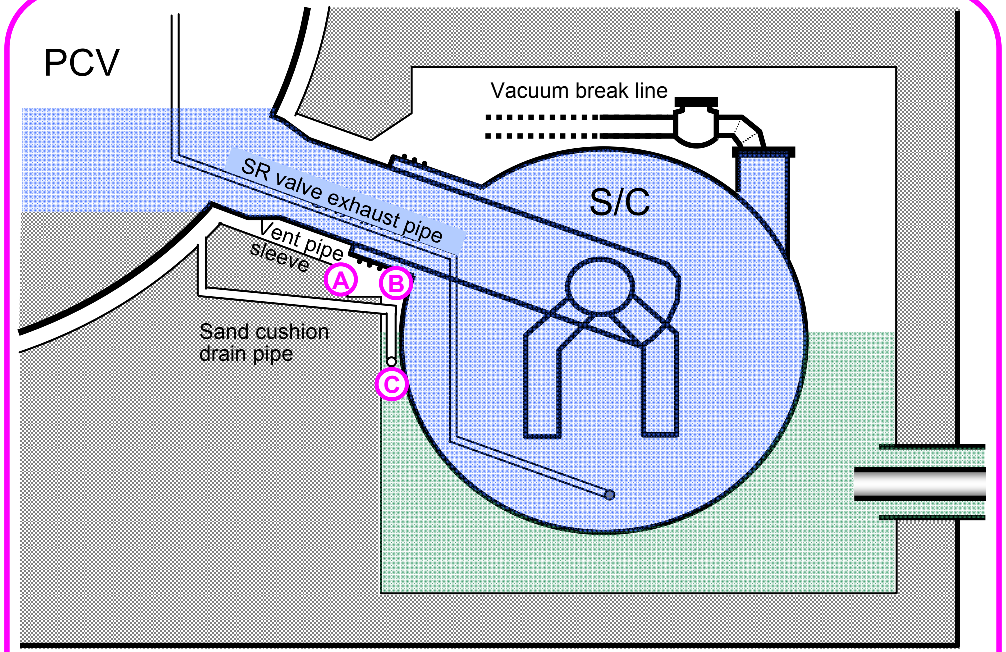
The ultrasonic geometry measurement result and the map information (CAD cross-sectional view) are compared, and a point for which data correspond with each other the most is found and calculated.

Illustrations of the actual device verification

4. Schedule (Tentative)



<Reference> Investigation and Future Actions (TECPO)



< Matters for investigation >

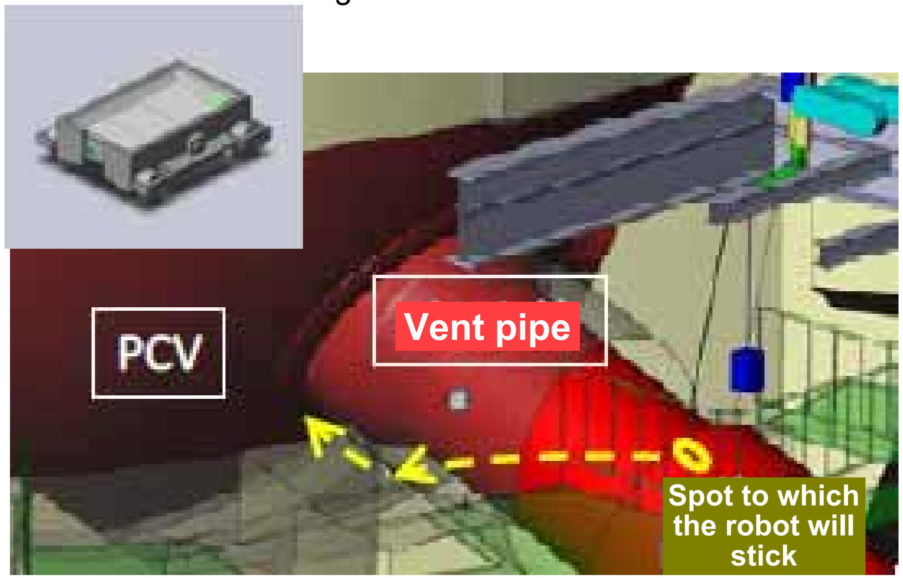
- (A) … Whether there is water flowing from the edge of the vent pipe sleeve
- (B) … Whether there is water flowing from the vent pipe sleeve and the air-surrounded part of S/C
- (C) … Condition of the sand cushion drain pipe

< When water has been found flowing in (A) >

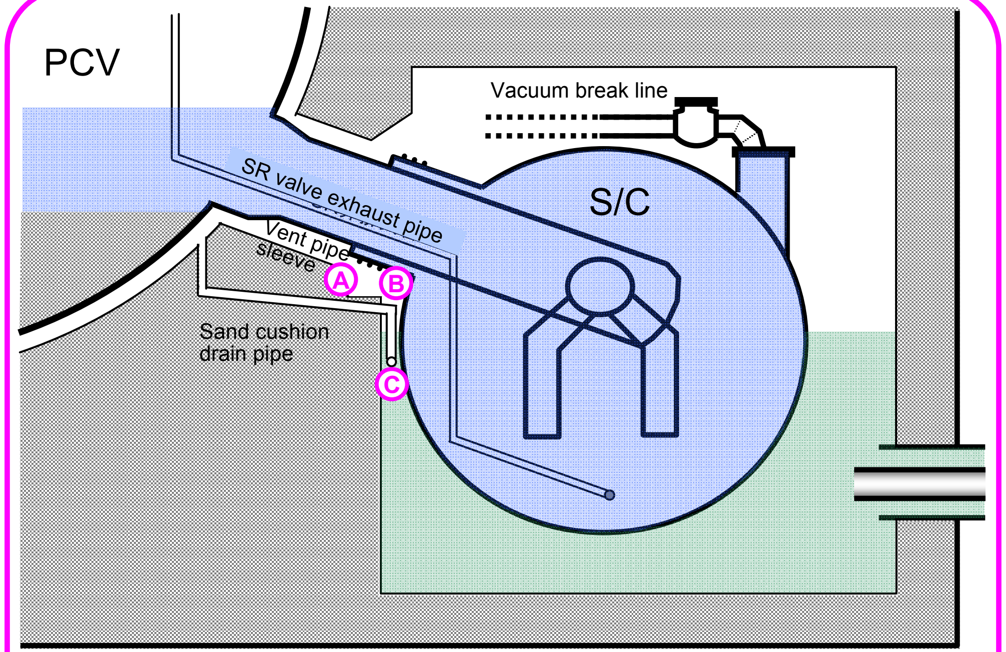
Leakage from PCV is likely. (The shell might have been hit by fuel debris.)

An investigation will be conducted on the vent pipe joint using a vent pipe joint investigation robot currently being developed in a governmental project (scheduled to be conducted in 2015).

Illustration of the investigation



<Reference> Investigation and Future Actions (TECPO)



< Matters for investigation >

- (A) … Whether there is water flowing from the edge of the vent pipe sleeve
- (B) … Whether there is water flowing from the vent pipe sleeve and the air-surrounded part of S/C
- (C) … Condition of the sand cushion drain pipe

<(C) Condition of the sand cushion drain pipe >

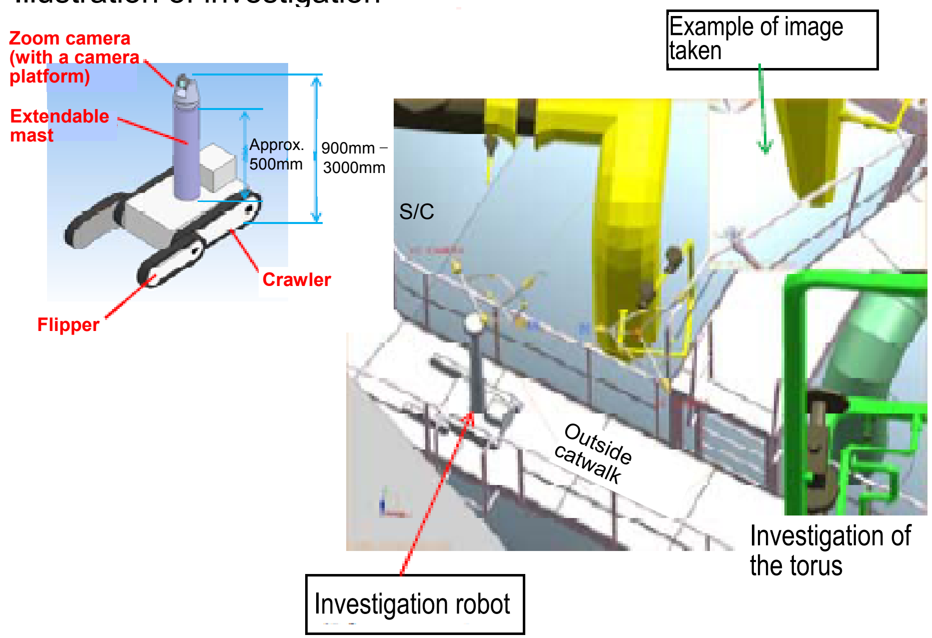
Findings regarding the condition of the sand cushion drain pipe (a vinyl chloride pipe only in the Unit 1) will be used to advance the development of a sand cushion drain pipe investigation device (a government project).

< When water is found flowing in (B) >

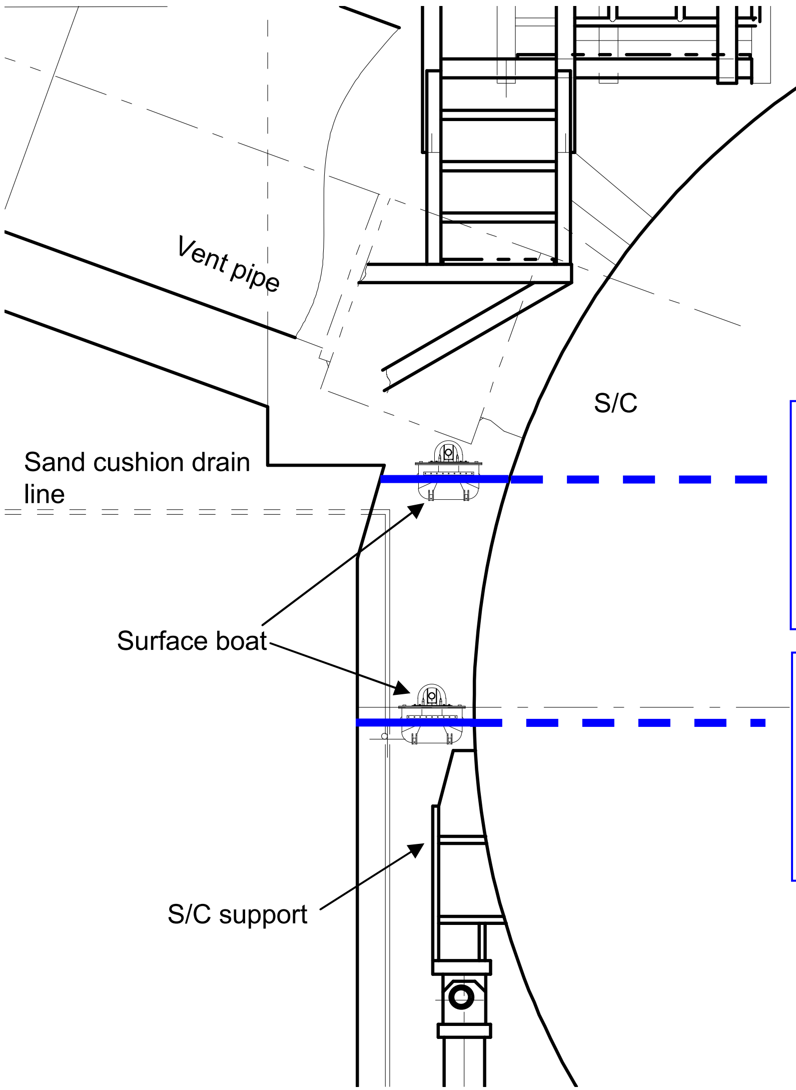
This information enables us to grasp the state of leakage from the vent pipe bellows and to estimate the possibility of leakage from a structure (such as the vacuum break line) in the air-surrounded part of S/C.

Regardless of whether there is leakage from the vacuum break line or not, the vacuum break line will be investigated (tentatively in FY2014) using a S/C upper part investigation robot currently being developed in a government project. This is because we are planning to fill the vacuum break line with a waterproofing material for stopping water at the lower part of PCV, and will make a judgment, based on the investigation, as to whether the filling is feasible.

Illustration of investigation



<Reference> Concerns over Accumulated Water Level (TECPO)



In a case where the accumulated water level is high, the surface boat may be unable to travel because of interference of the surface boat and the vent pipe with each other.
(The water level higher than OP.4800 or so makes it very difficult for the boat to travel.)

In a case where the accumulated water level is low, the surface boat may be unable to travel because of interference of the surface boat and the S/C support with each other.
(The water level below OP.3500 or so makes it very difficult for the boat to travel.)

At present, the accumulated water level is high because of such factors as typhoons (OP.4849 as at 4:00 PM on October 23). Whether to conduct investigations will be determined based on future observation of the accumulated water level.