# Development of Seafloor Geodetic Observation System Based on AUV and Submarine Cable Technologies

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***Abstract*-Institute of Industrial Science, University of Tokyo (IIS) has launched a five-year long project to develop next-generation seafloor geodetic observation system in 2005. Principal idea of the observation system is to utilize AUV, seafloor platform and submarine cable in place of using a research vessel and a stand-alone type seafloor benchmark transponder. This observation system aims at promoting efficiency of the observation for maintaining the observation system over a long period in response to geodetic events that have long time scales. Trial model of the surface system that should be installed on an AUV observation platform was finished. And then, based on this technological development, we have just started to develop the AUV specially design for seafloor geodetic observation. The seafloor transponder was also finished and installed on the existing submarine cable system. We are in the final stage of the development of the new observation system for seafloor geodesy.**

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## I. INTRODUCTION

Institute of Industrial Science, University of Tokyo (IIS) has been developing a method for precise geodetic measurement on the seafloor in corporation with Hydrographic and Oceanographic Department, Japan Coast Guard (JHOD) [1][2]. A combination of KGPS and acoustic ranging techniques is employed into the system to achieve centimeter-level geodesy on the seafloor.

The seafloor geodetic observation network, which consists of eighteen seafloor geodetic reference stations, has been established with this system [3][4][5]. The network has extended along the Japan islands from north to south covering the area between off the Tohoku area and off the Shikoku area. Repeated measurements with the system by JHOD lasting for about ten years have detected the seafloor crustal movements before and after the thrust-type earthquakes occurred along the ocean trench regions. One of them is related to the 2005 Off Miyagi Prefecture Earthquake. This

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earthquake occurred about 10km west of MYGW reference station, one of eighteen stations which we had deployed, on August 16, 2005.

Time series in the horizontal components obtained at the seafloor reference station MYGW from twelve campaign epochs during the period from 2005 to 2008 shows a series of crustal movements indicating the beginning of the reaccumulation after the release of crustal strain in the subsea focal area [6]. It was the first time in the world to observe it on the subsea area.

Even though the observational results show that the current observation system is practical, we do not fully satisfy it. The current observation system needs a JHOD's research vessel. This often gives limitations on our activities. Annual cruise schedules of the research vessels make it difficult to change daily schedules of the research vessels to meet our demands such as to avoid bad sea conditions while conducting observations and to have suitable GPS satellite conditions.

Generally speaking geodetic event has a long time scale of several decades or more. If we observe it, we need to maintain observation system for long time in response to its time scale. The current observation system which uses a 500 ton class research vessel as a surface observation platform is not suitable for long-term observation. The high cost of vessel operation including the requirement of a lot of crews may get in the way of maintaining order in the observation system.

Seafloor transponders of the current system are stand-alone ones which run on internal batteries. We expect five to ten years for a lifetime of a current seafloor transponder, even though it depends on how often we perform measurements with a transponder. Replacement of a seafloor transponder will be needed when we target seafloor crustal deformations that have long time cycles more than several decades. Continuity of seafloor geodetic observation will be stopped at that time.

We have started a project supported by the Japan Society for the Science Promotion as the Grants-in-Aid for Scientific Research [7][8][9]. In this project, we are aiming at technical development of new-generation seafloor geodetic observation system that conquers difficulties inherent with the current system and promote efficiency, time-saving and labor-saving in order to maintain observation for long time.

## II. New Observation System for Seafloor Geodesy

Fig. 1 shows a schematic image which explains the concept of new-generation seafloor geodetic observation system. Fundamental idea of the new system is to utilize techniques of AUV, seafloor platform and submarine cable to make measurements in place of using a research vessel. Combination of underwater robot, seafloor platform and submarine cable make it possible to provide permanent seafloor reference point, to conduct the observation with selecting favorable condition of sea and GPS satellite distributions, to make much more frequent observations and to enable flexible planning of observation in response to sudden geodetic events.

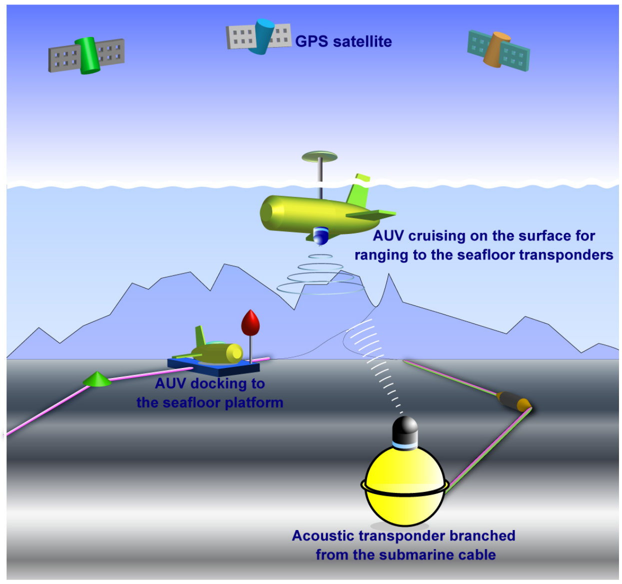


Figure 1. Schematic image of the new-generation seafloor geodetic observation system based on technologies of AUV, seafloor platform and submarine cable

## III. Development

In the first half of the project, we started with developments of key constitutive elements of the new-generation seafloor geodetic observation system; downsized sea surface unit, acoustic transducer, acoustic mirror transponder (seafloor unit), acoustic LAN system [10], non-contact battery charging system [11] and so on. In the latter half of the project, we devoted ourselves to develop and construct the sea surface platform and the seafloor benchmark transponder based on the developed constitutive elements .

### A. *Sea Surface Platform*

One of the key things in the new system is to utilize AUV as a surface observation platform instead of research vessel. We selected existing AUV named as “r2D4” as a testbed of the surface observation platform. r2D4 is an intelligent AUV developed by Prof. Tamaki Ura (IIS) for the purpose of research work at hydrothermal system on the seafloor. Developments of key constitutive elements related to the sea surface platform had been done assuming that they would be installed on r2D4.

The prototype of the sea surface unit had been tested through the sea trials with the surface observation platform based on r2D4. We had a sea trial in Sagami bay on July 10, 2007. The observation system based on r2D4 could locate the position of the seafloor transponder, which was temporally deployed, with the root mean square of the travel time (two-way) of 0.06ms which corresponds to 4-5cm in position [12]. This observation result shows that the newly-developed

Figure 2. Assenmble of the surface platform based on a S-AUV. The S-AUVsystem and the sea surface unit including acoustic ranging system, GPS receiver, motion sensor were installed into two cylinders for installation onto the S-AUV.

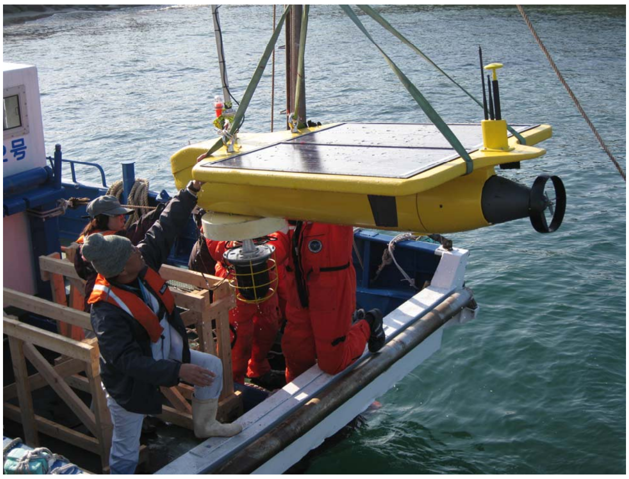

Figure 3. Deployment of the S-AUV-based surface platform using the davit equipped on the small working ship.

observation system is practical, and encourages us to move ahead with a plan to construct an AUV-based surface observation platform specially designed for seafloor geodetic survey.

The construction of the AUV-based surface platform has started in the end of the project. FSI's S-AUV was selected as a main body of the surface platform (Fig. 2). Utilization of a commercial product (S-AUV) reduced development resources greatly. S-AUV is compactly-designed AUV, and then we do not need a big boat and special facilities to operate it. This brings us the reduction of operating and maintenance costs. The measurement system including the sea surface unit, GPS receiver, INS and so on was assembled on the S-AUV.

### B. *Seafloor Transponder*

New seafloor transponder which we have developed is one which can be connected to submarine cable by wet-mate connectors. Power is supplied through submarine cable and then the new seafloor transponder will be a permanent reference station for seafloor geodetic survey.

The submarine cable system off Toyohashi (Tokai-SCANNER) in central Japan is located on the source region of the huge repeated earthquakes. It is under the control of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and used for long-term geophysical monitoring. This cable system is one to which we connected newly developed seafloor transponder. The installation of the seafloor transponder to the cable system was conducted with JAMSTEC's ROV KAIKO 7000 II on September 20, 2008 [13]. The first submarine cable transponder as a seafloor geodetic benchmark has been established.

### C. *Sea Trial with the Developed Observation System*

Ranging measurements with the newly developed system, i.e. the submarine cable transponder and the S-AUV-based surface platform, were carried out in order to locate precise position of the submarine cable transponder as a geodetic benchmark on December 23, 2009 (Fig. 3).

The swell remained over the surface during the observation due to the day just after transit of the low pressure. The surface platform based on S-AUV had difficulties in proceeding against the swell and in following the scheduled profile. It is obvious that the propeller currently in use is powerless. This encourages us to give thought to the replacement of the propeller so that we might not lose opportunities of observation.

Even if poor navigation of the surface platform, the sea surface unit worked very well. Acoustic ranging to the seafloor transponder had been repeated at interval of fifteen seconds. The position of the seafloor transponder could be located with those data.

## IV. SUMMARY

IIS has launched the project to develop the new-generation seafloor geodetic observation system based on the technologies of AUV, seafloor platform and submarine cable. This system aims promoting efficiency of observation, time-saving and labor-saving in order to maintain the observation over long period.

The sea surface unit was developed. It was compactly designed so that it could be installed on an AUV. Performance of this unit was ensured through the several sea trials. Besides, the surface observation platform based on S-AUV was also developed.

The submarine cable transponder was developed and installed on the Tokai SCANNER submarine cable observatory, off Toyohashi-city, in central Japan.

Observation system which fulfilled the most of the requirements of the initial design was come to realization, even though there still remains room for improvement on it.

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