Development of Japanese Scientific Cable Technology

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***Abstract*-Japanese ocean science community has installed eight cabled observatories in Japanese water in the past. Japan started installing cabled observatories in the middle of 1970's for disaster mitigation as countermeasure to possible megathrust earthquake in the Tokai region, about 100 km away from Tokyo. Their first system composed of metal wires used frequency modulated signal transmission for carrying data acquired on the seafloor to land. The first Japanese cabled observatory was installed in 1978, i.e., five years after the initiation of engineering development. Since 1990, all newly installed cabled observatories have used fiber optic communication lines following the technological development in the telecom industry. Obviously, the development of scientific cabled observations adjusted their stride with that in the industry. Since the major telecom cables have been installed in a point-to-point configuration, scientific cabled observatories have been developed in the same way. In general, they have a land station and a line of cable along which observational instruments or junction boxes are connected in-line in the place of repeaters. Recently, scientists started trying to expand their observations in a way to enhance observational capabilities using multi-disciplinary sensors as the growth of their understanding to invisible processes in the sea. Cabled observatory projects are now underway to enable next-step data acquisition on the seafloor with much wider spatial coverage and dense observational instruments. Technological development from a point-to-point configuration to a network, whose topology could be either ring or star shape, has become necessary. Power supply and communication mechanisms to all of sensors attached to observatory need to be revisited as well.**

I. Introduction

After the earthquake disaster in Kobe in 1995, the Headquarters for Earthquake Research Promotion in the Ministry of Education, Culture, Sports, Science and Technology (MEXT) advocated to install at least five cabled observatories [1], one for each sea area of high risk in the occurrence of plate boundary earthquakes, for the promotion of earthquake studies. Before the Kobe Earthquake (officially named as the 1995 Hyogoken Nambu Earthquake), there were only four cabled observatories for earthquake disaster mitigation in Japanese water. The Japan Meteorological Agency (JMA) installed two observatories in the eastern Nankai (Tokai) in 1978 and Off-Boso in 1986, Earthquake Research Institute of the University of Tokyo (ERI) in the eastern offshore of Izu Peninsula in 1992 and the National Research Institute for Earth Science and Disaster Prevention (NIED) along the Sagami Trough in 1994 (Fig.1). They all are composed of a set of a land station and a single line of sensors [2]. Technologies used by scientists and engineers were imported from that in the telecom industry. In other words,

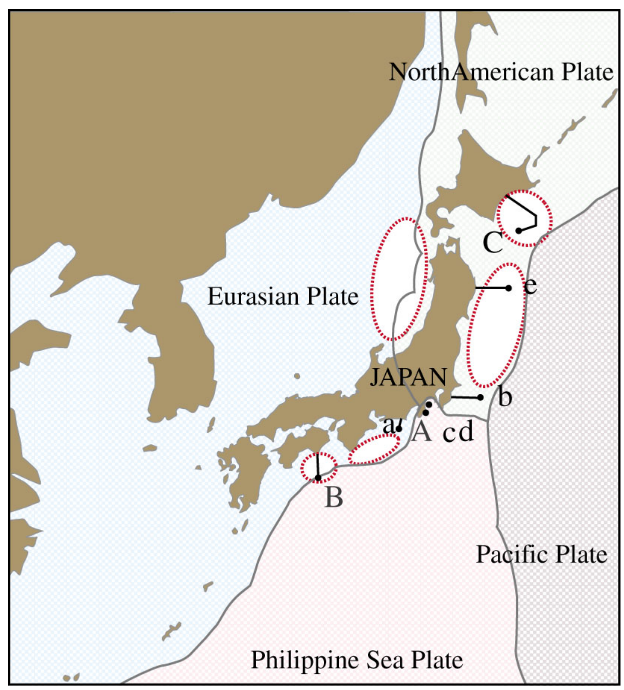

Fig. 1 Eight cabled observatories around Japan for Earthquake Monitoring and Engineering Developments [1]. They are a) JMA Off-Suruga, b) JMA Off-Boso, c) ERI East Off-Izu Peninsula, d) NIED Sagami-Trough, e) ERI Off-Sanriku, A) JAMSTEC Hatsushima Engineering Development, B) JAMSTEC Off-Muroto, and C) JAMSTEC Off-Tokachi-Kushiro systems. Circled water areas were advocated by the Headquarters of Earthquake Research Promotion that the real-time observations are necessary for future potential of catastrophic earthquakes.

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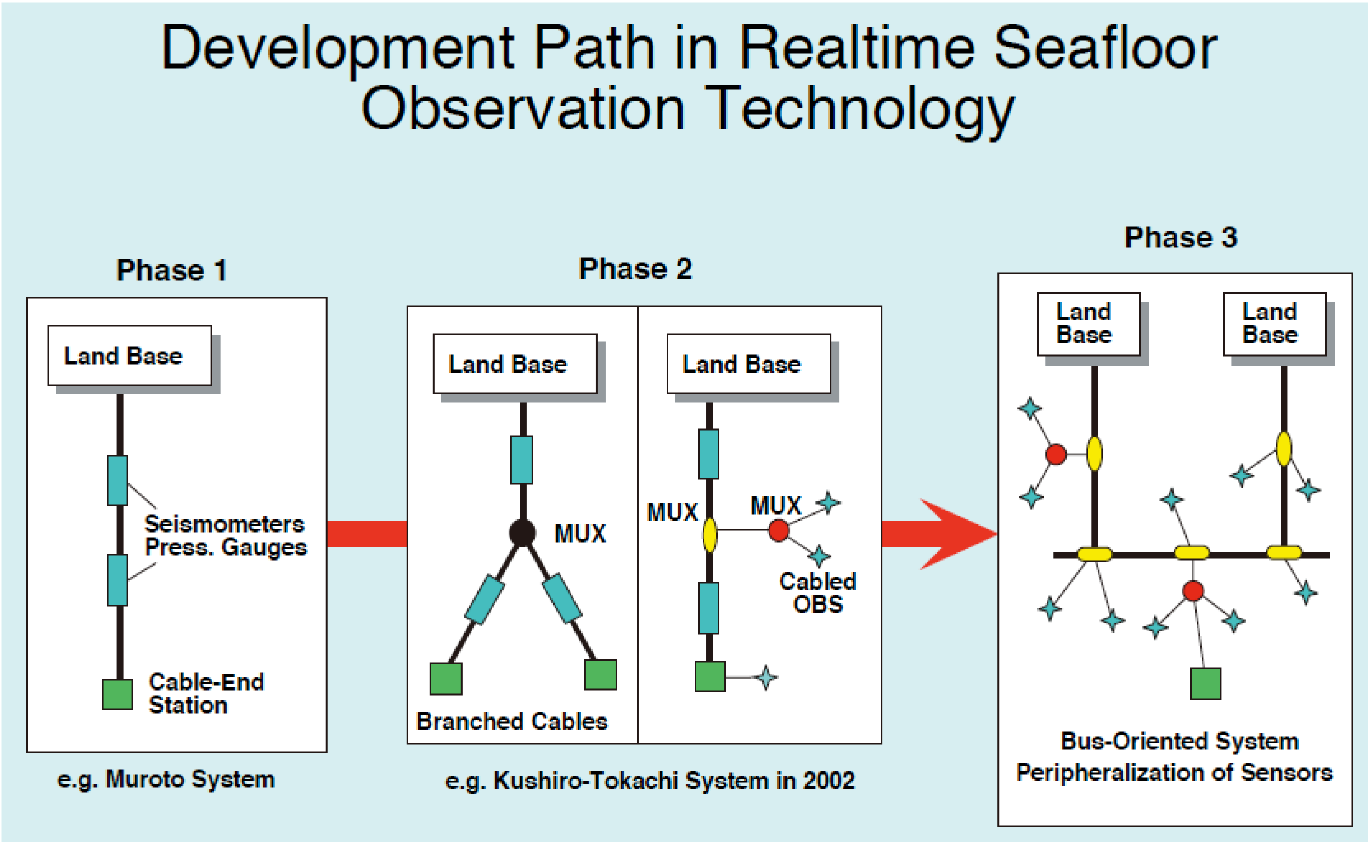

Fig.2 Configuration of Scientific Cabled Observatories and the path of development. Cabled Observatories developed in the twentieth century have phase-1 configuration, i.e., a single land base, a monocable, and in-line sensors. The development goes to phase-2 to 3 to enhance the spatial coverage of sensors and the operation stability.

scientists and engineers have applied the industrial standard technologies to acquire necessary data to achieve their scientific objectives. However, the number of observational instruments was limited and the spatial-coverage by their sensors was constrained by the length of cables. This configuration is applied until now but researchers started thinking about further extension of scientific cable technology to overcome the limitations in their observations.

II. TECHNOLOGIES INTRODUCED TO SCIENTIFIC CABLES

When Japan Meteorological Agency (JMA) started developing the first cabled observatory in 1974, they assorted the whole system into two, i.e., one for land and the other for marine equipment. For the latter, they introduced telecom technologies for real-time observations in the bottom of the sea. Their system composed of metal wires used frequency modulated signal transmission for carrying data acquired on the seafloor to land. Electric power is supplied to each of sensors based on constant current technology. Pressure housing is made of beryllium copper that is resistant to both corrosion and pressure. For accommodating sensors and transducers in the pressure housings, the inner diameter of the housing was chosen as 204 mm. They have chosen each of electrical parts to assure the mean-time-between-failure (MTBF) of 100 years introducing transistors and IC's from the state-of-the-art technology of those days. Two types of sensors, gimbaled-seismometers and tsunami gauges, were all manufactured from scratch. The first Japanese cabled observatory was finally installed in 1978, i.e., five years after the initiation of engineering development. Using the same technology, JMA installed the second cabled observatory in 1986, off Boso.

After the installation of these two cabled observatories in 1978 and in 1986, the deployment of cabled observatories were succeeded by ERI, NIED, and Japan Marine Science and Technology Center (JAMSTEC). Four cabled observatories were deployed. Metal wires for signal transmission were replaced with fiber-optic lines for observatories developed since 1990's. Four observatories deployed by ERI, NIED, and JAMSTEC, were equipped with seismometers and tsunami gauges for mainly earthquake disaster mitigation purposes but the other two observatories by JAMSTEC are characterized by the possibility of further observation using plural extension or auxiliary ports installed in either in-line branching multiplexing or cable-end terminal units. Underwater mateable connectors were introduced to enable additional connections of sensors or branching without recovering cables to the surface. So-called multi-sensor experiments were conducted using the same underwater connection technologies [3]. Since 1990, the development of scientific cabled observation technologies could be characterized by the introduction of fiber-optic signal transmission and of underwater mateable connectors. However, the power supply technologies have been left untouched other than the minimization of power consumption by the electronic revolution. Also, the configuration of the network is based on the point-to-point technology that connects each seafloor sensor to land data acquisition system. Scientific results have been reported using data acquired by these cabled observatories [4][5][6].

III. New Japanese System in The New Millenium

Since the beginning of the twenty-first century, the marine scientists and engineers started designing their observations in the new paradigm of cabled observatories. The utilization of underwater mateable connectors in conjunction with the usage of plural sensors, maintenance of the sensors, etc. has become a matter of course in new millennium (Fig.2). They started thinking about the modification of power supply [7] and data transmission technologies as well as the topological configuration of the observatories [8][9].

Since 2004, two new cabled observatories are under development for the installation along the Nankai trough in the southern side of the Japanese islands. One system is deployed by JMA [10] and is going to have the same configuration as before since the observatory will be strictly used for disaster mitigation purpose. On the other hand, the other system is to be configured to have both traditional in-line type sensors and those using topologically advanced concept. The latter sensors will keep the idea of point-to-point configuration but have both sustainability and expandability using underwater mateable connection and power-supply branching that allows the network to form a star-topology (Fig.2) [9].

IV. Other Innovative Projects

The reuse of decommissioned telecom-cables has been attempted since 1990's by many researchers to reduce the cost of deployment for real-time marine observations [3] [11][12]. The experience showed that the cost could be minimized if and only if any reuse projects are conducted in a well prepared

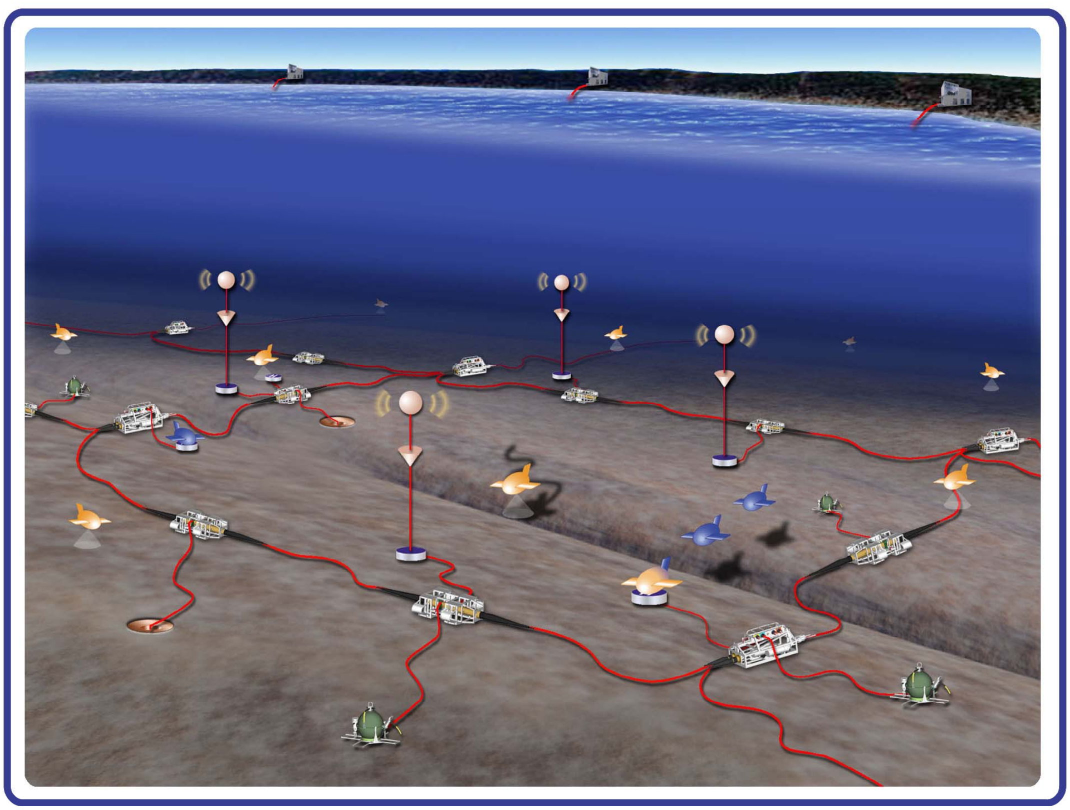

Fig. 3 Future underwater cabled observation system [1]. Scientific observation will be conducted towards understanding of the Earth's interior, material exchange through the seafloor, interactions among atmosphere, ocean, and soild earth, etc. Plural landings will surely support keeping the network integrity. Marine facilities including AUV, ROV, moored observation system, etc., will be used to satisfy scientific requirements to observations and to maintain the system integrity.

way by a well organized implementation structure of researchers. In the southern offshore of the Japanese main land, a project has been initiated to reuse a part of Japanese Information Highway cable [13]. Next generation sensors or array of sensors are also under development in seismology. Some frontier researches are ongoing to reduce the deployment and fabrication cost [14], to enhance the signal detection capability or signal resolution [15], to enhance the spatial coverage by the introduction of fiber optic sensors. These frontier researches are all related to the cable technology which could be introduced in the industry from scientific applications [16].

V. FUTURE DIRECTION

Researchers have been trying to install or to deploy instruments in the ocean to observe phenomena that were left invisible in the long history of human beings. Technologies developed in the telecom industry have been imported to make their dreams come true. Now multidisciplinary observations with much wider spatial coverage are keywords towards the advancement of science. Technologies we reviewed in this paper clearly indicate that the steady development in the industry have supported the observational requirements and we are ready to go into a next step in scientific observations. We hope both scientists and engineers approaches to each other not only for scientific advancements but for future prospect in telecommunication engineering.

Future observations could be supported by a set of oceanic infrastructure such as remotely operated vehicles, autonomous untethered vehicles, moored buoys, observation cables, etc (Fig.3). The communication technologies have been planned to accommodate internet protocol. Altough there are many kinds of hurdles, such as funding, technological limitations, etc., lying in front of the path of development, the direction might be justified.

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