NEW SCIENTIFIC CABLED OBSERVING SYSTEMS: NEPTUNE AND ARENA

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Abstract: Large scale, long term submarine cabled observatory systems represent a new direction for oceanographic research infrastructure. The power and bandwidth of recent generation technology provides several orders of magnitude more capability than has ever been available to the oceanographic research community. Coupled with a multi-decade observing presence, these new capabilities provide an opportunity for a new generation of observing equipment and techniques that will extend our knowledge of basic oceanographic processes. This paper will discuss two major scientific cabled observatories: the NEPTUNE system planned for the Juan de Fuca tectonic plate off the Northwest coast of the United States and Canada and the ARENA system surrounding the Japanese archipelago.

1. INTRODUCTION

Based on recent significant progress in underwater telecommunication technology and other related technologies, and our experiences with early scientific cabled observatories, it has become possible to construct a new generation of scientific cabled observing systems. In this paper, we outline the present technical status of two such scientific cable networks: NEPTUNE and ARENA. Scientific objectives and requirement for these new cable systems are described in the accompanying paper.

2. NEPTUNE

Several projects in the US and Canada, collectively known as NEPTUNE, are currently collaborating to develop a complete system to address the requirements of a regional cabled observatory (Figure 1). The overarching goal is to provide an infrastructure that provides 4D (X, Y, Z and time) observing capabilities for current, next and future generation instruments and experiments. The spatial scales we are designing for range from sub-meter to 100s of kilometers. The time scales we are designing for range from microseconds to 3 decades

Several national and international workshops have been held to develop the top level science requirements for these new cabled systems. A useful technique for helping ocean scientists and engineers to converge on an effective system specification is the development of use scenarios. These scenarios are detailed examples of how the system may be used to support specific current and future generation scientific experiments. One moderately complex use scenario is illustrated in Figure 2. This illustration demonstrates one key difference between a submarine scientific cabled observing system and submarine telecommunication system. A scientific cable system must support bi-directional data communication and deliver substantial power to nodes that may support dozens to hundreds of instruments and measurement platforms on the sea floor and in the water column. Further complicating the design is the fact the power and data delivery needs vary at each node and as a function of time.

The primary consideration in optimizing a design to meet our user requirements is minimizing overall life cycle costs. These systems do not generate a revenue stream and costs are generally fixed by National Science Foundation (NSF) budget requests. In addition, NSF has a substantial investment in UNOLS fleet assets that have the potential for substantially reducing the operation and maintenance fraction of the life cycle costs. There is no doubt in our minds that we cannot hope to match the engineering investment by the

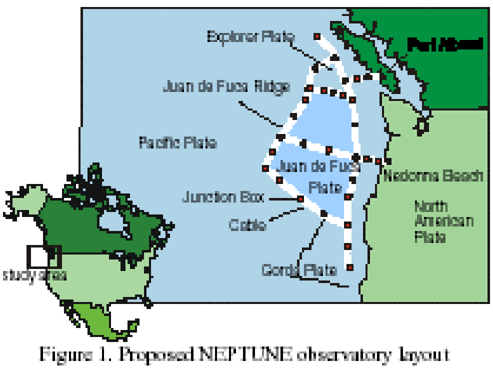

Figure1 Proposed NEPTUNE observatory layout

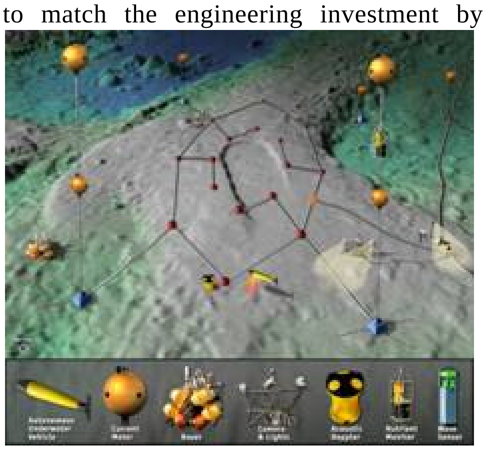

Figure 2. Detailed observatory use scenario

telecommunication industry in developing their current generation systems and we are making every effort to leverage this investment in our system design. We are working with industry partners to use existing cable, terminations, joints, housings and deployment vessels to the greatest extent possible. However, our cost constraints and user requirements have driven us to analyze a variety of additional designs. The current design[1][2][3] provides an 8 Gbit/second data backbone and a power distribution network capable of providing 10 kW peak and 5 kW average power to each of 25 or more science nodes distributed over 3000 km of standard submarine telecommunication cable. Accurate time distribution (of order 1 microsecond) and observatory management functionality are also provided. Particular attention is being paid to ensuring an effective process for developing, installing and obtaining *useful* data from the 100s to 1000s of instruments the design can support.

In addition to the differences between scientific cable systems and telecommunication systems mentioned above, the science sites of interest are distributed over a roughly rectangular region as opposed to a point-to-point topology typical of submarine telecommunication systems. For these and other reasons we were able to consider a mesh topology for our network. Reliability is a driving factor in our design, as in telecommunication system designs, although our reliability requirements are somewhat different. For example, we can survive one or two nodes failing if the rest of the system continues operating. A mesh provides orders of magnitude improvement in reliability by providing multiple paths back to shore from every science node. This allows individual nodes in the mesh to have substantially higher FIT rates than required for series topology telecommunication system where every node on the string must be working for the system to be operational. Fortunately, the requirement for delivering substantial power has driven us to a parallel power delivery architecture that supports the branching required in a mesh without the need for sophisticated electronics.

We evaluated in great detail the benefits of adapting current submarine telecommunication system equipment to our system. Our analysis indicated that the reliability benefits of the mesh topology allow the use of terrestrial networking hardware in the data communication subsystem and still meet our reliability requirements. Although the standard telecommunication system approach had other advantages, the cost did not justify these benefits.

In the United States, the National Science Foundation has selected a bidder to open the Ocean Research Interactive Observatory Networks (ORION) office. The ORION office is tasked with overseeing the specification, engineering, deployment and operation of the next generation of submarine cabled observing systems. The NEPTUNE consortium has spent significant time and energy in understanding the requirements and risks for the next generation of cabled underwater observing systems. We have developed very capable designs for the power and data networks that meet these requirements. These designs are currently being developed into small scale, operational test beds which will be used to develop the tools, techniques and processes required to operate these new observing systems as well as better quantify the risks and costs. However, we fully understand the tremendous range and depth of expertise required to successfully implement large scale systems of this scope and complexity. We are actively developing plans for teaming with qualified industrial partners in order to respond to the opportunities for developing this next generation of cabled ocean observing systems.

3. ARENA

In Japan, eight cabled observation systems[4] have already been constructed and are operating. The main objective of these cable systems are seismological observation as Japanese archipelago is located near plate boundaries where catastrophic earthquakes occur periodically. Recently, the newest cabled pressure meters detected the water depth change of about 40-50 cm due to the earthquake for the first time in the world[5]. This data can be used to study the detailed fault movement near the plate boundary, and shows the importance of cabled observation system.

In 2002, IEEE Ocean Engineering Society Japan Chapter has organized a committee on the underwater cable-network for scientific seafloor monitoring to conducted a feasibility study and proposed a new cable-network called ARENA. Forty-five engineers with various backgrounds from private companies, universities and research institutes participate in the committee. The committee consists of the steering committee, the power feeding working group, the data transmission working group and the underwater system working group. The underwater system working group handled the configuration of the underwater system, reliability, construction and maintenance. The results of the feasibility study are published as technical white papers[6].

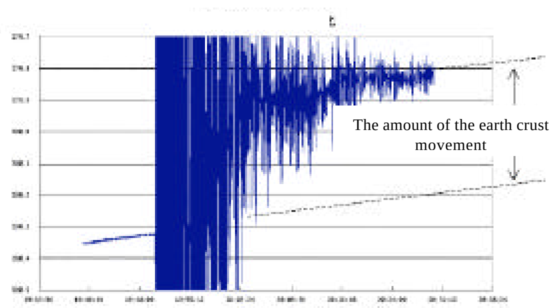

Figure 3 Movement of the earth crust detected with a pressure gauge attached to a scientific underwater cable.

Figure 4 depicts the image of ARENA. Although the major object for the previous Japanese cabled observation systems was seismology, the ARENA will

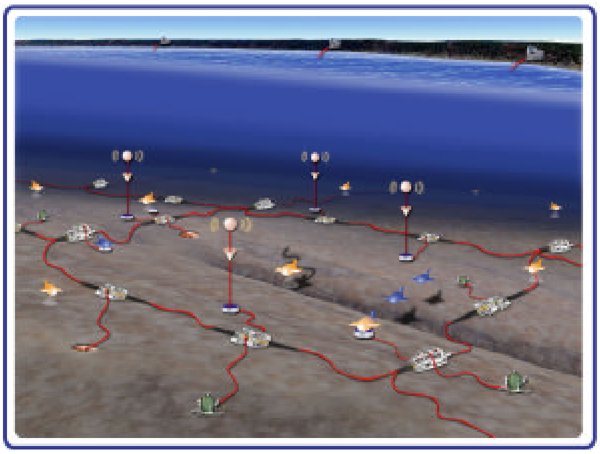

Figure 4 Illustration of ARENA

be used multidisciplinary as described in the accompanying paper. Many kinds of sensors are connected to the underwater cable network. As the cable-network has a mesh-like topology, many sensors are deployed three-dimensionally in a vast research area and provide longterm continuous data, which can otherwise hardly available. As the sensors are connected to the backbone cable through underwater mateable connectors, they can be retrieved for maintenance. As the cable-network has plural landing stations and a mesh-like topology, even if the cable breaks in a certain section, the power and the communication line will be re-routed and it can continue the operation. This feature is important to increase the reliability of the system, and ensure the operation even if the cable-network is damaged by disasters such as large earthquakes.

Figure 5 is an envisioned future network of ARENA. The network surrounds the Japanese archipelago. Off the coast of Sanriku, two backbone cables are placed on

Figure 5 Envisioned future cable network of ARENA

the both side of plate boundary.

The most challenging technical issue is power feeding. In the feasibility study, ARENA committee compared three power feeding methods and selected the constant current power feeding system as the most promising one. Although the constant power feeding system is commonly used in underwater telecommunication systems, and many advantages such as robustness against cable shunt fault, there was no device to divide a constant current into two constant currents. The ARENA committee proposed a new current to current converter[7] that is the key device for a mesh-like cable-network with constant current power feeding system. Some of the authors developed a prototype of the converter and showed with experiments and computer simulations that the proposed converter works well and has high conversion efficiency. It was confirmed that a mesh-like cable-work could be constructed by using converters.

Now, some further basic studies on the power feeding system and data transmission system are ongoing to realize a scientific cable-network of next-generation.

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