Abstracts on the topic of Cabled Ocean Observatories submitted for

SubOptic 2004

Monaco

29 March – 1 April 2004

A New Challenge and Opportunity for the Submarine Telecommunications Industry – Ocean Observatory Networks
Alan Chave, Gary Waterworth, Antoine Lecroart , Hitoshi Mikada, Gene Massion, Imants Priede, and Martin Solan.

Science Requirements as the Design Drivers for Cabled Ocean Observatories
Alan D. Chave, Hitoshi Mikada, and Eugene Massion

Proposal of new multi-disciplinary scientific underwater cable network in Japan: ARENA
Kenichi Asakawa, Yuichi Shirasaki, Minoru Yoshida, Takao Nishida, Katsuyoshi Kawaguchi, Hitoshi Mikada, and members of ARENA committee

Design of the NEPTUNE Submarine Cabled Observatory System for Oceanographic Research
Gene Massion, Alan D. Chave, Bruce Howe, Tim McGinnis, Peter Phibbs, Dave Rodgers

Scientific Reuse of Optical Underwater Telecommunication Cables
Junzo Kasahara, Hitoshi Mikada and Kenichi Asakawa (Tentative; some co-authors from USA, Europe, and Japan will be added in the final paper)

Ocean Observatory Science Interfaces
Peter Yinger and Art Ayres

When is a cable system really dead? (What to do with a cable as it gets old)
Peter Yinger, William Marshall, Tony Frisch

A New Challenge and Opportunity for the Submarine Telecommunications Industry – Ocean Observatory Networks

Alan Chave [3], Gary Waterworth[1], Antoine Lecroart [1], Hitoshi Mikada[2], Gene Massion [4], Imants Priede[5] and Martin Solan[5].
1) Alcatel, 2) Japan Marine Science and Technology Center, JAPAN, 3) Woods Hole Oceanographic Institution, USA, 4) Monterey Bay Aquarium Research Institute, USA, 5) University of Aberdeen, Oceanlab, UK

Volta and Galvani discovered the fundamentals of electricity, Newton derived the laws of gravitation and motion, Faraday and Maxwell uncovered electromagnetism, and then Einstein announced the theory of relativity. Are there any new fields of discovery left for the modern day scientists?

Ocean scientists have been studying the deep waters that surround us for many years; mapping out the sea floor, taking samples and measurements during cruises aboard specialist research vessels. They have now started to make the transition from this initial *exploration* phase to the *understanding* phase, where a permanent presence on the sea floor is required to monitor both sporadic short-term events such as earthquakes and long-term trends such as global warming.

Geophysicists want to monitor oceanic plate deformation patterns, submarine slides and volcanic eruptions; biologists want to search for new forms of life and study the migration of fish stocks and marine mammals; and ecologists want to study the effects of temperature change and the deep sea environment. These multidisciplinary projects require the long-term flow of reliable, high quality and timely data from sea bottom instruments to the scientists ashore and the supply of electrical power and command data to the submerged equipment. For some disciplines, networks of instruments are required with real time data available to the extended science community worldwide via the Internet.

A few successful attempts have been made to observe isolated deep-sea phenomena using out-of-service analogue cables. In 1997 a geophysical ocean bottom observatory was inserted into the Guam-Ninomiya section of TPC-1 and in 1998 a sea floor observatory, H2O, was installed in the Hawaii-2 cable. Following on this success, scores of academic institutes from Europe, Japan and North America are attempting to establish large and small-scale permanent observatories on the seabed. Numerous large and highly reliable undersea meshed networks are envisaged where several thousand kilometers of submarine cable link sea bottom nodes and arrays with power and communications. Smaller coordinated networks of short and long term sea floor observatories are also being planned.

The decommissioning of the first generation of regenerative optical systems such as TAT-8 to TAT-11 and TPC-3 & 4 might provide suitable infrastructure for observatories far out to sea in the Atlantic and Pacific oceans. These potential gifts have to be studied quickly before the opportunity is lost. The proposal that the ocean science community and submarine cable owners work together preparing for the seamless hand over of future retired systems is discussed.

Finally we re-introduce the concept that future generations of submarine cable systems could be built with pre-installed access nodes to allow for science observatories to be connected while the cable is carrying commercial traffic, without effecting the transmission quality or system reliability.

Science Requirements as the Design Drivers for Cabled Ocean Observatories

Alan D. Chave (Deep Submergence Laboratory, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA)
Hitoshi Mikada (Deep Sea Research Department, Japan Marine Science and Technology Center, Yokosuka, Kanagawa 237-0061, Japan)
Eugene Massion (Monterey Bay Aquarium Research Institute, 7700 Sandholt Rd, Moss Landing, CA 95039, USA)

The study of the dynamic, interactive processes that comprise the earth-ocean system requires new approaches that complement the traditional ship-based expeditionary mode that has dominated oceanography for the past century or more. Long-term access to the ocean is needed to characterize the diverse range of spatial and temporal scales over which natural phenomena occur. This can be facilitated using a seafloor-based cabled ocean observatory infrastructure containing many seafloor science nodes to provide power and two-way communications for distributed realtime sensor networks covering large areas.

The telecommunications market place has driven the functional requirements for submarine systems toward very high data rate data links implemented with comparatively simple, very high reliability wet plant. Electronic complexity is concentrated at a few terrestrial sites. Combined with advances in submarine cable installation, the result is an extremely reliable seafloor communications infrastructure.

The functional requirements which drive ocean observatory design differ from those for conventional submarine telecommunications systems in several key respects. First, ocean observatories require data to be input and output (i.e., switched and aggregated) at many seafloor nodes rather than at a few land terminuses. Second, ocean observatories must distribute a lot of power (5-10 kW per node) to the seafloor at variable and fluctuating rates for both seafloor instruments and internal systems. Third, science requires the delivery of accurate (1μs in an absolute sense) time to the seafloor nodes. Fourth, the seafloor infrastructure for an ocean observatory is inherently dynamic, and hence the wet plant has to be expandable and reconfigurable to meet changing science needs. Finally, because the wet communications and power infrastructure is comparatively complex, ocean observatory infrastructure must be designed for low cost maintainence and upgradeability.

Despite these differences, a key design driver in ocean observatory design is reliability. The primary reliability measure is the probability that data will be received on shore from a given science instrument on the seafloor. The least reliable infrastructure components in this path inevitably are the node power and communications electronics. An immediate corrollary is that there may be no reliability gain from combining high reliability submarine telecommunications wet plant with node electronic systems, and hence the design of ocean observatories will be fundamentally different from that of submarine telecommunications systems.

This paper will define the design differences between submarine telecommunication and ocean observatory systems and attempt to predict where the market opportunities for the submarine community lie and don t lie.

Proposal of new multi-disciplinary scientific underwater cable network in Japan: ARENA

Kenichi Asakawa, Yuichi Shirasaki, Minoru Yoshida, Takao Nishida, Katsuyoshi Kawaguchi, Hitoshi Mikada and members of ARENA committee

Subject: Market Place
Preferred choice: Oral Presentation

Scientific underwater cable systems draw attentions of many scientists as they can provide continuous long-term data in real-time that otherwise can hardly be obtained. These data are essential to study the globe dynamics, seismology and mitigation of disasters, long-term variation of marine environment and climate, marine organism, ecology, marine microbes, etc.

In Japan, several scientific underwater cable systems have already been constructed and been working. The objective of most of these systems is monitoring of earthquakes, as Japan is located near plate boundaries where massive earthquakes periodically occur. The ocean-bottom seismometers connected to underwater cables have contributed to the progress in seismology, because they can detect micro earthquakes that can not be detected with land-based seismometers, and heighten the accuracy of localization of earthquake-hypocenters.

Recent evolution in underwater telecommunication cable technology, especially WDM, optical amplifier, and other related technologies including Internet and computer communication made it possible to develop a versatile and flexible scientific underwater cable network of the next generation.

Based on the previous accomplishment of the scientific underwater cables and evolution in underwater telecommunication cable technology, some regional scale projects on scientific underwater cables have been proposed in USA and Canada (NEPTUNE), Europe (ESONET) and Japan (ARENA).

The ARENA was proposed by a technical committee organized by IEEE OES (Institute of Electrical and Electronics Engineers Oceanic Engineering Society) Japan Chapter. Forty five Engineers from universities, research institute and private companies took part in the committee and conducted the technical feasibility study. The objective of ARENA is to provide an interdisciplinary infrastructure for scientific research and observations. It is an open system to which any researcher can take part in and can connect his/her instrument to the cable system.

Although cable systems have been developed based on the underwater telecommunication cable technology, the concept of ARENA is slightly differing from the past conventional system. The most outstanding feature of ARENA is that it has mesh-like cable configuration that enables the deployment of two-dimensional underwater observatories in vast research area across plate boundaries. In order to realize this configuration, a design of new power feeding system has become indispensable. One of the other features is that the source of information is phenomenal and originating on the sea bottom. Therefore laser diodes or optical modulators should be installed in underwater housings. The other features includes (1) more than 3,000km total cable length, (2) over 66 observation nodes with 50km interval, (3) system expandability, (4) exchangeability of sensors for maintenance, (5) conformity with Internet.

This paper will describe the role of the scientific underwater cable system, its historical background, the outline of the results of the feasibility study, and some preliminary works on the power feeding system.

Design of the NEPTUNE Submarine Cabled Observatory System for Oceanographic Research

Gene Massion (Monterey Bay Aquarium Research Institute, Moss Landing, CA 95039, USA)
Alan D. Chave (Deep Submergence Laboratory, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA)
Bruce Howe (Applied Physics Laboratory University of Washington, Seattle, WA 98105, USA)
Tim McGinnis (Applied Physics Laboratory University of Washington, Seattle, WA 98105, USA)
Peter Phibbs (Mallin Consultants Ltd., Vancouver, British Columbia, Canada)
Dave Rodgers (Jet Propulsion Laboratory, Pasadena, CA 91109, USA)

Large scale, long term submarine cabled observatory systems represent a new direction for oceanographic research infrastructure. The power and bandwidth delivery capabilities of recent generation technology provide several orders of magnitude more capability than has ever been available to the oceanographic research community. Coupled with a multi-decade long 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. Several relatively small coastal observatories have been put into service in recent years and planning and design of larger scale observatories is well underway. This paper will discuss the NEPTUNE regional scale cabled observatory system currently being designed for deployment on the Juan de Fuca (JdF) tectonic plate off the Northwest coast of the United States and Canada. The system consists of roughly 3000 km of cable interconnecting 20-30 nodes at specific sites of scientific interest on and around the JdF plate. The system can support nodes from the coast to the deepest section of the plate in about 4000 meters of water. The system provides a data network capable of providing up to 8 Gbits/second of data telemetry, a power network capable of delivering an average of 5 kW to all nodes and a time distribution system capable of providing absolute time with an accuracy goal of 1 microsecond. While the data network provides modest capabilities relative to current generation telecommunication designs, the power network uses a novel parallel DC design and this combination of data, power and timing capability provide unprecedented opportunities for oceanographic researchers. We will discuss how the science requirements described in a companion paper drive the proposed design, the current state of the design and the associated smaller scale test beds along with the risk mitigation efforts taken to date and planned for the future. The differences between a research observatory system and a submarine telecommunications system will be highlighted. In addition, we will describe the opportunities for industry involvement in the design, manufacture, deployment and operation of the system.

Scientific Reuse of Optical Underwater Telecommunication Cables

Junzo Kasahara, Hitoshi Mikada and Kenichi Asakawa (Tentative; some co-authors from USA , Europe and Japan will be added in the final paper)

Subject: Market Place
Preferred choice: Oral Presentation

Some commercially retired underwater telecommunication cables have played important roles for the scientific studies. In TPC-1, TPC-2 and Hawaii-2, commercially retired coaxial cables, junction boxes were installed to which several instrumental packages were connected. These instruments receive electric power and continuously send the real-time data to laboratories on shore. Some other cables have been used to estimate the electrical conductivity structure of the Earth and the ocean current by monitoring the induced voltage on long-haul underwater cables.

These days, some of the optical cables of the first generation are going to be decommissioned due to the rapid technical revolution of sub-optic technologies. As the data transmission capacity and the power feeding current of the optical cables going to retire is larger than that of the coaxial cables, these cables will be able to accommodate more underwater junction boxes and sensors than the coaxial cables. Some optical cables cover the area where the previous cables did not cover. These cables will provide a new and greater opportunity than the previous cables did to scientists.

There are many scientific fields in which commercially retired cable can be used other than monitoring of the ocean current and the inner structure of the Earth. As Japan is located near plate boundaries where catastrophic earthquakes periodically occur, seismological study in the ocean is extremely important. The ocean-bottom seismometers connected to underwater cables contributes to the progress in seismology, because they can detect numerous micro earthquakes and long-distance earthquakes that can not be detected with land-based seismometers, and heighten the accuracy of localization of earthquake-hypocenters and filling the gap of data on the globe. The sensors such as acoustic current meters and transducers for acoustic tomography combined with induced voltage measurements will clarify the ocean circulation that has great influence on the earth climate. TV cameras will reveal the ecology of deep-sea inhabitants. Hydrophone arrays connected to cables will monitor submarine volcanic eruptions and sounds of large marine mammals that are at the top of food chain and can be used as a measure of the healthy of the ocean.

In order to utilize the opportunity and promote scientific studies, new technical developments are needed and collaboration between engineers and scientists is essential. In this paper, after some previous accomplishment using commercially retired cables are overviewed, some other usage and its importance will be presented.

Ocean Observatory Science Interfaces

Peter Yinger and Art Ayres, Nautronix-Maripro, Santa Barbara, California

Subject: Network Architecture and Design

Ocean Observatories provide a growing application for undersea telecommunication components. This includes the reuse of abandoned telecommunications cables and the design, fabrication and installation of new systems. Some of the proposed observatories, such as Neptune, are major installations. These systems provide power to and data from science nodes connected to a telecommunications cable. The inclusion of power distribution and diverse data sources (science nodes) that will add/drop data at multiple in-water locations is a significant variation from standard telecommunication practice where data and power is transported from shore to shore. A wide range of instrumentation is required in order to sense physical phenomena as diverse as biology, physical oceanography or seismology. Signal bandwidths range from DC to megahertz. Some of these sensors are electrically connected to the sea that includes the return current for overall system power. All of these transducers have input voltage levels in the micro to nanovolt range. The challenge to the system designer is to provide power and data in the cable trunk compatible with the sensor inputs. This paper survey's the typical types of instrumentation the Observatory designer must consider. For each instrument class, representative signal levels, impedance and frequency at the input to the first amplifier and parasitic path impedance from sea to the input are presented. Examples are given for several typical operational systems. The use of this data is essential to the selection of electrical frequencies and waveforms used in analog to digital conversion, data formatting and power conversion in the branching and science nodes and levels of filtration in the local power supplies to prevent contamination of the science data.

When is a cable system really dead? (What to do with a cable as it gets old)

Peter Yinger (1), William Marshall (2), Tony Frisch (2)

(1) NAUTRONIX MariPro, INC
(2) Alcatel Submarine Networks

At one time a cable died when its relatively low traffic volume represented only a small fraction of that of a younger cable and it became more economic to transfer the traffic and remove the old cable from maintenance. In the past "dead" cables would be left to rest in peace, but with today's market strongly focused on economics, and relatively easy availability of cable ships, it makes sense to ask if the cable still has some value, either for recovery, or for re-use.

In the case of recovery, the value could be in re-cycling the cable materials, but the cost of recovery can be high, depending on where the cable is, where it is buried etc. In general the economics are against recovery, but occasionally a cable cannot be left in place because of the potential hazard it could pose - for example the potential for a fishing vessel experiencing problems after snagging a cable - and recovery is driven by the need to remove/reduce a liability.

Even when a cable appears dead, it may still have some value in a different application, and with the high quality of construction, cables can easily live up to their 25 year design life. For many years, the scientific and military communities have utilized retired analog and digital cable systems, to support monitoring and data transport tasks. Cables have been employed as trunks for sensor systems such as current meters, seismic monitors and tsunami warning systems. A key issue when using cable in this manner is the requirement for specialized expertise in the jointing of legacy cables often to custom terminations or connectors. Further the marine component required for these programs, can be different from standard telecom installation practices and procedures often requiring specialized handing equipment for both cable recovery and sensor/system interfacing.

Another example of re-use is where the configuration of a cable is changed to modify the traffic distribution, or to create a new route. The incentive is that a "dead" cable may be purchased for very little and the major cost is that of re-configuration, or recovery and re-deployment. The second case is both more costly and also poses greater risks, particularly where buried cable is involved. It's also worth noting that older cables are, in general, limited in terms of their capacity - although this isn't necessarily a blocking factor.

Finally, there have been cases where resurrection has been considered. Here the idea is that a cable system might be saved by a component transplant. Lab experiments have shown that the addition of specialised equalisers can extend the bandwidth, and the more radical (and complex) option of replacing all the repeaters has also been considered. The marine operations involved in adding new elements to a system, or replacing existing ones, represent a very significant cost element. Also there a number of technical issues in mixing different generations of technology.

The paper will address all these possibilities focusing on practical and economic issues.