TO BOLDLY GO WHERE NO SYSTEM HAS GONE BEFORE

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Abstract: Cabled Ocean Observatories are being developed around the world by science and engineering teams. These observatories will transform the way traditional ocean science is conducted with data now being available in continuous streams and in real time. Ocean science will no longer be solely dependant on ship availability and weather windows.

Projects such as the NEPTUNE Canada Cabled Ocean Observatory required an innovative approach to the marine engineering and planning of the network infrastructure.

As the network layout was driven by the research themes selected by ocean scientists, the challenge was to deliver a network that provided reliable power and data transmission to some of the harshest environments on the northern Juan de Fuca plate.

This paper outlines how the marine teams from the University of Victoria and Alcatel Lucent approached the challenge of the NEPTUNE Canada route and developed new tools to manage the data and engineering process.

1 INTRODUCTION

The way we view and study our oceans will forever be transformed by the construction of Cabled Ocean Observatories (COO). These observatories will allow scientists to study the ocean as never before, in real time and uninterrupted by weather window requirements and ship availability.

One such COO is the University of Victoria's NEPTUNE Canada Cabled Ocean Observatory (Figure 1). NEPTUNE Canada is a combined effort of twelve major Universities in Canada of which the University of Victoria (Uvic) is the lead. As such, UVic was tasked with the challenge of developing the worlds first real time cabled ocean observatory and appointed Alcatel Lucent (with its co-contractor L3-Maripro) to support this task.

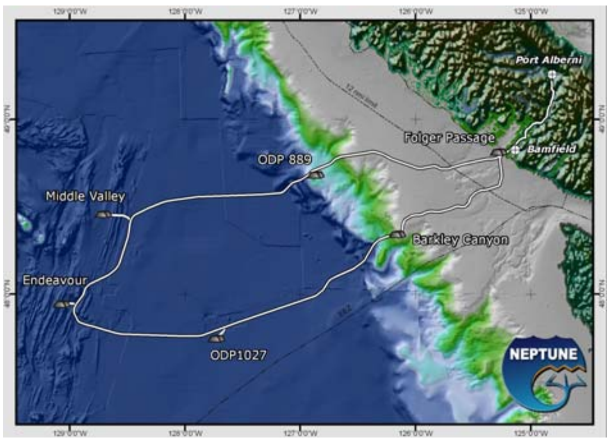

Figure 1. NEPTUNE Canada Cabled Ocean Observatory Proposed System Layout

The design of NEPTUNE Canada was driven by the scientific objectives identified and selected by teams of scientists from Canada, the United States and Europe. These science themes include; the structure and seismic behaviour of the ocean crust, seabed chemistry and geology, ocean climate change and its effects on marine life at all depths, the diversity of deep sea ecosystems and engineering and computational research.

In order to fully develop the NEPTUNE Canada science themes the limits of traditional telecommunications network design had to be pushed, as the locations of interest tend to be in regions that traditional telecom networks strive to avoid. These high-risk environments include hydrothermal vents, active submarine canyons, tectonically active spreading centres and areas of heavy fishing activity.

NEPTUNE Canada will be one of the first networks capable of providing real time information from multiple sites without present bandwidth, power, depth and time constraints, as it is designed around the use of optical fibre submarine cable technology rather than satellite imagery or instrumented moorings.

Just as the sites of scientific interest will push the boundaries of network design the development of a reliable and robust observatory has pushed the boundaries of traditional cable route surveys and route engineering.

2 GEOGRAPHIC SETTINGS AND CHALLENGES

NEPTUNE Canada is heading directly to some of the harshest and most unforgiving areas on the northern Juan de Fuca plate. The geographic considerations faced by the engineering teams of NEPTUNE Canada and Alcatel Lucent included the Cascadia Subduction Zone, Endeavour Ridge spreading centre, Endeavour hydrothermal vents and active submarine canyon and gas hydrate outcrops.

The sites proposed for instrumentation are:

- Folger Passage – a shallow water site in Barkley Sound,
- ODP 889 - a cold vent site with subsurface gas hydrates,
- Middle Valley – an area with hydrothermal discharge through a thick sedimentary cover over a spreading ridge,
- Endeavour Ridge – an extremely active spreading centre with hydrothermal vents,
- ODP 1027 – on the ridge flank of with a basement rock outcrop and subsurface ridge features, and
- Barkley Canyon – a heavily fished active submarine canyon.

All of these sites, except Middle Valley, are to receive instrumentation on the initial system roll-out.

As illustrated in Figure 1 the network cables will be surfaced laid down Alberni Inlet due to the numerous out of service cables within the inlet that make burial impossible. Burial will commence as the two legs exit Barkley Sound. Both cables cross the continental shelf crossing through a series of mud filled troughs (*Bornhold & Barrie, 1981*), of which the banks are highly productive fishing grounds. The southern leg upon turning south prior to entering the troughs crosses several kilometres of active sand waves, which may cause difficulties for burial. The northern leg crosses La Perouse Bank, which is also heavily fished, and runs down the continental margin to the ODP 889 site. As the cables cross down the continental slope they will traverse ridges that result from the active movement of the Cascadia Subduction Zone. The northern cable crosses the abyssal plain to the Middle Valley site and south to the Endeavour Ridge. The cable will then turn east crossing out of the Ridge Flank back into the sedimented Abyssal plain to the ODP 1027 site, and back to the continental slope at the foot of Barkley Canyon. Installation at Barkley Canyon will be up slope due to the significant slope challenges presented by the surface features of the Cascadia Subduction Zone.

3 NETWORK DEVELOPMENT AND SECURITY

The NEPTUNE Canada network design marries traditional submarine cable system elements, such as optical fibre submarine cable, repeaters and branching units, together with specialised node assemblies. These nodes act as hubs to which the nearby scientific instruments, or those further afield, will be connected to the network.

In view of the complexity of the seabed conditions at each node site and the associated risks, a ring network approach was selected to achieve maximum network security in a cost-effective manner. This approach allows key network elements, such as branching units and nodes, to be positioned as close as possible to areas of scientific interest with minimum hazard and within the boundaries of network requirements. In doing so, each scientific site is isolated from events elsewhere, which aids in maintenance as well as system upgrade. Situating the nodes in relatively benign areas also provides easier access for operations and maintenance of the system, such as node repair, removal and extension cable connection.

The science nodes comprise of a base frame into which the node module is freely housed. For ease of maintenance the node modules are designed to be removable by an ROV, to decouple connectors and free the node. Underwater wet-mateable connectors provide the connectivity between the cable and node and for extensions to be connected in-situ. The base frame contains a cable terminating assembly to provide the optical/electrical interface between shore and the node. The base frames are designed to be semi-permanent and can be recovered if necessary.

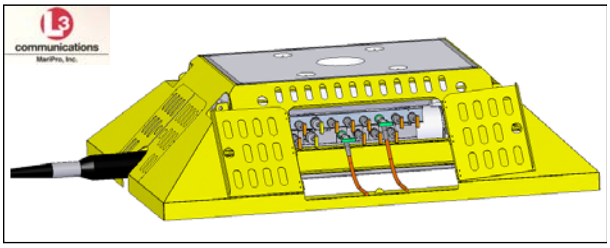

Figure 2. Trawl Resistance Frame (TRF)

Whatever the design, the large and generally heavy base frame needs to be installed in an attitude that allows unrestricted node access and maintenance. Specifically, the base frame needs to lay relatively flat on the seabed and remain like that without undue sinkage.

The main ring route, branching unit locations, spur cable routes and instrumentation sites and routes also need to be considered in parallel, taking into account network power/transmission requirements. Wherever possible the aim is to provide as flat an approach to each site as possible, to minimize the potential of cable suspensions, maximize potential burial and reduce overall risk to these cables.

Installation, maintenance and system upgrade-ability must also be taken into account. This includes, for example, the location of any deployment/recovery ropes used, as well as node position and orientation for potentially new/amended scientific sites.

The quantity of survey data needed to address all such aspects optimally is beyond normal survey demands considering the terrain and water depths involved. A different survey approach was therefore necessary, focusing on utilizing the vast scientific data already available and supplementing data only where necessary.

4 ROUTE SURVEY DEVELOPMENT AND OPTIMIZATION

The 850 KM NEPTUNE Canada route surrounds the northern Juan de Fuca plate and the western edge of the North American plate. Of the 850 kilometres involved approximately 380 kilometres had been previously surveyed to varying standards and with varying resolutions (Figure 3). In order to meet the increased survey needs NEPTUNE Canada reached out to other educational institutions and government agencies to provide existing data and for support in the collection of new data.

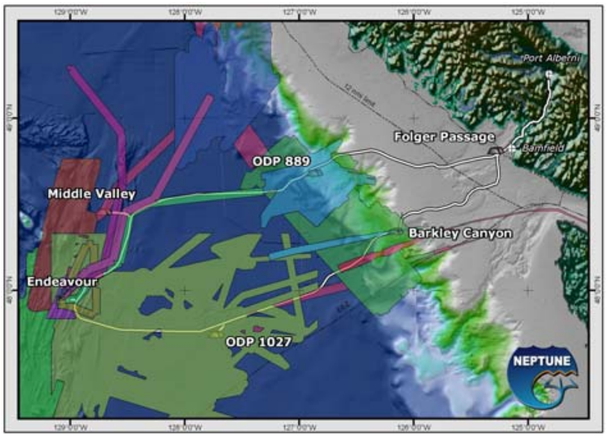

Figure 3. Outline of Existing Survey Data Sets

The data sets combined and developed for NEPTUNE Canada include traditional ship based acoustic surveys using a variety of generations of multibeam systems, core, CPT and grab data (up to 30 years old), remotely operated vehicle (ROV) videos, scanning sonar data and sampling, AUV sonar data, sub bottom and sidescan data as well as considerable data from scientific research publications.

Expecting the route engineers to be able to review and use all this amount of data in native form was considered too time consuming and challenging. All of these differing sources needed to be combined into a single easy-to-use access point, to provide the engineering team with the strongest set of resources to determine the best cable route possible. A Geographic Information System (GIS) platform was therefore adopted.

This GIS platform allowed for the integration of older paper based data sets, previously collected sediment samples and data from research papers such as geological maps, fishing zones, Ocean Drilling Program sites, Geological Survey of Canada sample cores, Environment Canada ocean disposal sites, KECK Foundation Seismometer sites and many other supplemental geographic data sets.

The initial route was selected to meet the science requirements using existing survey data compiled by NEPTUNE Canada. The principal source for the shallow water route were paper charts from a Geological Survey of Canada map series (Conway et al., nd) and a research paper on Surficial Sediments on the Western Canadian Continental Shelf (Bornhold & Barrie, 1981).

These and other applicable maps were scanned and digitally stretched as necessary to overcome any print/scan induced errors. Viewing this data together with bathymetric data and hydrographic charts allowed the selection of a highly optimized pre-survey route tailored to suit NEPTUNE Canada.

Once all the existing data was on layers in the GIS system, the gaps in the data could be easily identified and the survey efforts and methods optimized based on the level of risk associated with installation, operations and maintenance. For example the team decided that installation within the Endeavour Ridge would require multibeam data with greater resolution than the 50 metre grid that was in existence. High resolution data was needed with a resolution of approximately 1 metre. Similarly, there was a concern about the relative stiffness of the sediments and their ability to support the node at the ODP 1027 site. Therefore sediment samples were required to confirm the seafloor conditions.

With the gaps in the existing survey identified and requirements of additional survey outlined, resources were sourced to complete the additional survey. The shallow water bathymetric and burial assessment survey utilized traditional survey tools; towed side scan sonar, towed sub bottom profiler, hull mounted multibeam, gravity cores and CPT's.

Other Institutions and Agencies were approached with requests for assistance for the collection of the survey data deeper than 200 meters. In good cooperation with the University of Washington, MBARI, WHOI and the Canadian Coast Guard most of the deep water and supplemental shallow water survey data was collected. These data sets included hull mounted multibeam, high resolution AUV multibeam, AUV sidescan and sub bottom data, push cores and digital video.

Survey data was also required to collect specific details about each science site, such as the sediment properties, in order to assist in the design of specific network components such as trawl resistant frames and their ability to resist sinking into areas of heavy sedimentation. This data was also utilized to determine the location of the individual science instruments. For example an instrumented crawler needing to be within tens of metres of rock outcrops, to study gas hydrate outcrops, can at the same time provide invaluable video and scanning sonar data.

The result of fully evaluating the existing survey data and defining the remaining gaps was that the project-specific survey needs were substantially reduced in scope, as they were limited to solely supplementing outstanding data and addressing areas of particular interest.

In this way the NEPTUNE Canada survey requirements became manageable in a timely and cost-effective manner. This was also in no small part due to the tailored GIS data management scheme employed.

5 AN INNOVATIVE APPROACH TO DATA MANAGEMENT

Traditional submarine system data management techniques (paper/file) are efficient in handling survey data from approved resources on a line basis. However, the area needs for COOs and the quantity of data that can now be sourced through survey, supportive groups and the Internet should not be underestimated, nor the handling problems that this can cause. Data between multiple sources will also range widely in its processing, collection, quality and resolution. A reliable means of sorting, storing and viewing such vast information is essential, not only for immediate use but also for the ongoing operational and development requirements of the network.

As NEPTUNE Canada had already adopted a GIS programme to meet its long-term objectives, an innovative approach utilizing the GIS for survey data was developed. Traditional paper based route working groups were replaced with interactive meetings where route changes were made real-time as the team of engineers viewed in tandem sidescan mosaics, sediment and sub surface interpretations, sub-bottom profiles, ROV videos and sector scanning sonar files. These interactive route working group meetings resulted in increased efficiency in data review, reduced manual input of route engineering changes and increased ability to make confident decisions with regards to cable engineering.

6 COLLABORATIVE & REAL TIME ROUTE ENGINEERING

Traditional route working groups tend to work off interpretations of the data overlaid on alignment charts. Working from raw data sets (especially when these sets include non-traditional data such as old paper charts, video and scanning sonar) would be impossibly time consuming using the traditional approach.

In this case, since all the data, both raw and interpreted, was available and visible through a single GIS portal, route engineers could look at the raw data where the interpretation was unclear or suspect. They could also zoom in and out to get a big picture view before looking for ways around a local feature, such as when determining the route up near Barkley Canyon (Figure 4). They could also refer instantly to ROV video when they needed confirmation of the acoustic record.

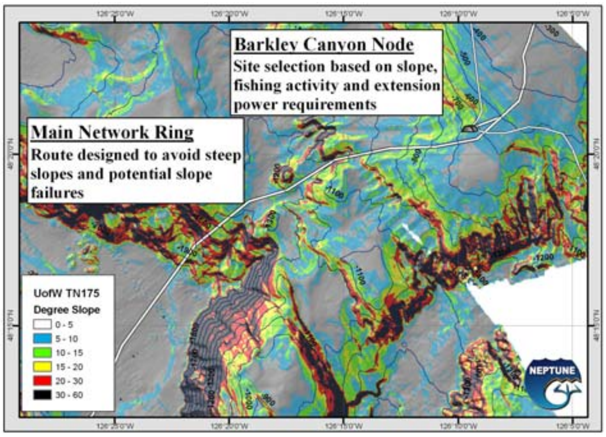

Figure 4. Slope Map Utilized near Barkley Canyon

This unprecedented access to route data allowed the team to fine-tune the extent of ploughing without undue risk. It also allowed the engineers to find and confirm a path through a sandwave field using ROV video and scanning sonar record. Additionally it removed much of the guesswork involved in the interpretation of acoustic records.

The GIS platform was not developed solely for the route engineering; it was (and still is) utilized by NEPTUNE Canada as the main tool for engineering layout and geographic tracking of instrument and extension placement. The use of digital databases to integrate these datasets also provided a means of readily updating the information as the project progressed and/or changes made. The GIS allowed for remote correspondence between Alcatel Lucent and NEPTUNE Canada with regards to potential route changes as geographic databases are easily transmitted by email.

7 THE FIRST STEPS

Validation of the GIS platform’s effectiveness was first seen in a TRF installation trial in Q3 2006, carried out in some 200 metres water depth on La Perouse Bank near the NEPTUNE Canada route. ROV inspection of the test TRF found that its as-laid attitude and seabed penetration were as expected in the soft clay/silt sediments (as CPT data for site known).

8 INTO THE FUTURE

The traditional approach to route engineering using paper charts could not have coped with the variety of data forms available to NEPTUNE Canada. The security of the route selected by Alcatel Lucent for NEPTUNE Canada was significantly improved by giving the route engineers not only easy access to all of the data sets, but the ability to manipulate them and the cable route in real time. Such access was only possible by presenting the data through a GIS system.

This innovative approach developed for the NEPTUNE Canada project has benefits and impacts that reach beyond the immediate engineering requirements of the project. The database now in existence is used to document and control instrument locations, to calculate length of extension cables required, and has played an important role in the consultations with the fishing industry. In a telecom scenario it could be used to track product data, serial numbers, cable types and lengths, repair data, and all the survey and inspection data.

NEPTUNE Canada will continue to use and improve the database for eventual adoption by scientists in support of their science objectives. The GIS will also be a critical tool for the operations and maintenance of the network.

This new approach reaches beyond the needs of NEPTUNE Canada; owners of telecom networks can utilize similar methodologies developed to optimize their surveys, fully document the resulting cable route survey and maintain maintenance records of their system. Complete data to investigate cable faults can be made accessible through any computer, rather than requiring trips to the document storage room to find charts and manufacturing, installation, survey and inspection data.

Cable Suppliers could benefit from the developed tools in that they should provide opportunities to engineer cable routes quicker, for easier manufacture and billing integration.

Other Science Observatories around the world may consider the benefit of following the GIS approach to planning their networks. GIS would allow them to build upon the wealth of knowledge available in their own science communities, who are deeply invested in the success of these projects and augment the wealth of data that will be collected by the observatory.

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