Ship To Shore: ROV Dive Logging and Data Acquisition

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***Abstract*—The Observatory Operations Division at Ocean Networks Canada (ONC) is responsible for the maintenance and operation of the entire digital and marine infrastructure across the VENUS, NEPTUNE, and Cambridge Bay facilities. Depending on planned work, environment and scheduling limitations, various ships and Remotely Operated Vehicles (ROVs) are contracted for the numerous expeditions conducted each year. For instance, during August and September 2015, ONC will be conducting four major expeditions concurrently with multiple ships (EV Nautilus, RV Thomas G. Thompson) and ROVs (Hercules, Argus, Jason/Medea) in the North East Pacific, divers in Cambridge Bay, and a 24 hour shore support centre. This paper focusses on the enabling digital infrastructure that is serving to streamline ROV data acquisition, enhance shore support and multi-vessel expeditions, and enable derivative applications and outreach initiatives.**

ROV instrumentation commonly includes video cameras, digital still cameras, navigational sensors, scientific sensors (e.g., CTDs, oxygen sensors) and sonar. Leveraging high-bandwidth satellite communications, ONC has developed a ship-based version of Oceans 2.0 that interfaces with selected ROV instrumentation and data streams for data collection, parsing and viewing purposes on the ship. It also transmits that data to shore where it is automatically integrated into the main ONC data repository and instantly available to anyone via ONC's data distribution platforms. High resolution video is typically archived on the ship (and archived on shore post-cruise), while lower resolution video is streamed to shore to be recorded, archived and made available through SeaTube in Oceans 2.0. In the last 2 years, ONC has started to incorporate audio into the video streams and recordings that capture the dialog between ROV operators, ONC staff and other participants. This networked ship to shore data acquisition approach streamlines the data archival process and allows shore-based personnel and scientists to engage in cruise activities.

In conjunction with specialized Oceans 2.0 modules and an audio communication system, these high-bandwidth communications and transmitted data streams also enhance shore support capabilities. ONC has recognized this as an opportunity to conduct dive logging operations from shore and to include participants whose guidance is needed for specific operations, reducing the burden of limited ship berths. The two-way audio communication system permits dive loggers to engage with ROV operators and the dive chief almost as if they were on the ship. The SeaScribe dive logging annotation module, first developed by ONC in 2013 and presented at Oceans '13 in San Diego, has recently been extended to support annotations on up to 10 servers on multiple vessels simultaneously. Annotations are synced from one server to another whenever communications permit. Other features to improve usability and functionality have also been added since its initial conception. Shore support duties like systems operations, data stewardship, data commissioning, and public engagement also benefit from these enabling technologies.

Derivative applications and outreach initiatives demonstrate further advantages from the integrated data and dive log annotations. Examples of derivative applications include the Oceans 2.0 SeaTube module, a Marine Protected Areas geodatabase for Endeavour Ridge, and scientific analysis on visual survey transects. These applications have in turn driven improvements to the dive log annotation syntax, filtering and export options. Outreach initiatives surrounding expeditions, such as the Wiring the Abyss website, feature live feeds of the video, audio and dive logs. Video streams from webcams showing on-deck and lab activities are also incorporated.

The level of coordination between shore personnel and multiple ship/ROV crews would not be possible without this sophisticated digital infrastructure. Further intended improvements include data acquisition support for additional ROV instrumentation, more automated video transcoding and integration, and better support for recording deck operations.

Keywords—dive logging; ocean observing; remotely operated vehicles; telepresence; underwater video

I. INTRODUCTION

Ocean Networks Canada maintains and operates the digital and marine infrastructure for VENUS, NEPTUNE and Cambridge Bay observatories. Since various ships and ROVs are contracted for regular maintenance expeditions, the Oceans 2.0 digital infrastructure has been expanded to include platform-independent ship-to-shore data acquisition and dive logging tools. Using telepresence and other Oceans 2.0 tools, an extensive shore support team augments the expedition crew at sea. A subset of applications demonstrate the potential for this growing database of ROV metadata and data to be utilized.

II. DATA ACQUISITION

Typically, ROV and ship data are collected and stored as files on hard-drives which are curated and archived post-cruise

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at shore facilites. In order to streamline data acquisiton and archival, provide more immediate access to data and support live ROV operations, a ship-to-shore data acquisition system has been developed. The increased use of high-bandwidth satellite communications for telepresence has motivated the creation of live streaming data applications [1].

A requirement for design and implementation is to maximize flexibility due to changing ROV and ship platforms. Effective communications between ONC staff and ROV crew is essential before the expedition to ensure necessary platform and instrument documentation can be obtained, determine necessary customizations, and conduct testing. Ongoing communications after the cruise can assist with any troubleshooting or improvement efforts.

A. Scientific and Navigational Instruments

As a result of operating the NEPTUNE and VENUS cabled ocean observatories, ONC has developed a wealth of experience and significant code repository for data acquisition of oceanographic instruments. In order to leverage these assets for ROV data, software engineers at ONC revamped the architecture to support a standalone instance of Oceans 2.0 that could interface with ONC's central data centre. Stand-alone instances of Oceans 2.0 have been designed to always include core modules and as needed extension modules. Full functionality of the Oceans 2.0 data viewing tools at sea is supported by retaining a copy of raw and parsed data on a local database. Configuration options were also added for streaming raw data to the central data centre at UVic in order to have it parsed and archived in near real-time as well, with buffering capabilities to mitigate any communication interruptions.

B. Video and Digital Stills

ROVs often have multiple video cameras and a digital still camera. The high-resolution video from a primary camera is normally recorded onboard. ONC imposes additional requirements for closed captioning, file naming conventions and file sizes. Secondary camera may also be recorded depending on the camera purpose, staff resources, and available hardware. Lower resolution video is streamed to shore for live broadcast on the ONC website, and archival in a web-streamable format for access in SeaTube.

Digital stills are normally triggered by an ROV operator or dive chief, saved locally in camera memory, downloaded post-dive, and stored on a hard drive for later on-shore curation. Depending on the ROV system, image timestamps are obtained by the camera clock or software that interfaces with the triggering mechanism. Currently, mechanisms to trigger and practices for curation of digital still images vary greatly from one ROV to another. More efficient data ingestion procedures and increased integration into Oceans 2.0 tools and services are desired.

Video and digital still cameras may have lasers that can be turned on and off. In that case, guidelines need to be communicated and distance of lasers documented.

III. Dive Logging

In 2013, ONC first released SeaScribe, a dive logging software within Oceans 2.0 [2]. By the end of September 2015, it will have been used on six ships and seven ROVs. Annotations from human diver expeditions have even been integrated. Expansion to support shore-based dive logging and multiple concurrent ROVs were introduced in 2014 and 2015, respectively. Improvements to the syntax, semantics and user interface have been driven by user feedback and new applications.

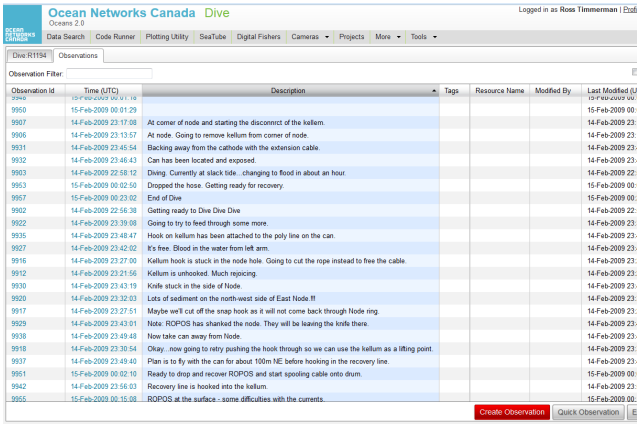

Figure 1: SeaScribe screenshot depicting observation list with quick links for full observation details, frame grab generation (via timestamp), sortable headers, and buttons for creating observations and generating CSV exports.

A. Multi-Vessel Expeditions

SeaScribe now supports multiple on-ship installations with consistent or intermittent internet connectivity. One to ten ships can be outfitted with a server running an instance of SeaScribe. Observations, dives, cruises and other select SeaScribe entities are saved to a local database and then bi-directionally propagated to other SeaScribe instances that have been configured to work together. A messaging bus is used to facilitate data transfer, and, in the case of internet connectivity outages, data is buffered until connectivity is restored.

B. Syntax and Semantics

ONC dive loggers are provided resources and training to follow defined syntax and semantics for dive operations, organisms, sampling and seafloor substrate. This approach facilitates searchability, filtering and consistent metadata. A Marine Field Guide [3] assists dive loggers with identifying specimens in the NEPTUNE locations. An updated version is pending release. Sampling syntax and fields are under review to support more extensive and standardized curation of physical samples. The initial substrate classifications focused on Endeavour [4], but a more encompassing and community-adopted schema [5] is being developed.

C. User interface

Since its initial implementation in 2013, a number of usability and functionality improvements have occurred in the user interface. From a usability perspective, there are additional shortcuts, a quick observation button, and revised layout for better use of screen space. New functionality includes frame-grabs from the highest resolution video available in the archive

and CSV exports of dive logs. Integration of archived ROV navigational data (latitude, longitude, depth, heading) is currently being added to both SeaScribe and SeaTube observation tables.

IV. Shore Support

There are multiple motivating factors for shore support at ONC. First, on-shore staff have more direct and reliable access to the Oceans 2.0 tools and database that allow them to control and monitor cabled infrastructure as disconnection and connections occur at sea. Second, telepresence capabilities mean that ROV dive logging and data monitoring can occur on shore and alleviate limited berthing on ships. Third, scientific or technology experts who are only concerned with a subsection of operations, can participate remotely on call.

A. *Technical Infrastructure*

The functionality and reliability of technical infrastructure are key to shore support success, and mitigation strategies for lapses in communication need to be accounted for. The ship-to-shore data acquisition systems for ROV data can buffer data on the ship and resume transmission if connections are lost. The multi-vessel support in SeaScribe allows observations to be synchronized across all server instances. During loss of communications, ship personnel are responsible for annotating all operations. Two-way voice and audio communication systems allow shore personnel to talk directly to the ROV operators and dive chief, in case extra direction or clarifications are required. Depending on the ROV, digital stills might only be taken on the ship. In that case, dive loggers need to communicate with or provide advance instructions to the ship personnel for necessary photos. Skype is also used for messaging remote scientists. A shore support mailing list is used for distributing daily updates and updated ROV dive plans.

B. *Roles & Responsibilities*

Shore support duties that support operations, science and public outreach are mainly conducted by ONC staff, principal investigators and graduate students.

On-shore dive logging alleviates limited ship berths and enables input from specialized experts during particular dives. The primary responsibility of dive loggers is to record observations and metadata for scientific and infrastructure dive operations. Dive loggers are often also responsible for communicating updates to other shore support personnel and principal investigators. For instance, when an instrument is connected on the seafloor, the corresponding database metadata needs to be updated, instrument power and comms need to be established, and the dive chief needs to be notified so that the dive can continue as planned or take corrective measures if required. Principal investigators occasionally participate so that they can help direct and record specialized operations.

Systems operators at ONC are responsible for networked instrument power and communications, and recording and archiving ROV video streams (described in Section II, B). Specialized tools in Oceans 2.0 allow them to control and monitor primary infrastructure (e.g., junction boxes) and instrument data acquisition drivers. Once an instrument is powered, they check for isolation faults and confirm stability of available telemetry. Next, relevant instrument drivers are started and basic data streams are confirmed.

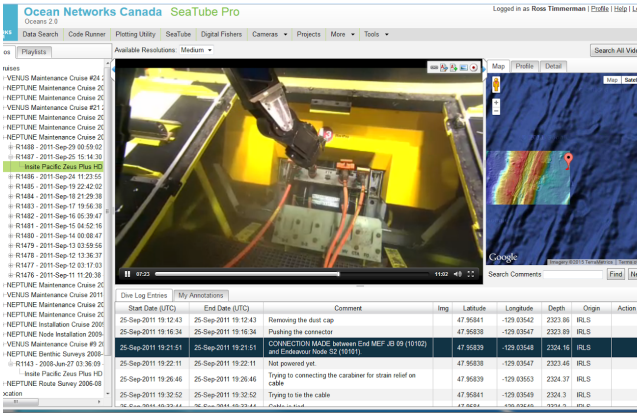

Figure 2: SeaTube screenshot depicting a tree-structure at left to navigate between expeditions and dives, video player, tabs for dive context information, and dive logger annotations below.

Data stewards enter metadata controls instrument settings (configurations, calibration formulas, driver synchronization), instrument position and orientation, topology/IP addressses for communications/power, search interfaces (searchtreenode, data product mappings, postprocess jobs), ftp jobs.

Data team members validate data and derived data products, enter parameters for automated QA/QC routines, and perform manual QA/QC annotations.

Outreach staff manage public outreach initiatives (expedition website, blogs, twitter) updates, classroom interactions and media requests.

V. Applications

There are many possible applications for the ROV dive metadata and data once it is curated and archived in Oceans 2.0. The selected applications in this section provide illustrative examples of the varying purposes and platforms.

A. *Oceans 2.0 SeaTube*

SeaTube is an ONC-developed portal (refer to Fig. X) to view dive videos combined with their dive logs, navigational data, and metadata [2]. The recording of satellite streamed video is normally available in near-real time. After the cruise, higher resolution transcodes can be performed and made available from the high resolution video recordings. Dive logger observations are immediately integrated. Navigational data and digital still images appear once they have been archived and processed in Oceans 2.0.

B. *ONC Wiring The Abyss Website*

For major expeditions, ONC maintains its *Wiring the Abyss* website with telepresence, video, imagery and daily updates from sea. The live video streams, accompanied by audio and dive logger observations, serve to inform scientists and shore support of the events at sea, and to engage the general public in

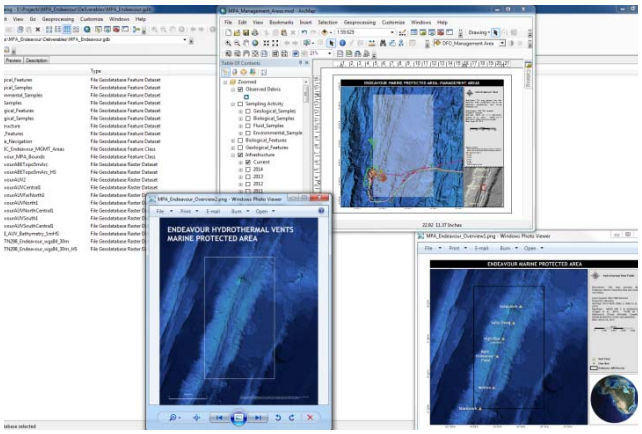

Figure 3 This screenshot of the ONC-produced geodatabase for the Endeavour Hydrothermal Vents Marine Protected area shows high-level contents, MPA boundaries and ROV dive tracks.

ocean exploration activities. Expedition and dive metadata maintained by dive loggers is used to control website features.

C. *Scientific Research*

A vast array of scientific applications using ROV dive data and observations exists. For instance, visual surveys are used to assess biological distributions and habitat [6], to monitor feature changes over time (e.g., with photogrammetric time series), and to validate observations in observatory fixed-position cameras. Substrate annotations can facilitate comparison and/or training of automated classifiers of substrate along seafloor visual [7] or multibeam transects [8].

Measurements from physical samples can be used for a greater understanding of ocean biology (e.g., taxonomic identification of species), geology (e.g., composition of seafloor sediment) and water properties (e.g., oxygen concentration).

D. *Marine Protected Area Management*

Sample collection and activities by ROVs in Marine Protected Areas (MPA) often require special permitting and subsequent reports. Thus, data and metadata must be collated and provided to managing agencies. For example, the Department of Fisheries and Oceans (DFO) Canada requires reports to be submitted following any permitted work at the Endeavour Hydrothermal Vents, which must include details about samples collected, deployed instrumentation, access to georeferenced video, raw data and impacts or incidences [9].

In 2014/2015, ONC was contracted by the DFO to produce an initial implementation of a geodatabase for Main Endeavour Field that included ROV dive tracks, ONC instruments and cables, physical samples, geological and biological features (refer to Fig. X). This geodatabase is intended to assist in their management, monitoring and coordination of human activities in the MPA [9].

E. *Operations*

Previous ROV video, data and dive logs are extensively used in preparing for subsequent expeditions. Cable lay plans and new instrumentation sites use georeferenced visual and multibeam survey information. Dive logs include references to equipment left on seafloor, potential issues with cables (e.g., flattened or kinked sections) and other infrastructure that should be revisited. Historical video is also used to create examples of planned operations that can be used as training resources for contracted ROV operators.

VI. Future Directions

ONC is continually reviewing and prioritizing options for improving its Oceans 2.0 tools and services. With respect to ROV data and metadata, upcoming priorities include additional drivers and parsers for ROV navigation systems, automated video transcoding and integration, improved syntax and semantics for substrate, sampling and surveys.

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