SUBJECT: COVIS (Cabled Observatory Vent Imaging Sonar) Project Annual Report
Report Period Year 1: 1 November 2008 to 31 October 2009

PROJECT TITLE: Collaborative Research (Applied Physics Laboratory-University of Washington and Rutgers University): Acoustic Instrumentation for Imaging and Quantifying Hydrothermal Flow in NEPTUNE Canada Regional Cabled Observatory at Main Endeavour Field, Juan de Fuca Ridge

REPORT INTRODUCTION:
Collaborative Research Objective: This is a collaborative project between the Applied Physics Lab-University of Washington (Russ Light, PI, APL-UW) supported by NSF grant 0824612 and Rutgers University (Peter Rona, Co-PI) supported by NSF grant 0825088:
1) Develop a sonar system to image flow from seafloor hydrothermal vents (COVIS= Cabled Observatory Vent Imaging Sonar): APL-UW, period 1 November 2008 to summer 2010
2) Test and connect the sonar to the NEPTUNE Canada seafloor cabled observatory: APL-UW, scheduled for summer 2010
3) Initiate imaging of hydrothermal flow at a vent cluster in the Main Endeavour Field on the Juan de Fuca Ridge through the NEPTUNE Canada Oceans-2 DMAS (Data Management and Archiving System) to the user community with near real time quick-look plume images: Rutgers and APL-UW with NEPTUNE Canada, scheduled for summer 2010 (contingent on system preparation).

The annual report consists of two sections::
I. Applied Physics Laboratory-University of Washington, Russ Light, PI
II. Rutgers University, Peter Rona, Co-PI:

ANNUAL REPORT SECTION I:
APL-UW section of COVIS Annual Report (Period Year 1-1 November 2008 to 31 October 2009)
PROJECT TITLE: Collaborative Research (Applied Physics Laboratory-University of Washington and Rutgers University): Acoustic Instrumentation for Imaging and Quantifying Hydrothermal Flow in NEPTUNE Canada Regional Cabled Observatory at Main Endeavour Field, Juan de Fuca Ridge.

1.0 Project Participants (APL-UW)
Russ Light, PI, University of Washington Project coordination with Dr. Peter Rona, PI, Rutgers University Engineering management and lead electrical engineer for project
Dr. Darrell Jackson, Physicist, APL-UW Acoustic signal processing, sonar specification
Vern Miller, Mechanical Engineer, APL-UW
Mike Kenney, Software Engineer, APL-UW
Pete Sabin, Electrical Engineer, APL-UW
Larry Joireman, Fiscal Coordinator, APL-UW

2.0 MAJOR RESEARCH AND EDUCATION ACTIVITES
2.1. Specification and acquisition of a sonar that meets the project requirements
2.2. Specification and acquisition of pressure balanced rotator motors for tri-axial translation system
2.3. Design of a triaxial translation system for the sonar transducers
2.4. Design of the COVIS tower
2.5. Investigation into titanium material costs for COVIS tower
2.6. Market survey and selection of components for the System Interface Case - CPU board, multi-serial board, digital I/O board, power conditioning
2.7. Preliminary functional block and wiring diagrams

2.8. Preliminary design of 400VDC power converter system
2.9. Interface with University of Victoria Neptune Canada engineers on system integration issues
2.10. COVIS Software

3.0 MAJOR RESEARCH AND EDUCATION ACTIVITES FINDINGS

3.1. Specification and acquisition of a sonar that meets the project requirements

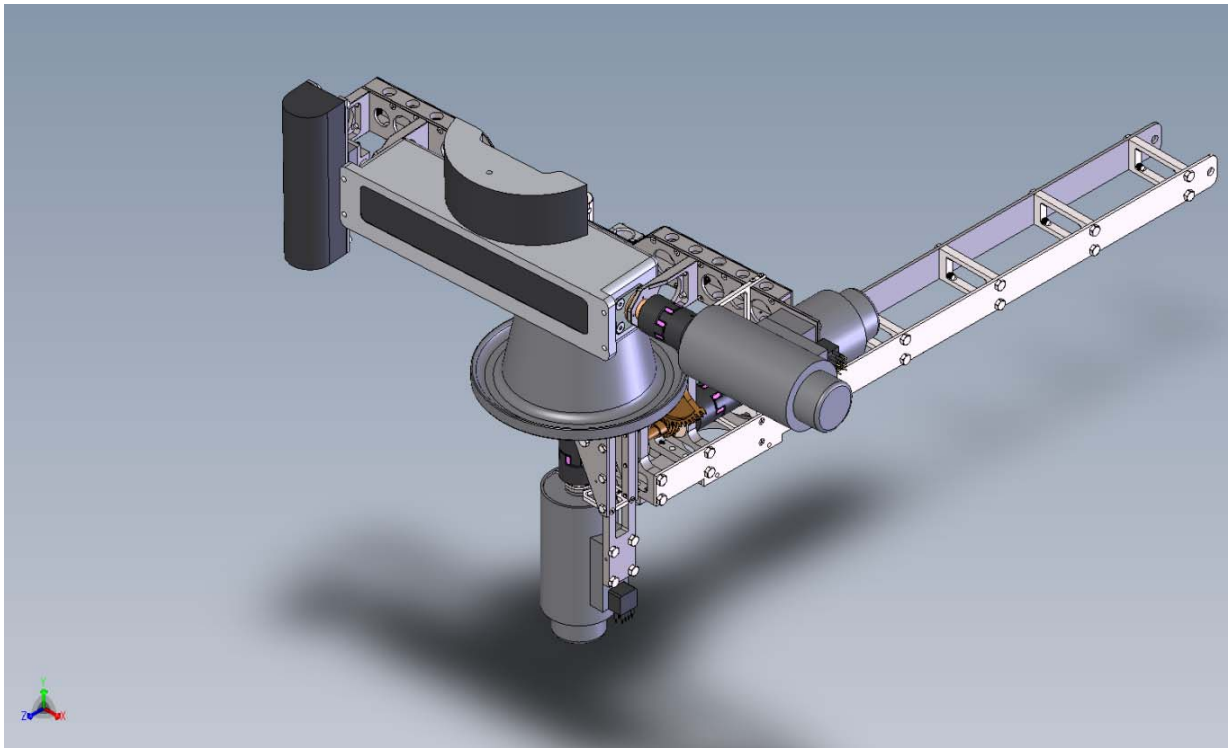
The AUV version of the Reson Seabat 7125 has been the focus of an intense investigation for the COVIS. Numerous interactions with Reson over a 6 month period have resolved the issues but have delayed the sonar acquisition. A final statement of work and quote were provided to APL 7/17/09. The final quote plus Wa State sales tax exceeded the proposal budget for the sonar by ~$26k. The increase in cost was influenced by changes needed in the sonar to meet the project requirements and inflation.
Issues
• The current version of the 7125 has a phase jitter problem between signal generation and receive signal digitization. The 7125 did not use a common clock for these components and therefore the ping to ping phase was not consistent. This is a requirement for COVIS signal processing. The solution was to dedicated one of the receive channels as a monitor of the sonar transmission signal which is digitized in phase will all of the other receive channels.
• The 200 kHz narrow beam projector originally envisioned for the project is no longer offered by Reson for reliability reasons. Design changes and the companies focus has been on the 400 kHz narrow beam projector. COVIS staff reviewed the 400 kHz projector and found it would meet and exceed project requirements.
• Certain features, namely switching between two projectors were not implemented in the Ethernet command set. Reson agreed to modify the software to allow full functionality via the Ethernet command set.
• Enhanced reliability by converting from electro-mechanical hard drives to solid state drives was worked out to improved low temperature performance and MTBF.
• The addition of an Ethernet Keyboard-Video-Mouse (KVM) interface was added to improve reliability by allowing direct user interaction and monitoring of the Windows based operating system during bootup.

3.2. Specification and acquisition of pressure balanced rotator motors for triaxial translation system

Discussion and interaction with Remote Ocean Systems (ROS) was undertaken to define requirements of a pressure balanced, oil filled motor to be the basis of the tri-axial translation system for the sonar transducer system. Preliminary design of the translation system was performed to gain understanding of the required motor toques for the static and dynamic loads of the sonar components. These efforts led to a design where the sonar loads are supported by bearing structures on both sides of the load rather than a single bearing with the load cantilever. This design is more complex and less compact but keeps the axial shaft loads and motor torques within specification of the rotator motors.
The order for (3) of the rotator motor R25 types fabricated in titanium housings was placed in June of 2009 with an expected delivery in September of the 2009.

3.3. Design of a triaxial translation system for the sonar transducers

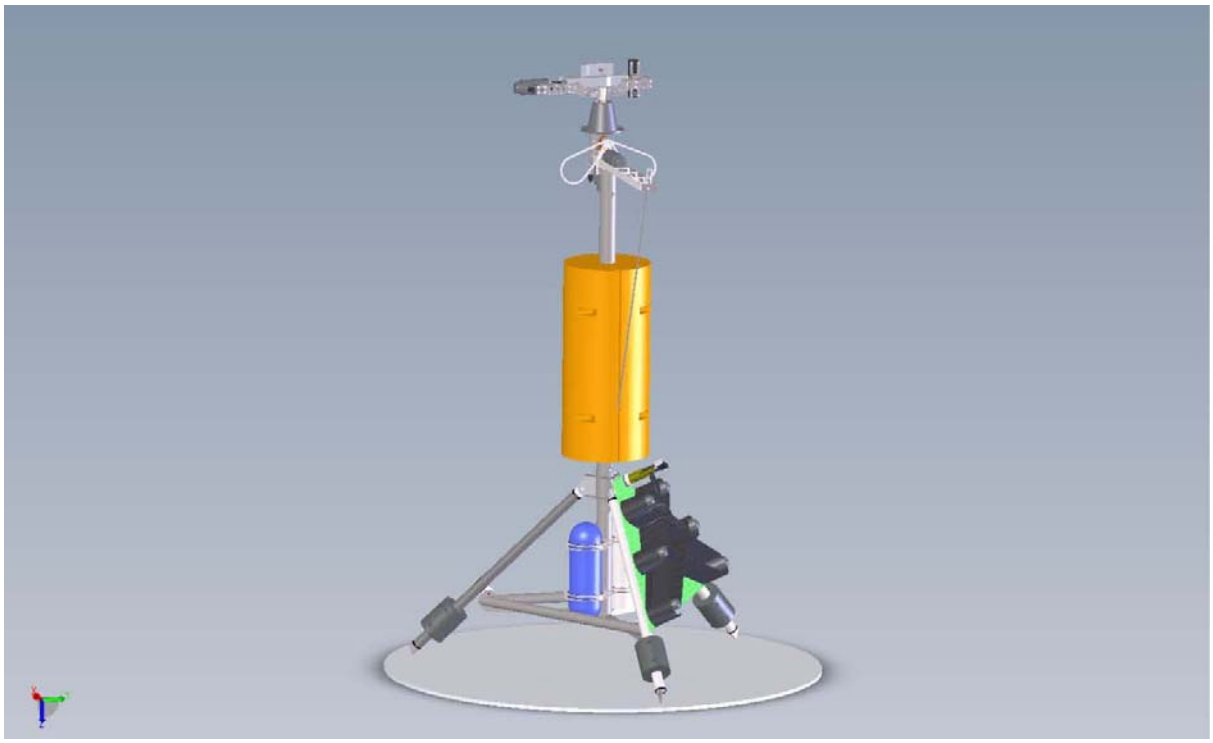
The 3d model of the mechanical design of the triaxial translation system has been completed. The final dimensioned drawings will be performed upon delivery and inspection of the R25 rotator motors. In particular, considerations of electrical cable management have been investigated and present one of the bigger design challenges. In total (7) electrical cables will come off the translation system for connection to the Reson ICPU (electronics pressure case) and the APL designed System Interface Case (SIC).



3.4. Design of the COVIS tower

The 3d model of the mechanical design the COVIS tower is approximately 75% completed. Additional discussions with the ROPOS ROV group at the University of Victoria are required to move the design forward. Due to the intensive operations occurring with the installation of the cable nodes in the summer of 2009 APL-UW has been unable to get any interaction with the ROPOS staff. It is hoped that after the summer field season we will be able to engage this staff to discuss the deployment issues so that the design can be finalized.

Design features include syntactic foam for weight compensation for ROPOS handling (orange structure), observatory cable management (125m Fi/Cu cable for connection to Endeavor Junction Box), lifting management, Reson ICPU and APL SIC pressure cases.



3.5. Investigation into titanium material costs for COVIS tower

The entire COVIS tower, pressure cases, and components will be constructed from Titanium to prevent corrosion at the Endeavor site. The cost and availability of this material is being investigated.

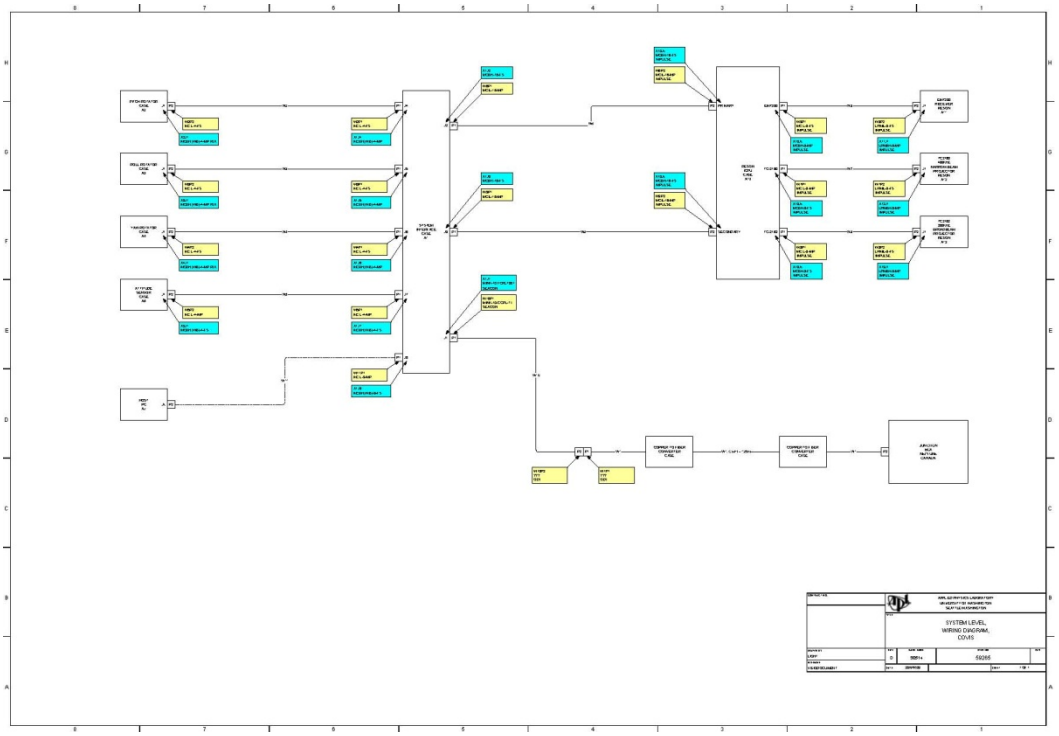
3.6. Market survey and selection of components for the System Interface Case - CPU board, multi-serial board, digital I/O board, power conditioning

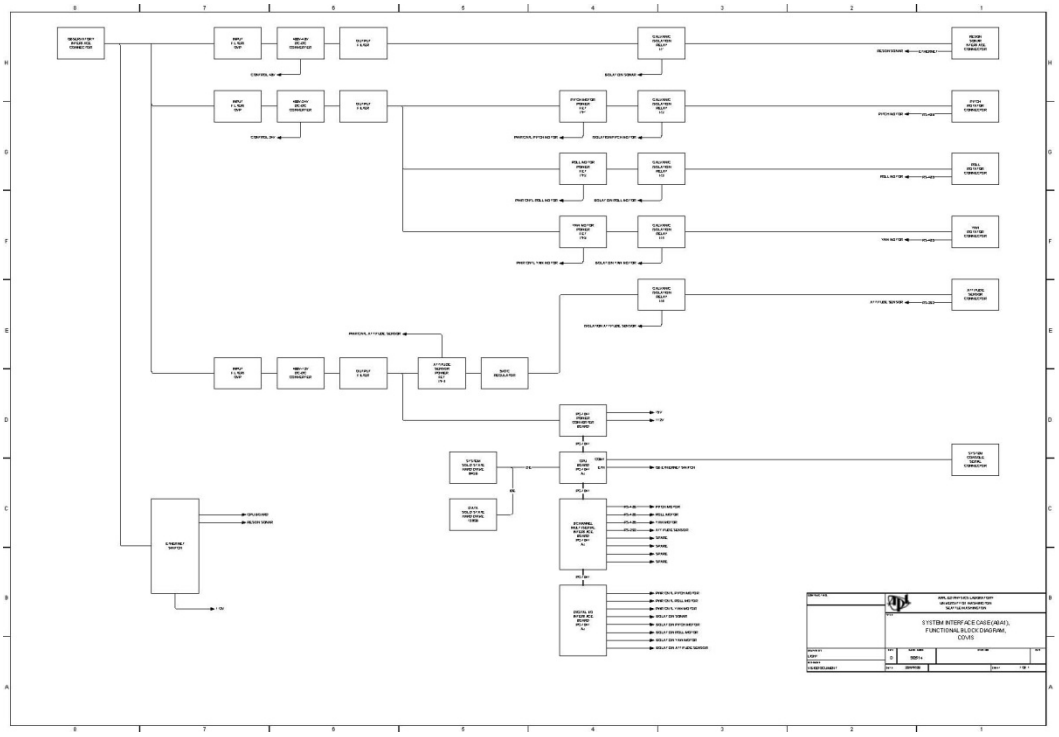
A market survey of available PC-104+ products has been investigated to find suitable products for specifying the electrical components of the SIC. Main consideration has been given to vendors that provide MTBF specifications for their products. At this time Parvus Corporation has been selected as the major vendor for the PC-104+ hardware.

Solid state drives (SSD) has been another topic of investigation for both the SIC and the Reson system. It has been determined that the best drives on the market are the Intel X-25 drives. This drive is only offered with a SATA interface which will work with the CPU system in the Reson ICPU. Unfortunately Parvus does not offer a CPU board with this interface. A conversion device such as SATA-USB will be investigated or an alternative PC-104+ CPU vendor will need to be identified. Final specification and acquisition of these components is planned for Aug 2009.

3.7. Preliminary functional block and wiring diagrams

Functional electrical block and wiring diagrams have been completed for the system level and SIC. The SIC will be designed from PC-104+ COTS components and several APL custom designed power supply boards.





3.8. Preliminary design of 400VDC power converter system

COVIS staff met with University of Victoria Neptune Canada (NC) staff in Dec 2008. During the proposal development NC had indicated that COVIS would be hosted on a 48VDC port on the Endeavor Junction Box. Subsequently all available 48VDC ports were committed and APL-UW was informed that we would need to use the 400VDC port. This change was both a benefit and a hardship. The benefit is that the COVIS uses relatively high power from the observatory and site selection will be problematic dictating the desire to have a longer observatory interface cable. The longer this cable is, the more voltage drop that will develop in the cable due to cable wire resistance. There was some concern that 48VDC with its higher current requirement for COVIS could potentially be a problem. Switching to the 400VDC port allows for much lower current in the cable wire and cable length will not be an issue. The hardship is that the proposal was not originally budgeted for developing a 400Vdc to working voltage converter system. Work has begun on identifying appropriate 400Vdc to 48Vdc, 24Vdc, and 12Vdc converters required by the COVIS. There is concern that switching frequencies of standard converters (e.g. Vicor) which change with load may cause noise interface with the sonar. Unfortunately this is hard to know until the system is integrated. APL-UW will need to design several custom boards to provide this power conversion. Additionally, these boards will provide for software controlled galvanic isolation and software controlled power switching of the sonar, translation rotator motors and translation attitude sensor. The design and fabrication of the custom power conditioning boards is planned for Nov 2009.

3.9. Interface with University of Victoria Neptune Canada engineers on system integration issues

COVIS staff met with UVIC NC staff in Dec 2008 in Victoria. Discussions covered numerous topics from COVIS/NC testing, junction box interface, site selection, cabling, ROPOS/Tully deployment/recovery, data management and archiving (DMAS), COVIS command/control, etc. Subsequent to the Dec 2008 meeting periodic e-mails have been exchanged regarding NC instrument requirements and requests by APL-UW for information on power conditioning, sub-sea connectors, and other issues. Due to the intensive operations of commissioning the NC system, feedback has been sporadic to these requests. It is hoped that as the summer 2009 field season winds down, better interaction will be accomplished.

ANNUAL REPORT SECTION II: This section of the Annual Report pertains to the Rutgers component of the collaborative grant Year 1 (1 November 2008 to 31 October 2009).

1.0 Project Participants (Rutgers):

Dr. Peter Rona, PI, Rutgers University: Project coordination with Russ Light, PI, APL- UW; management of Rutgers component of project; participation in all aspects of the Rutgers work.
Dr. Karen Bemis, Rutgers Co-PI: Scientific Data Processing.
Dr. Deborah Silver, Rutgers Co-PI: Scientific Data Visualization.
Kristina Santilli Bennett, graduate student: two-phase rending for construction of realistic images of hydrothermal plumes as part of Ph.D. dissertation.
Jay Takle, graduate student intern: Development of project web pages, visualization programming for project and as a possible part of MS thesis.
Vijay Penemetsa, graduate student, visualization programming.
Craig Gutterman, undergraduate student summer intern: Matlab and other programming.

2.0 Activities and Findings:

The Rutgers effort is devoted to conversion of our prior plume imaging software, adaptation to COVIS, and incorporation into the NEPTUNE Canada Oceans-2 DMAS (Data Management and Archiving System) to produce user-friendly quick look plume images in near-real time when COVIS (Cabled Observatory Vent Imaging Sonar) is connected and functional (scheduled for summer 2010). Integration and data flow of COVIS in the NEPTUNE Canada system is showin in Figures 1, 2 and 3 (at end of this section of report). We are preparing to provide two types of quick look images: a) plume image based on contours of equal intensity (isointensity) of 3D acoustic backscatter from the buoyant plume volume; b) plume image based on rendering the plume volume as if it were illuminated by light instead of sound showing the actual expansion of the buoyant plume with height above source vents. We are engaged in multiple tasks to achieve this objective:

• Existing acoustic data processing can be divided into two stages: i) construction of volume files (voxels; 3D arrays of acoustic backscatter intensity values); and ii) visualization and quantification software that uses volume files.

• We are engaged in four main tasks to incorporate our processing software into NEPTUNE Canada are, as follows:

- o Streamline and modify the existing Matlab code so it can function as a standalone.
- o Collect our existing programs that use volume files including feature tracking, object segmentation, centerline and eddy extraction code. Modify some subset of this software to work as a standalone.
- o Determine the correct triggering of the above functions so that they run every time a new data file is available.
- o Develop data quality assessment algorithms to fulfill NEPTUNE Canada's request for data quality monitoring, as well as to assist the user in determining the detail level to interpret the images

•We are currently working in the Rutgers Visiometrics Lab (Director, Co-PI Dr. Deborah Silver) on two aspects of the software transformation:

1) Automation of Matlab code for processing anticipated COVIS acoustic imaging data (with undergraduate student Craig Gutterman)

2) Automation of two-phase volume rending program (developed by graduate student Kristina Santilli Bennett) to produce realistic plume images that show expansion with height (with graduate student Jay Takle), in contrast to images produced by acoustic backscatter isosurface volume rendering which do not show plume expansion with height. Both types of plume images will be made available to users.

• We are developing project web pages to document and inform the user community of our work: URL http://www.caip.rutgers.edu/vizlab_group_files/MarineScSite/AcoustImag/index.html (graduate student Jay Takle, Webmaster).

• Conversion of functions (feature tracking and object segmentation) of commercial software package (AVS=Advanced Visualization System) that we presently use to visualize and reconstruct hydrothermal plumes to appropriate updated open source program (VTK) that can be incorporated into the NEPTUNE Canada Oceans-2 DMAS (graduate student Vijay Penemetsa).

3.0 Products:

1) Journal Publications:

Bennett, K.S., D. Silver, K. G. Bemis and M. Chen, Visually validating expansion characteristics in acoustic hydrothermal plume data, to be submitted to Journal of Computers and Graphics.

Rona, P.A. and C.D. Jones, Acoustic scintillation thermography, in Editors J.H. Steele, K.K. Turekian, and S. Thorpe, Encyclopedia of Ocean Sciences (Second Edition), Elsevier, 3430-3433, 2009.
2) Project web pages
(URL http://www.caip.rutgers.edu/vizlab_group_files/MarineScSite/AcoustImag/index.html): under development
3) Other Publications:
Contributions to NEPTUNE Canada meetings and workshops (see NEPTUNE Canada website http://neptunecanada.ca/
P.A. Rona, K.G. Bemis, C. Jones, D.R. Jackson, K. Mitsuzawa, D.R. Palmer, and D.Silver, Acoustic imaging and quantification of plume and diffuse flow at vent clusters in the Endeavour Integrated Study Site (ISS): integration with in situ measurements (poster abstract), Ridge 2000 Integration and Synthesis Workshop, 1-3 October 2009.

4.0 Contributions:
Principal disciplines of the project:
NSF OOI (Ocean Observatories Initiative); engineering (development of COVIS sonar and tri-axial orientation system); cyber-infrastructure (development of acoustic visualization software for long-term monitoring of seafloor hydrothermal flow; archiving, and dissemination of data to the community); and science (seafloor hydrothermal processes)

Other disciplines of science or engineering:
• Development of human resources: undergraduate and graduate education: Participation as summer intern of Craig Gutterman, Rutgers undergraduate; participation as research assistants of Rutgers graduate students Jay Takle and Vijay Penemetsa
• Incorporation of project methods and findings into undergraduate courses (Rona, Introduction to Oceanography,), and graduate courses (Bemis, Visualization; Rona, Ocean Ridge Processes).
• The physical, institutional, or information resources that form the infrastructure for research and education: Our acoustic images and software to derive information from the images will be openly distributed to the research and education communities through the NEPTUNE Canada O2 Data Management and Archiving System (DMAS).
• Other aspects of public welfare beyond science and engineering: Monitoring the oceans for earthquake and volcanic hazards.

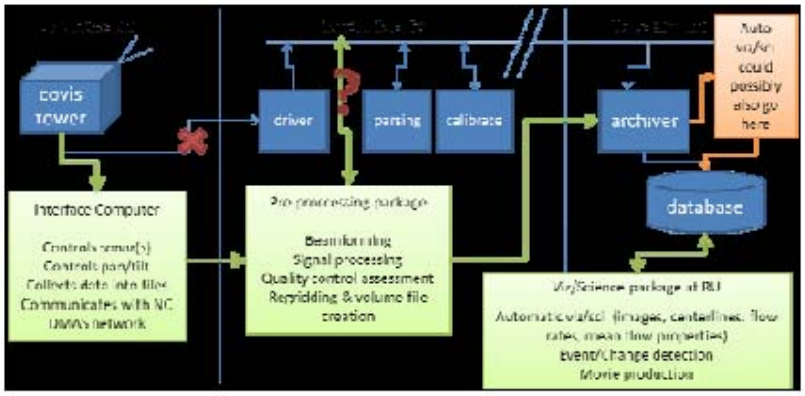


Figure 1. Integration of COVIS into the NEPTUNE Canada DMAS structure indicating the location and type of processing both during and after data acquisition (K. Bemis).

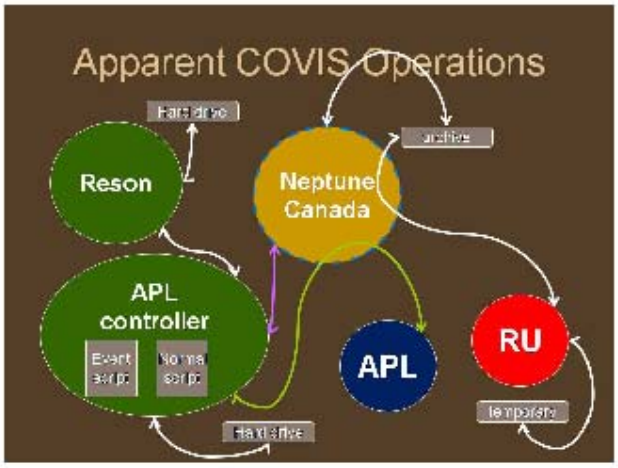


Figure 2. Data flow within the COVIS- NEPTUNE Canada system (Russ Light).

Figure 3. Diagram of the NEPTUNE Canada DMAS (Data Management and Archiving System) plans for data access through a Web 2.0 interface, Oceans 2.0 (diagram from http://www.neptunecanada.ca/data-collaboration/dmas/oceans2/).