

LEO-15 Observatory – The Next Generation

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Abstract - The cabled LEO-15 observatory was a vision of Fred Grassle and Chris von Alt that became a reality in 1996 with the deployment of Nodes A and B in 15 meters of water off of Tuckerton, New Jersey. These nodes have served the scientific community well for almost a decade providing power to a variety of sensors and bi-directional real-time communication between the sensors and the PIs computer located on shore. However, technology and scientific needs have changed since these nodes were deployed making it necessary to upgrade the nodes to meet not only today's demands but also to provide expandability and flexibility for the future. The nodes must be able to do more than provide real-time data. They need to be a part of a sustained and interactive network of autonomous and remote platforms that coordinate sampling in space as well as in time. Rutgers University Mid-Atlantic Bight National Undersea Research Center (MABNURC) has partnered with WETSAT, Inc. to accomplish the LEO upgrade and expansion.

The nodes will be expanded to include 10 guest ports for visiting scientists to plug their sensors into as well as ports for an auto-profiling unit, and two video ports (with lights and pan/tilt capability). There will also be expansion capabilities with two 10/100BASE-TX ports so that more guest ports can be added if necessary. Communications will be upgraded to TCP/IP over Gigabit Ethernet. Each science port will have regulated isolated power, at a software selectable voltage where necessary that is individually ground fault and over-current protected. Finally, the DACNet ocean observatory operating system software will be used to control the observatory. Phase 1 of the node upgrade, will be completed in the summer of 2005, and is concentrated on the refurbishment of Node A and installation of DACNet.

In addition to the nodes, plans are underway to deploy an instrumented buoy and bottom mooring on the Endurance Line at the 60 m isobath to augment the Slocum Gliders that operate between LEO-15 and the shelf break.

I. INTRODUCTION

In the early 1990's Fred Grassle and Chris von Alt were designing a visionary cabled observatory system for the sea floor [1]. The result of these efforts, the Long-term

Ecosystem Observatory at 15 m (LEO-15), was implemented by the Department of Applied Ocean Physics and Engineering at WHOI. The vision became a reality in 1996 with the deployment of Nodes A and B in 15 m of water, located 8.1 and 9.6 km, respectively, offshore from the Rutgers Marine Field Station (RUMFS) near Tuckerton, New Jersey [2]. This system has served the scientific community well for over a decade [2, 3, 4]. The public, and pre-collegiate educational programs have also been utilizing the data from LEO-15 [5,6].

However, technology and scientific needs have changed since these nodes were deployed making it necessary to upgrade them to meet not only today's demands but also to provide expandability and flexibility for the future. Now the nodes must be more than a stand-alone system that provides real-time data. They need to be a part of a sustained and interactive network of autonomous and remote platforms that coordinate sampling in space as well as in time. To achieve this upgrade and expansion goal, Rutgers University Mid-Atlantic Bight National Undersea Research Center (MABNURC) partnered with WETSAT, Inc. in 2004.

The first phase of this expansion plan is to provide upgraded power and communications services to the LEO-15 Node A. The primary objective of these upgrades is to make it as easy as possible for scientists to connect to the new system, while improving system capacity, and isolating each of the science ports so that problems experienced on one port have no effect on the others.

II. SYSTEM DESIGN

The key features of the system upgrade design address improvements to the communications, power, monitoring, and control systems. The communication system implements TCP/IP over Gigabit Ethernet. The power system provides hotel loads and each science port with regulated, isolated power, at a software selectable voltage

that is individually ground fault and over-current protected. The status monitor and control system uses industrial SCADA (Supervisory Control and Data Acquisition) RTUs (Remote Terminal Units) and the MODBUS standard application layer messaging protocol enabling voltage control, and power consumption monitoring of each individual port. The shore station server hosts DACNet (Data Acquisition and Control Network) ocean observatory operating system software that controls and monitors the underwater node infrastructure and instruments. An observatory port simulator (OPS) replicates the node serial and Ethernet science port interfaces for testing scientific instruments for observatory compatibility in the lab before deployment.

The complete Node A Electronics Module upgrade will constitute the RU COOL SIIM (Rutgers University Coastal Ocean Observing Laboratory Scientific Instrument Interface Module), a highly advanced science experiment support system (Fig. 1) based on the SIIMs deployed at the Bonne Bay Cabled Observatory [7].

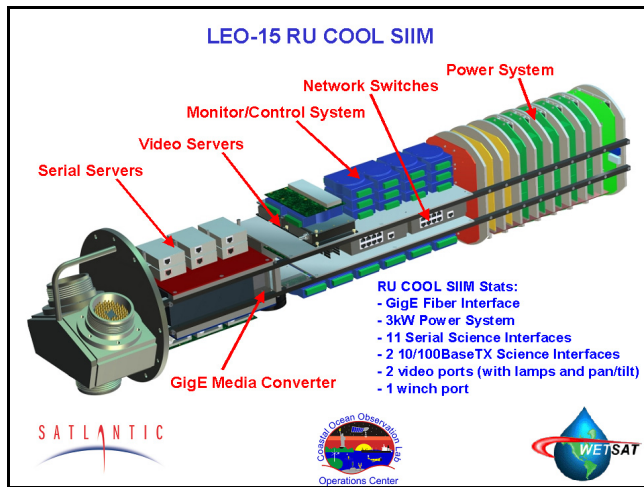


Fig. 1. RU COOL SIIM Assembly

The new shore station server hosts DACNet R4 ocean observatory operating system [9] currently in use on the CNRS BOUSSOLE [10], Dalhousie MEPS [8], UNH Great Bay NERR Observatory, and Memorial University Bonne Bay Observing systems [7]. DACNet controls and monitors the node infrastructure and instruments using proven standardized technologies from the field of industrial process control and networking. The DACNet web interface provides remote access, over the Internet, of control functions, monitoring functions, and telemetry data from any secure web browser, providing full remoter Network Operations Center (NOC) capabilities.

The current phase of LEO-15 upgrades makes no changes to the LEO-15 power feed equipment on shore and allows for the complete parallel operation of Node B as is while the upgrades are installed and commissioned on Node A. No changes have been made to the primary AC

power system, transformer boxes, or node mechanical systems for this initial phase.

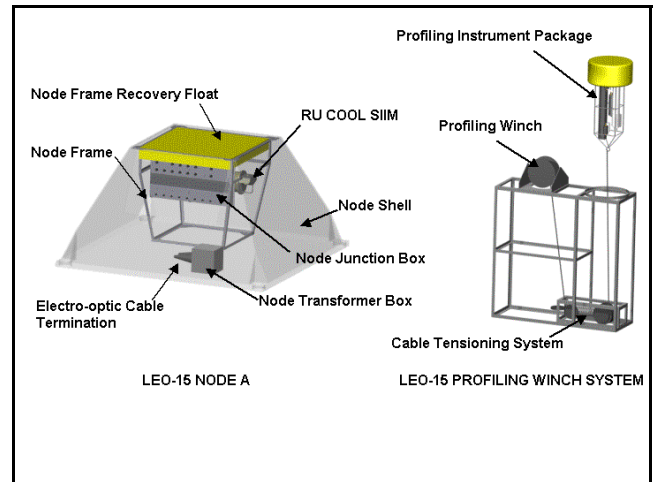


Fig. 2. LEO-15 Node A Layout

III. SYSTEM CONFIGURATION

The LEO-15 Node A is located 8.1 km from the shore station. The electro-optical cable connecting the node has three fibers and three conductors. Each node has its own fiber and they both have access to the third fiber.

A significant requirement for the upgrade of LEO-15 for this and future phases is to use the existing electro-optic cable, to avoid the potential environmental impact of running a new cable through the near shore region. The conversion of the communication system to standard networking protocols makes extending the LEO array feasible even within this constraint.

Each node consists of a node shell which houses the electro-optic cable termination, transformer box, node frame, and a profiling winch system which is outside the shell, located about 10 m from the node (Fig. 2). The node frame holds the node junction box, and the new RU COOL SIIM. Two diver mateable fiber optic cables connect the transformer box to the RU COOL SIIM. Power is fed from the Transformer Box to the Node Junction Box by diver mateable cables. The RU COOL SIIM connects to the junction box via three 88 pin connectors and oil filled hoses. Divers connect guest instruments to the node using wet mateable connectors by accessing the node junction box through doors in the node shell.

The RU COOL SIIM has 20 user interfaces: 11 serial science interfaces, two 10/100BASE-TX Ethernet interfaces, two video interfaces, two video pan/tilt interfaces, two video lamp interfaces, and a winch interface (Fig. 3). Three of the serial science interfaces are normally used for node instruments (ADCP, pressure sensor, and the profiler package), leaving eight for serial guest instruments. All other interfaces (except the winch interface) are available for guest instruments. The Ethernet interfaces can be used for future expansion to other SIIM

modules, or for Ethernet based instrumentation. For more complex instrument systems, access to a spare fiber is possible and an experimental copper 1000BASE-TX gigabit Ethernet port has been installed.

IV. POWER SYSTEM

The upgraded LEO-15 power system is designed to make it as easy as possible for guest instruments to connect to the node, while isolating each port so that a fault on one port does not affect instruments on the other ports. The primary power feed equipment on the shore station (a 8 kW 1650 VAC 3 phase power supply), and the step down transformer box in the node shell that provides unregulated full wave rectified 120 and 240 VDC in the node shell, remain unchanged. The new system provides isolated and regulated power busses from both the 120 VDC and 240 VDC unregulated outputs from the existing node transformer box to reduce effects of shore voltage brown outs during heavy load periods in the summer. The new 240 VDC regulated supply is rated for a 2.5 kW output and is designed to provide power to the node’s profiling winch. The unregulated 120 VDC is now stepped down to 48 VDC (rated for a 2 kW output) for the main science bus allowing the use of single, compact, 48 V input DCDC converters for the primary science ports.

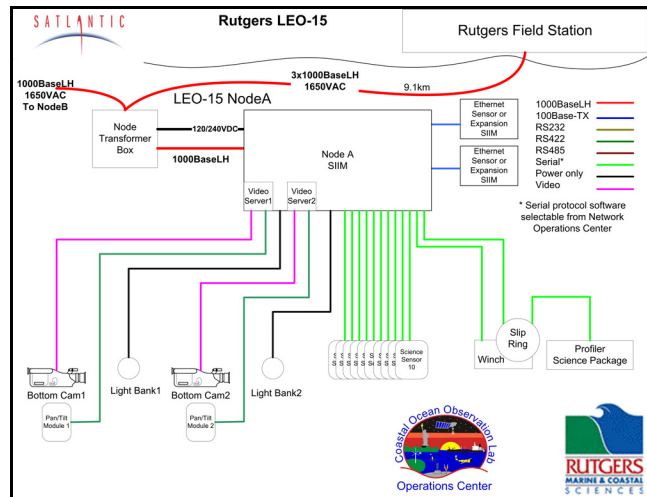


Fig.3. LEO-15 Node A Block Diagram

Each of the 15 science ports on the RU COOL SIIM has a 250 W DCDC converter that has an output voltage that is software controlled from the shore station. This allows instrumentation to be connected to the node using a simple adapter cable to match the instrument interface to the SIIM science port connector, and should not require any modification of the instrument itself. All SIIM ports are dynamically configurable without affecting other science ports. Science port voltage, current limits, and ground fault current limits are all set in the instrument XML metadata at the shore station. A series of hardware and software interlocks assure that the port voltage

matches the value set in the metadata. The DACNet ocean observatory operating system continuously monitors all the ports and notifies operations staff and the instrument PI should the instrument operate outside of the preset limits.

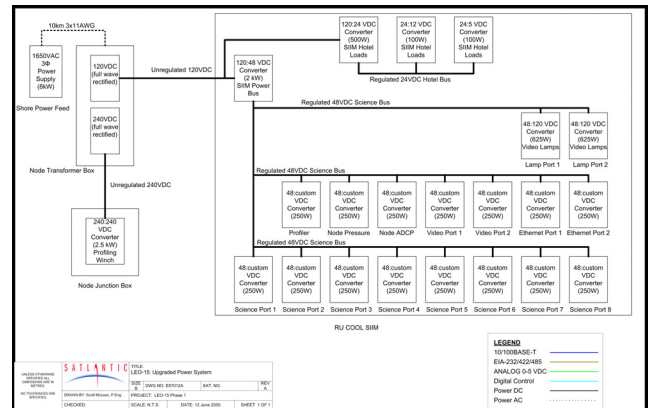


Fig. 4. LEO-15 Node A Power System

V. COMMUNICATIONS SYSTEM

The communications system is designed to make it easy for observatory users to connect instruments and access the data on shore (Fig. 5). The system is implemented as a local area network using Internet Protocols (IP) over gigabit Ethernet (1000BASE-TX). User computers can connect to the observatory infrastructure through the Alcatel OS6300, 24 port 10/100/1000BASE-TX, Gigabit network switch at the shore station or access data over the Internet. The shore station switch is connected to a bi-directional wave division multiplexed (BWDM) media converter that translates the 1000BASE-TX used in the shore station to 1000BASE-LH that is transmitted over a single fiber to the observatory node. In the SIIM, another BWDM media converter changes the 1000BASE-LH back into 1000BASE-TX, which connects to a primary gigabit network switch in the SIIM. The switch in the SIIM connects to each of the science ports for serial or Ethernet based instrumentation. Extra Ethernet ports are used for local control and monitoring within the SIIM.

The RU COOL SIIM has 12 serial terminal servers to convert serial instrument protocols to Ethernet. The protocols in the serial terminal servers are software selectable to RS232/422/485 with input baud rates of 300 – 115200 bits/s. Each port is optically isolated from the SIIM. Serial protocol, data byte format, and baud rate are all dynamically configurable in the instrument metadata at the shore station.

The video port converts RS-170A analog video (Color NTSC or PAL) to streaming digital video over Ethernet. The video ports have both composite video and S-Video connections. Each video port uses a video server to MPEG-2 compress the incoming video. Web services for this device, including video options and pan/tilt/zoom controls (if the camera is so equipped) are accessed from

the shore LAN. The compression is selectable for bandwidths of 0.5 to 8 Mbits/s.

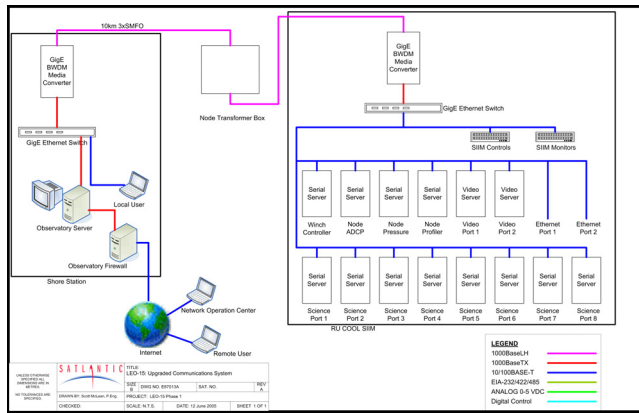


Fig.5. LEO-15 Node A Communications System

Currently the observatory has two T1 (1.5 Mbits/s) connections for real time access to data outside of the field station. Command and control interfaces are available over the Internet through a secure HTTP connection to the shore server.

VI. CONTROL SYSTEM

The LEO-15 Node A is controlled by the DACNet R4 ocean observatory operating system running on the shore station host server. DACNet provides remote interfaces for both manual and fully automated control of the observatory instruments and infrastructure. These interfaces allow the observatory to be monitored and controlled remotely from the Institute of Marine and Coastal Sciences (IMCS) in New Brunswick located 150 km away from the shore station. DACNet's primary roles are observatory command, observatory control (including the profiling winch), and to acquire data from the observatory instruments. Observatory infrastructure configuration and acquisition scheduling is implemented using XML metadata, which makes the system dynamically configurable and provides a mechanism to implement adaptive sampling.

DACNet communicates with the hardware control elements of the observatory through the MODBUS application layer protocol implemented over TCP/IP. The primary hardware control elements are 32 SCADA relay control and acquisition modules placed within the SIIM and node junction box. A web browser user interface allows for easy configuration of the infrastructure either remotely or through the shore station.

DACNet provides a web browser interface for scheduling acquisition from instruments in the infrastructure. This includes the ability to script pre and post acquisition commands to the instruments for clock synchronization, internal configuration and interactively changing instrument sampling.

DACNet stores all acquired data on the shore server in native instrument format (optionally with imbedded frame-level time tags) prepended with XML descriptors that fully map the data stream with its contextual metadata. Users may access data from the server or they can acquire data directly from the instrument by connecting to the instruments network socket. Currently two T1 connections are available for data backhaul from the shore station. DACNet will be able to stream instrument telemetry in real time to users on the Internet, depending on bandwidth availability.

DACNet continuously monitors system states and reports any detected changes or deviations to the system log file. Critical problems are immediately reported to the system operators and users via email and/or pager. This includes fault detection (voltage deviations, ground faults, port over currents and shut downs) and loss of instrument telemetry.

A more detailed description of DACNet is provided in a companion paper [9].

VII. PORT SIMULATOR

The observatory port simulator (OPS) replicates the SIIM 250 W serial and Ethernet science port interfaces for testing scientific instruments for observatory compatibility in the lab before deployment (Fig. 6). The OPS simulates the SIIM power and communication system in a single rack mounted enclosure. This allows verification of sensors at locations other than the shore station or on the node itself. The OPS measures the current requirements and the ground fault characteristics of the instruments under test. DACNet R4 can be run on a laptop computer and provides the same functionality for the port simulator as for the observatory, so all aspects of instrument integration, including metadata can be tested as well as offline observatory operator training.

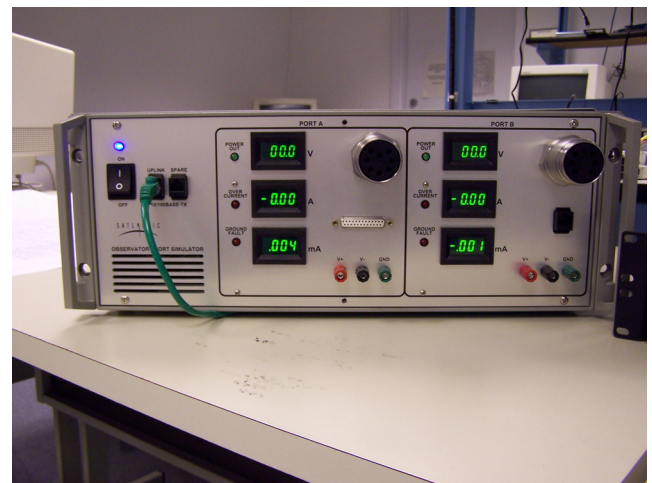


Fig.6. LEO-15 Port Simulator

VIII. FUTURE PLANS

Work on the interactive network of autonomous and remote platforms to be used in conjunction with the upgraded nodes is underway. The science team plans to deploy an instrumented buoy and bottom mooring on the Endurance Line at the 60 m isobath (LEO-60) in the next year. Sensors on the mooring will be interchangeable with those on the nodes. Like the nodes LEO-60 will be operated with DACNet software. However, since the buoy site is 100 km from shore, satellite rather than the electro-optic cable will be used for communication between it and the shore station.

Filling in the spatial data gap between the nodes, the 60 m buoy and the shelf break will be the Slocum Gliders which have been routinely swimming between the nodes and the shelf break, located 125 km offshore, collecting CTD and optical data since October 2003 and will continue to do so into the foreseeable future. Additional AUVs and moorings will be deployed in the observatory as financing permits. All instrument packages in the expanded observatory will use the same XML metadata format, streamlining the data processing from the different systems – the nodes, the buoy and the gliders, and simplifying the coordination of sampling in both space and time.

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