A System for Remote Access to Deployed Source and Receive Acoustic Arrays

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***Abstract* – A new communication and control system has been developed at the Marine Physical Laboratory (MPL) to provide remote control and data access for acoustic transducer arrays. This system was specifically designed to interface to the MPL Reconfigurable Autonomous Vertical Arrays (RAVAs) and Source Receive Arrays (SRAs). These communication systems provide a significant expansion of the capabilities of the existing transducer arrays by allowing for low power sleep modes, remote control of system parameters such as sample rate and channel gain, and remote access to data files for near real time processing and system analysis. The technical details of the system components and electronics are provided, as well as a description of the various deployment configurations. In addition, the use of these systems during the 2013 Target and Reverberation Experiment (TREX13) near Panama City, Florida is described and specific details of system performance are provided.**

INTRODUCTION

This paper describes a new communication and control system that provides remote control and data access for acoustic receive and source-receive array systems [1-2]. Fig. 1 shows the communication system as deployed with a RAVA hydrophone array during the 2013 Target and Reverberation Experiment. Communication is provided between a surface ship and a subsurface array electronics package via a small surface buoy and umbilical cable. Not shown is the ship communication node, which is described later in the paper. The system has two independent communication channels that include a low bandwidth, long range 900 MHz channel that provides access to system status information, power control and mode control. A much higher bandwidth but shorter range 2.4 GHz (802.11) channel provides access to recorded data files and remote control of the embedded CPU in the array electronics. The 900 MHz channel is the primary means of communication and is always powered on, while the higher power 802.11 channel is only turned on when required. For autonomous deployments without a surface buoy, an acoustic modem can provide a low data rate channel for status and control information in place of the 900 MHz radio modem. Low power microcontrollers in the buoy and subsurface electronics package function as power and communication controllers and also allow for preprogrammed control of the arrays when remote control is not possible, such as when the ship is out of radio range.

The following are the basic operational requirements of the communication system:

- Interface to existing transducer array systems
- Provide remote access to recorded data files
- Place electronics into low power mode or recording/transmitting mode
- Monitor battery capacity and system status
- Shutdown CPU and latch off power on battery depletion
- Change key operating parameters (Fs, gain, etc.)
- Provide GPS position and orientation
- Preprogram a sequence of timed operations

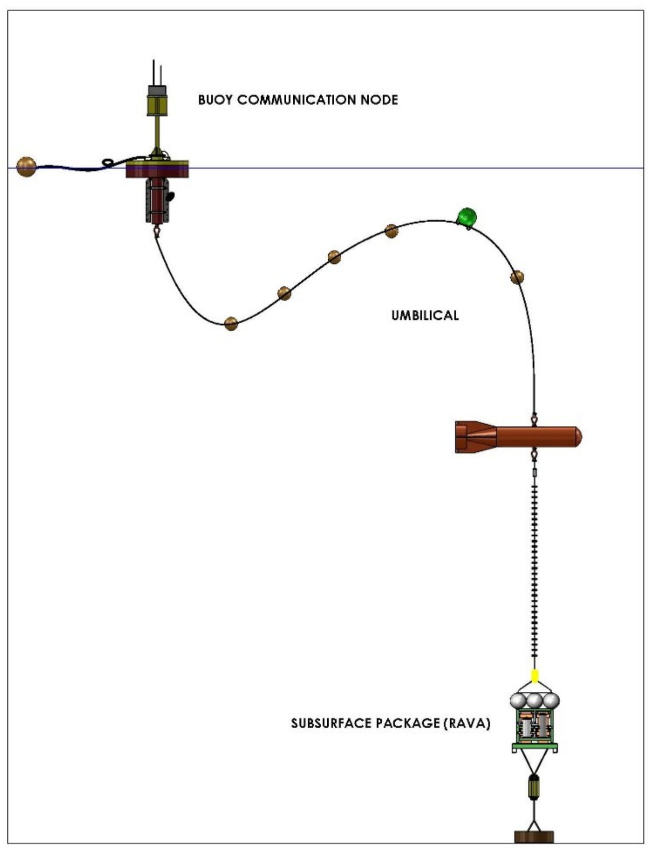

Figure 1. Deployment with RAVA Hydrophone Array

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BUOY COMMUNICATION NODE

A functional block diagram of the buoy communication node is shown in Fig. 2. The node contains a Garmin 17X HVS GPS receiver, a Freewave HT-Plus 900 MHz radio modem, a Ubiquiti 802.11 radio, a Precision Navigation Prime compass module, a Patton 2174 Ethernet transceiver, and a CF2 microcontroller interface that controls power to the radios and other components. Optionally, an acoustic modem can be included that provides an alternative data link to the subsurface system in place of the umbilical cable shown in Fig. 1. A single buoy with an acoustic modem can provide a low data rate link to multiple subsurface systems.

Basic communication with the buoy occurs through one serial port on the Freewave modem to the CF2 microcontroller. A single Freewave modem on the ship can communicate with multiple buoys by operating as a point to multipoint gateway, and a command is directed to a particular buoy or subsurface system by preceding the command with a unique identifier (i.e. BUOY1, BUOY2, RAVA1, etc.). In this manner, communication can be maintained between all deployed systems (surface and subsurface) without needing to reconfigure the modems to redirect communication to different systems.

The following are sample remote commands for a surface buoy:

- GPS Power on/off
- AMODEM power on/off (acoustic modem)
- WLAN power on/off (controls Ubiquiti radio and 2174 transceiver)
- CF2 status (responds with latest status sentence as recorded to flash)

Embedded in the seafloor package (SRA or RAVA subsurface pressure case) is a separate CF2 microcontroller interface that controls power to the CPU and other components in a similar manner to the buoy controller. The subsurface package contains an FEI-Zyfer 380 GPS Time and Frequency interface, a PNI Prime compass module, and a CF2 microcontroller interface that controls power to the CPU and other components. The FEI-Zyfer 380 is synchronized to GPS prior to deployment and contains an oven-controlled crystal oscillator that maintains a precise sampling clock and real-time clock after deployment. The Patton 2174 transceiver pair (one in the buoy and one in the subsurface package), provide for Ethernet communication at rates up to 100 Mb/s through a single twisted pair in the umbilical cable. Basic command and control communication is provided by an additional twisted

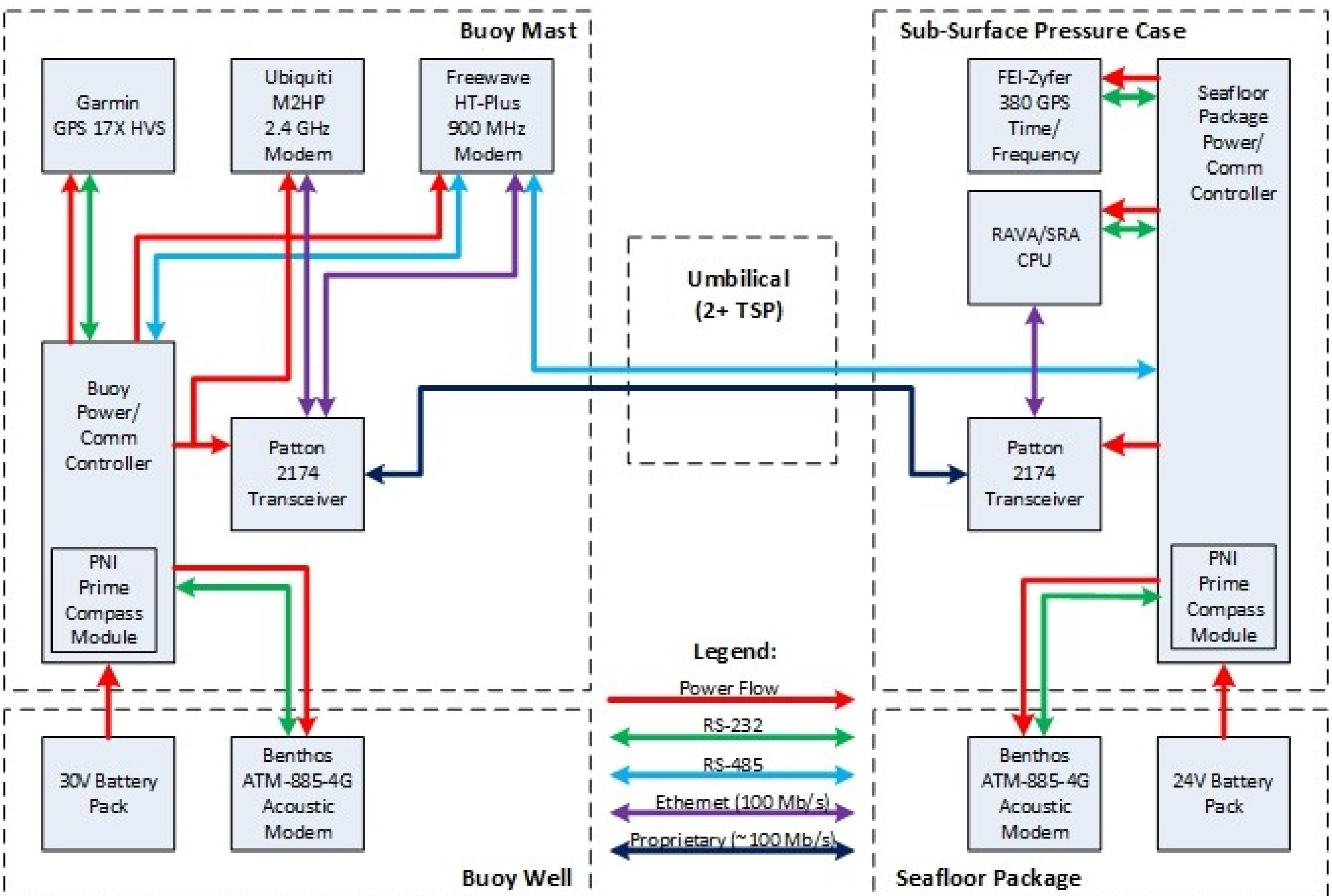

Fig. 2. Block Diagram of Buoy Communication Node

pair in the umbilical that allow for RS485 communication between the second serial port of the Freewave HT-Plus 900 MHz radio modem in the buoy and the CF2 in the subsurface package.

The following are sample remote commands for a RAVA/SRA subsurface package:

- CPU power on now
- CPU power off now (initiates CPU shutdown followed by power off)
- CPU power on/off HH:MM:SS (preprogrammed)
- CPU status (CPU responds with recording start time, sample rate, and number of channels)
- CPU restart recording fs=NNNNNN (after sample rate change)
- GPS power on/off (controls FEI-Zyfer 380)
- AMODEM power on/off (acoustic modem)
- WLAN power on/off (controls 2174 transceiver)
- CF2 status (responds with latest status sentence as recorded to flash)
- CF2 set gain=NN (0 – 24 dB)
- CF2 set freq=NNN (Fs = 25, 50 or 100 kHz)

Ship Communication Node

The ship communication node consists of a GPS receiver, a Freewave HT-Plus 900 MHz radio modem, a Ubiquiti M2HP 802.11 radio, and two Patton 2174 Ethernet transceivers. A functional block diagram of this node is shown in Fig. 3. The node is intended to be installed as high on the ship as possible, while keeping the radios near the antennas to reduce the antenna cable lengths and associated signal losses. As with the buoy node, the 2174 transceivers in the ship node provide a high data rate, reliable Ethernet link through a single pair in the umbilical cable that is resistant to crosstalk and external noise. By having two 2174 transceivers (one for each radio), the Ethernet link can be switched between the Ubiquiti and Freewave radios by changing connections in the ship lab. The ship node is contained in a watertight enclosure that is ordinarily mounted on the ship mast with omni-directional antennas mounted on top for the 900 MHz and 2.4 GHz (802.11) radios. Connecting the radios to directional antennas mounted external to the enclosure is also possible to expand the radio range.

Power And Communication Controller

A separate power and communication controller is contained in the buoy and in the subsurface package. Each is composed of a custom built circuit board with a CF2 microcontroller, four port UART, eight channel A/D, and assorted relays and DC/DC converters to control power to the individual components.

In the buoy, the CF2 functions as the main communications controller for command and control, and interfaces directly to the first serial port on the Freewave HT-Plus radio via RS-485. The remaining 4 serial ports for the CF2 interface to the GPS, acoustic modem (if present), and

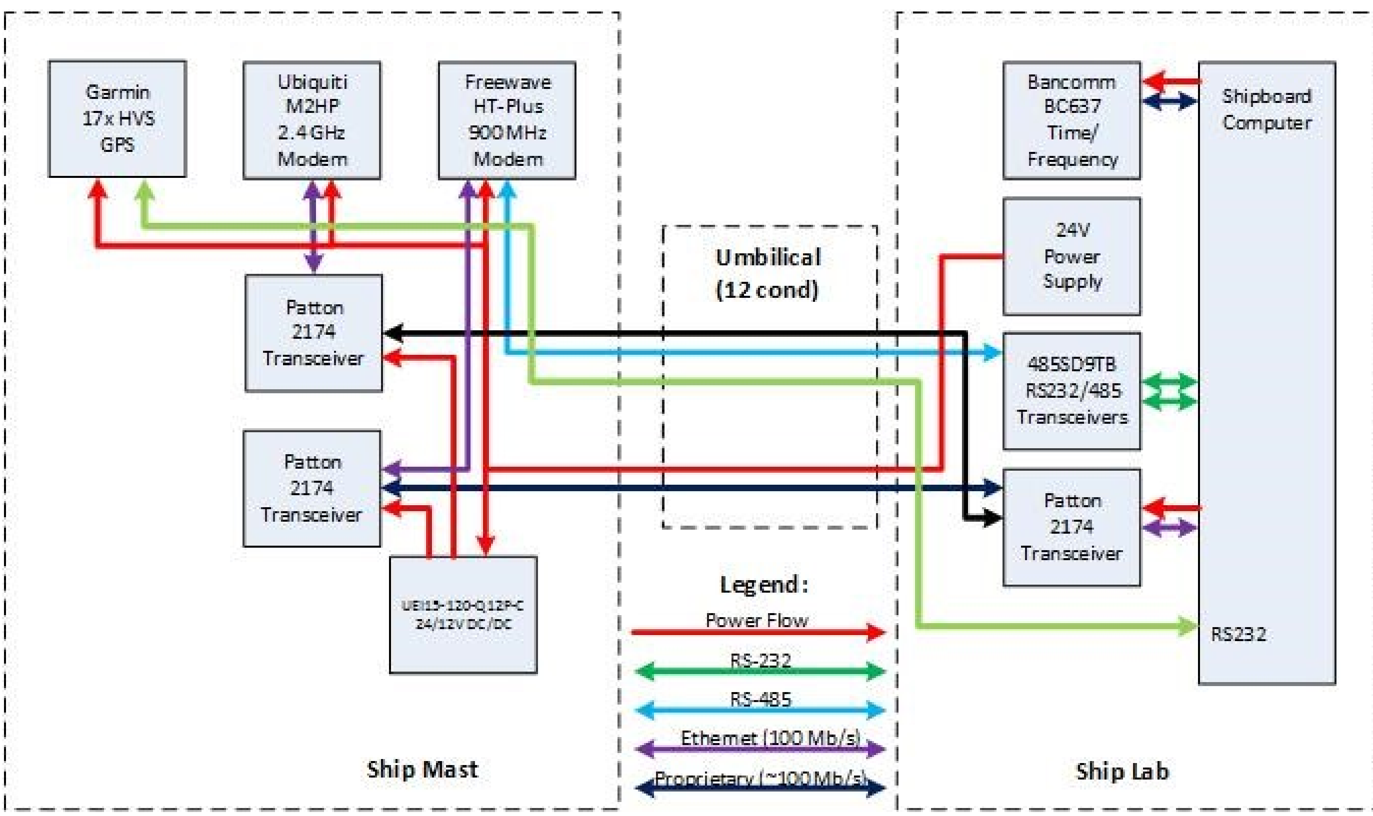

Figure 3. Block Diagram of Ship Communication Node

compass module. The relays control power to the GPS, acoustic modem, Freewave modem, Ubiquiti radio, and 2174 transceiver.

In the subsurface package, the CF2 also functions as the main communications controller and interfaces directly to the second serial port on the Freewave HT-Plus radio via RS-485 using one twisted pair in the umbilical. The remaining four serial ports for the CF2 interface to the GPS, CPU, acoustic modem (if present), and compass module. The relays control power to the CPU, GPS, acoustic modem, Freewave modem, Ubiquiti radio, and 2174 transceiver. The CF2 also interfaces to a shift register on the signal conditioning board to control channel gain (0 to 24 dB) and sample frequency (25, 50 or 100 kHz).

For both the surface buoy and the subsurface package, the CF2 microcontroller records all commands, status changes, and errors to a log file on a flash card. In addition, the CF2 records the following information to a separate file on the flash card every 10 seconds:

- System ID (i.e. BUOY1, RAVA1, etc.)
- Julian day and GMT
- GPS position (buoy only)
- Gain and sample rate (RAVA/SRA only)
- Power status of controlled devices (on or off)
- Battery Volts, Amps, Watts and running Watt-hours
- Heading, roll and pitch

RADIO MODEMS

The Freewave 900 MHz HT-Plus radio modems provide the primary communication link between the research ship and the surface buoy and subsurface package. The HT-Plus provides an Ethernet connection and two serial ports that operate in RS-232 or RS-485 mode. Basic command, control and status information is transferred through the modem serial ports to the CF2 microcontrollers in the buoys and subsurface packages. A single serial port on the shipboard gateway modem is configured to communicate in a multicast mode to both serial ports on all endpoint modems, allowing for the communication with all deployed systems simultaneously. Commands are directed to a particular buoy or subsurface package by address (i.e. BUOY1, RAVA2, etc.), or broadcast to all deployed systems using the BDCST address. The CF2 in the subsurface package is connected to the modem serial port through the umbilical cable using RS-485 to reduce crosstalk.

In addition to the two serial ports, the Freewave HT-Plus provides an Ethernet port which allows for a low data rate Ethernet connection to the subsurface CPU. Though the data rate is low, the connection is sufficient to allow for the transfer of small (~1MB) data files to confirm system operation. Power consumption for the Freewave HT-Plus is 850 mW idle, 1.8 W receiving, and 6.6 W transmitting.

The Ubiquiti Bullet M2HP is a small, inexpensive 802.11 b/g radio that provides high bandwidth wireless Ethernet over relatively long ranges. Though the M2HP is sold as an outdoor radio, it is not adequately sealed for marine use and must be protected inside a secondary enclosure. The manufacturer documentation describes up 100 Mbps over multi-kilometer ranges, and the tradeoffs between throughput and range are described in more detail later in the paper. The M2HP is highly configurable using the built-in AirOS software, and the network can be configured in a bridge or router topology. Each radio can be individually configured as a client or an access point.

The Ubiquiti M2HP radio modems in combination with the 2174 Ethernet transceivers provide a high throughput Ethernet connection between computers on the ship and the CPU in the subsurface package. Since the Ubiquiti radio modem and both Patton 2174 Ethernet transceivers must be powered on for the high-bandwidth Ethernet connection to be active, all of these devices are off by default and only turned on by the CF2 when needed. The combined power consumption for the Ubiquiti M2HP radio modem and Patton 2174 Ethernet transceiver is 10 – 15 Watts, depending on operational mode (power consumption is higher when the radio is transmitting versus receiving).

PATTON 2174 TRANSCEIVERS

The 2174 Ethernet transceiver (Patton Copperlink Ethernet Extender Model 2174) eliminates most of the limitations of Ethernet through the umbilical cable for both the ship communication node and between the surface buoy and the subsurface package. Standard Ethernet has a maximum cable length of 100 meters, requires twisted pair cable with specific impedance properties, and is sensitive to noise and crosstalk from external sources (particularly in a noisy environment like a ship). The Model 2174 can provide data rates of 4 Mb/s over a single twisted pair (shielded or unshielded) of length up to 3 km, and can provide higher data rates up to 168 Mb/s over shorter cables (75 m). The 2174 is a single circuit board that draws 4 Watts at 12 VDC, so is easily integrated into existing systems. The 2174 is a reliable and cost-effective, off-the-shelf solution to providing Ethernet connectivity through a single twisted pair cable and can tolerate a wide variety of cable lengths and properties.

Figure 4. Surface Buoy as Configured for TREX13

Performance During 2013 Target And Reverberation Experiment

The 2013 Target and Reverberation Experiment (TREX13) near Panama City, Florida provided the first opportunity to extensively test the communication nodes at sea. Fig. 4 shows the surface buoy as configured for TREX13, which is basically a modified version of the Mooring Systems G-300 Surface Buoy. The subsurface well has a 6" ID and contains three 30V alkaline battery packs that can power the buoy for up to 21 days. The surlyn foam hull is 38" in diameter and 10" high, and provides 200 lbs. of net buoyancy when the well is loaded with batteries. The flange on the top of the well (above the flotation collar), mounts to the aluminum mast structure and has four connectors that currently provide the connection to the subsurface umbilical cable and to external power (two connectors remain as spares). The watertight enclosure above the radar reflector on the mast contains the buoy communication node with the radio modems, power and control board and related electronics. The GPS, 2.4 GHz and 900 MHz antennas are mounted directly to the top surface of the enclosure.

During TREX13, the Freewave modems were configured with a 6 dBi collinear omni-directional antenna at a height of 1-2 m on the buoy, and an identical antenna with a height of 6-8 m on the ship. The Hyperlink HGV-906U antenna was chosen because it is a rugged construction and a good compromise between a 30 degree vertical beam width and 6 dBi gain. Using this configuration for the Freewave HT-Plus 900 MHz radio modems, consistent command and control communication was maintained within a range of 6-7 km between the ship and buoy. During the course of the experiment, this command link was used to remotely modify the receiver gain for the 32 hydrophones on each RAVA array, as well as monitor operational parameters such as battery voltage on the buoy and subsurface package, GPS position of the buoy, and operational mode and error status of the RAVA CPU.

When the Freewave modems were configured to also provide Ethernet, a consistent connection and FTP data rate of 250 kb/s was available anywhere within the same 6-7 km range. This low data rate Ethernet channel was used to transfer small (1 MB) data files from the RAVA CPU to confirm system operation. The antenna height aboard ship was limited by the relatively small size of the RV *Walton Smith,* so for future deployments on larger ships we can experiment with greater antenna height and directional antennas to expand the radio range.

The configuration of the Ubiquiti M2HP 2.4 GHz 802.11 radio modems was similar to that of the Freewave modems; with a 6 dBi collinear antenna at a height of 1-2 m on the buoy and an identical antenna with a height of 6-8 m on the ship. The Hyperlink HGV-2406U 2.4 GHz antenna provides a rugged construction and a good compromise between a 28 degree vertical beam width and 6 dBi gain. With this configuration, consistent FTP data rates of 30 – 40 Mb/s were measured at a range of ~1 km. At a range of 2 km, the data rate dropped to 10 – 20 Mb/s. Up to the maximum range of 3 km, the data rate drops to 2 – 10 Mb/s. At the 1 km range, 1 minute recorded data files (100 MB) on the RAVA CPU could be transferred by FTP faster than they were being recorded by the sampling system.

Also at the 1 km range, a test was performed to show that the time series from a single channel on one RAVA array can be broadcast in real time over the 2.4 GHz channel and played through a speaker in the ship lab as well as displayed on a spectrum analyzer. The single channel time series is placed in a UDP data stream by the RAVA CPU, transferred through the Ethernet link between the subsurface CPU and ship where it is received by a computer in the ship lab and played through a DAC channel to the speaker. Such a configuration can be used to monitor the transmissions from other deployed acoustic systems in the area.

During TREX13, testing was also performed using external 2 Watt, 2.4 GHz 802.11 amplifiers (Hyperamp HA2402GXI-NF) on both the ship and buoy. The amplifiers did not significantly increase the maximum range, and appeared to limit the maximum throughput at close range (~ 1 km). Since the Ubiquiti M2HP transmits at a maximum power of 630 mW (28 dBm), an external 2 W amplifier does not appear to provide a benefit. The preference is to not use external amplifiers since they increase the size, power consumption, and complexity (and resulting likelihood of failure) of the system.

Summary

A communication system has been described which provides remote control, status, and access to recorded data for existing transducer array systems when deployed at sea. The main components of the system are a ship communication node and a small surface buoy with a similar communication node. The system utilizes two separate radio modem technologies to provide a high reliability, long range, but lower bandwidth channel as well as a close range, high bandwidth secondary channel. Testing during the TREX13 experiment showed that these systems can effectively allow for monitoring of array status, remote modification of system operating parameters, power down and placement into low power states, and the remote transfer of recorded data files for on-ship analysis.

Acknowledgments

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