AUTOMATED METEOROLOGICAL AND OCEANOGRAPHIC SYSTEM (AMOS)

Presented by
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UNIVERSITY OF MIAMI
AT INMARTECH 2014
OREGON STATE UNIVERSITY, CORVALLIS, OREGON
OCEANSCOPE

• AMOS was designed and deployed for the OceanScope project
• Development supported by Royal Caribbean Cruises Limited, the parent company of Royal Caribbean International and Celebrity Cruises
• The automated observing system is a pilot program initiated by the formal partnership between RCCL and the University of Miami
AMOS BENEFITS

• Uses “off-the-shelf” components
• Uses National Instruments cRIO Real Time Controller
• Program and data are stored in solid-state memory, therefore eliminating rotating storage with high potential for failures
• Critical functions are executed in an FPGA, improving reliability
• Written in LabVIEW Graphical Programming Language
• Leak detection: automatic shutdown with audible and visual alarms
• Pressure monitoring: programmable over pressure level signals automatic shutdown
AMOS BENEFITS CONT’D…

• Bypass valve allows regulation of system pressure and flow
• Bio-fouling controlled through fresh water flushing and mechanical wipers
• Pump monitoring provides protection if air bound due to high sea conditions
• Exclusion zones – system turns on and off automatically based on predetermined coordinates – reducing system contamination in ports and eliminates ship’s “discharge”
• Network Camera – provides real time observation of system and valve states
• Remote monitoring
  • Allows diagnosis of problems with system state
  • Permits instruction of crew members to perform tasks/maintenance on the system
RCCL – EXPLORER OF THE SEAS

- Legacy System installed in 2000
- System was manned from 2000 - 2007
- Redesigned in 2008
- Included fully automated functionality

INSTRUMENTATION
- AMOS
- ADCPs (38 & 150 kHz)
- MAERI

- Decommissioning science equipment in February 2015
- Moving instrumentation to Freedom of the Seas

FUN FACTS – Size and capacity comparison
137,308 GT  311m (1,020 ft)  3,114 passengers  1,180
USS NIMITZ

FUN FACTS – Size and capacity comparison
100,020 GT  332.8m (1092 ft)  3200 Ship’s company, Air wing
RCCL – FREEDOM OF THE SEAS

FUN FACTS – Size and capacity comparison
154,407 GT 339m (1,112 ft) 3,634 passengers 1,360

• Replaces EXPLORER of the SEAS science installation
• Scouting trip scheduled early November 2014
  • Meet staff – Environmental and Engineering officers and crew
  • Find potential locations for equipment
  • Discuss timeline, assistance required, potential issues
• Dry dock Jan 2015
  • Bow intake and discharge
  • Seachests for ADCPs
AMOS PARAMETERS
EXPLORER OF THE SEAS

- Sea Surface Temperature
- Sea Surface Salinity
- Turner Designs C6 Fluorometer
  - Chlorophyll $a$
  - DOM
- Auxiliary system
  - $pCO_2$
RCCL – ALLURE OF THE SEAS

FUN Facts – Size and capacity comparisons
225,282 GT  362m (1187 ft)  6,296 passengers  2,384 c

- Installation in 2012
- AMOS MK III
- Seawater intake located mid-ship, tapped from ship’s main seachest
- Met data provided by ship’s sensors
- Dry dock in 2015
  - Relocate AMOS to bow thruster space
  - Install 75 kHz ADCP
  - Auxiliary pCO₂
CELEBRITY – EQUINOX

FUN FACTS – Size and capacity comparison
121,878 GT  317.2m (1,041ft)  2,850 passengers 1,250 crew

- Latest Cruise Ship Installation
- Cadiz, Spain
  - May 2014
NEWEST AMOS INSTALLATION – EQUINOX

• Located in bow thruster space
• Dedicated through hull valves

PARAMETERS
• Sea Surface Temperature
• Sea Surface Salinity
• Turner Designs C6
  • DOM
  • Chlorophyll a
  • Turbidity
  • Phycoerythrin (Cyanobacteria)
  • Crude Oil
  • Optical brighteners (detergents)
• Auxiliary System
  • pCO₂ (soon)
INSIDE THE BOXES

Dry Box

Wet Box
NI cRIO-9024 Real-Time Controller

- Embedded controller runs LabVIEW Real-Time for deterministic control, data logging, and analysis
- 800 MHz processor, 4 GB nonvolatile storage, 512 MB DDR2 memory
- Dual Ethernet ports with embedded Web and file servers for remote user interfacing 10/100 & 10/100/1000
- Hi-Speed USB host port for connection to USB flash and memory devices
- RS232 serial port for connection to peripherals; dual 9 to 35 VDC supply inputs
- –20 to 55 °C operating temperature range
- Operating humidity
  - (IEC 60068-2-56) 10 to 90% RH, noncondensing
- Vibration
  - Random (IEC 60068-2-64) 5 grms, 10 to 500 Hz
  - Sinusoidal (IEC 60068-2-6) 5 g, 10 to 500 Hz
- Operating Shock
  - (IEC 60068-2-27) 30 g, 11 ms half sine, 50 g, 3 ms half sine, 18 shocks at 6 orientations
NI cRIO–9114 RECONFIGURABLE CHASSIS

- 8-Slot, Virtex-5 LX50 cRIO Reconfigurable Chassis
  - Number of flip-flops 51,840
  - Number of 6-input LUTs 28,800 (Look Up Tables)
  - Embedded block RAM 3,456 kbits
- LabVIEW FPGA automatically synthesizes electrical circuit implementation
- cRIO extreme industrial certifications and ratings
- cRIO FPGA core executes at default rates of 40 MHz

Example
I/O MODULES INSTALLED

- NI 9208 +/- 21.5 mA, Current Analog Input, 500 S/s. 16 Ch Module
- NI 9425 24 V, Sinking Digital Input, 32 Ch Module
- NI 9265 0 to 20 mA, Analog Output, 100 kS/s/ch, 4 Ch Module
- NI 9485 SSR Relay, 60 VDC/30 Vrms, 750 mA, 8 Ch Module
- NI 9481 (3) 4-Channel Relay [30 VDC (2 A), 60 VDC (1 A), 250 VAC (2 A)]
REMOTE PANEL

CONFIGURATION DISPLAY
REMOTE PANEL

EXCLUSION ZONES
SEA–BIRD SBE 38 DIGITAL OCEANOGRAPHIC THERMOMETER

- **Range:** -5 to +35 °C
- **Initial Accuracy**: ± 0.001 °C (1 mK)
- **Resolution**: 0.00025 °C (0.25 mK)
- **Stability**: 0.001 °C (1 mK) in six months, certified
- **Response Time**: 500 milliseconds
- **Self–heating Error**: less than 200 µK
## SEA-BIRD SBE 45 MICROTHERMOSALINOGRAPH

<table>
<thead>
<tr>
<th></th>
<th>Conductivity</th>
<th>Temperature (°C) *</th>
<th>Salinity (PSU), typical</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measurement Range</strong></td>
<td>0–7 S/m (0–70 mS/cm)</td>
<td>-5 to 35</td>
<td>-</td>
</tr>
<tr>
<td><strong>Initial Accuracy</strong></td>
<td>± 0.0003 S/m (0.003 mS/cm)</td>
<td>± 0.002</td>
<td>± 0.005</td>
</tr>
<tr>
<td><strong>Typical Stability (per month)</strong></td>
<td>0.0003 S/m (0.003 mS/cm)</td>
<td>0.0002</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>0.000001 S/m (0.0001 mS/cm)</td>
<td>0.0001</td>
<td>0.0002</td>
</tr>
<tr>
<td><strong>Calibration Range</strong></td>
<td>0–6 S/m (60 mS/cm), physical calibration over the range 2.6 to 6 S/m (26–60 mS/cm), plus zero conductivity (air)</td>
<td>+1 to +32 °C</td>
<td></td>
</tr>
</tbody>
</table>
SBE 360
CAROUSEL SAMPLER
ABOARD ALLURE OF THE SEAS
The C6™ Multi-Sensor Platform integrates up to six Cyclops-7™ fluorescence and turbidity sensors for extended or short-term deployments. The C6™ provides individual automatic gain control, calibration, and digital data reporting for each Cyclops-7™ sensor. Each C6 comes with factory-installed temperature and pressure sensors.
<table>
<thead>
<tr>
<th>Application</th>
<th>Minimum Detection Limit</th>
<th>Dynamic Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDOM/FLDM</td>
<td>0.15 ppb 0.5 ppb</td>
<td>0-1250 ppb 0-5000 ppb</td>
</tr>
<tr>
<td>Chlorophyll in vivo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue Excitation</td>
<td>0.025 μg/L 0.5 μg/L</td>
<td>0-500 μg/L &gt;500 μg/L</td>
</tr>
<tr>
<td>Red Excitation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluorescein Dye</td>
<td>0.01 ppb</td>
<td>0-500 ppb</td>
</tr>
<tr>
<td>Oil - Crude</td>
<td>0.2 ppb</td>
<td>0-2700 ppb</td>
</tr>
<tr>
<td>Oil - Fine</td>
<td>10 ppb 10 ppm</td>
<td>&gt;10,000 ppb &gt;100 ppm</td>
</tr>
<tr>
<td>Optical Brighteners</td>
<td>0.6 ppb</td>
<td>0-15,000 ppb</td>
</tr>
<tr>
<td>Phycocyanin (Freshwater Cyanobacteria)</td>
<td>2 ppb</td>
<td>0-40,000 ppb</td>
</tr>
<tr>
<td>Phycoerythrin (Marine Cyanobacteria)</td>
<td>0.15 ppb</td>
<td>0-750 ppb</td>
</tr>
<tr>
<td>PTSA Dye</td>
<td>0.1 ppb</td>
<td>0-650 ppb</td>
</tr>
<tr>
<td>Rhodamine Dye</td>
<td>0.01 ppb</td>
<td>0-1000 ppb</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>3 ppb</td>
<td>&gt;20,000 ppb</td>
</tr>
<tr>
<td>Turbidity</td>
<td>0.05 NTU</td>
<td>0-3000 NTU</td>
</tr>
</tbody>
</table>
MSRC VDB–1 VORTEX DEBUBBLER

• Developed at Stony Brook University’s Marine Sciences Research Center (MSRC)

• 2 inch diameter, internal volume approximately 0.5 liter. Suggested flow rate 9 to 12 liters per minute (2.4 – 3.2 gallons/min).

• Contact:
  Thomas.Wilson@stonybrook.edu
DIGITAL LOGGERS INC – WEB CONTROLLED, 8 CHANNEL DIN RELAY

Allows remote power cycling of individual instrumentation
- cRIO
- SBE 38 Remote Temperature Sensor
- SBE 45 MicroTSG
- Turner Designs C6
LOAD CONTROLS PMP-25

- Monitors Load on Pump
- Dry Running
- Overload
- Cavitation
- Bearing Failure
PRESSURE AND FLOW

Omega Absolute Pressure Gauge

- Monitors pressure at multiple points
  - Pre-strainer
  - Post-strainer
  - Instrument Manifold
- 316 Stainless Steel Wetted Parts
- 4–20 mA output
- Loop Powered

Dynasonics Clamp-On Transit Time Ultrasonic Flow Meters

- Monitors pump and sensor flow externally
- No wet or moving parts (no fouling)
- Outputs
  - Serial
B&B ELECTRONICS ESR904 ETHERNET TO SERIAL CONVERTER

- Supports either UDP or TCP protocols
- Allows transmitting to and receiving from multiple IP addresses

- Used to interface ship’s bridge sensors (GPS, Gyro & Meteorological) to AMOS
- Internal AMOS interface
  - SBE 38 Remote Temperature Sensor
  - SBE 45 Microthermosalinograph
  - Turner C6
AMOS BLOCK DIAGRAM

**Bow Thruster Room Installation**
- B&B Electronics 8-Port Unmanaged Ethernet Switch Model-ESW-108
- Toshiba Network Camera Model IK-WB16A-W
- National Instruments dRIO-9022 Industrial Controller
- B&B Electronics 4-Port Serial Port Server Model-ESR-904
- Digital Loggers Inc. Network Controlled Relays Model-DIN Relay II
- Store Room 01-1-006

**Bridge Installation**
- B&B Electronics 5-Port Unmanaged Ethernet Switch Model-ESW-105
- Toshiba Network Camera Model IK-WB16A-W
- B&B Electronics 4-Port Serial Port Server Model-ESR-904
- AMOS Laptop FTP Server Model-FTPServer
- NTP Server Windows Server 2012
- Store Room 01-1-006

**Ships Network**
- VendorNet

**Ships Shoreside Data Link**
- Science Supplied Network

**Bridge Console**
- Serial Navigation Feed
- Serial Meteorological Feed
Data stored locally on cRIO, transferred hourly by FTP to AMOS laptop

Data stored on AMOS laptop on a RAID drive

Satellite Connection – Ship to Shore

Data pulled by FTP from AMOS laptop to RSMAS Server

Data made available to registered science users
THANK YOU

• Royal Caribbean/Celebrity Cruise Lines
• Crew of:
  • Explorer of the Seas
  • Allure of the Seas
  • Equinox
  • Freedom of the Seas
• NOAA
• NSF
• NASA
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• Kevin Sullivan – pCO₂ – kevin.sullivan@noaa.gov