

# AUTOMATED METEOROLOGICAL AND OCEANOGRAPHIC SYSTEM (AMOS)

*Presented by*

AUBRI VAIL

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

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

- 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



# 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<sub>2</sub>





# RCCL – ALLURE OF THE SEAS

FUN Facts – Size and capacity comparisons

225,282 GT 362m (1187 ft) 6,296 passengers 2,384

- 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 pCO<sub>2</sub>



# CELEBRITY – EQUINOX

FUN FACTS – Size and capacity comparison

121,878 GT 317.2m (1,041ft) 2,850 passengers 1,250 c

- Latest Cruise Ship Installation
- Cadiz, Spain
  - May 2014



# NEWEST AMOS INSTALLATION – EQUINOX

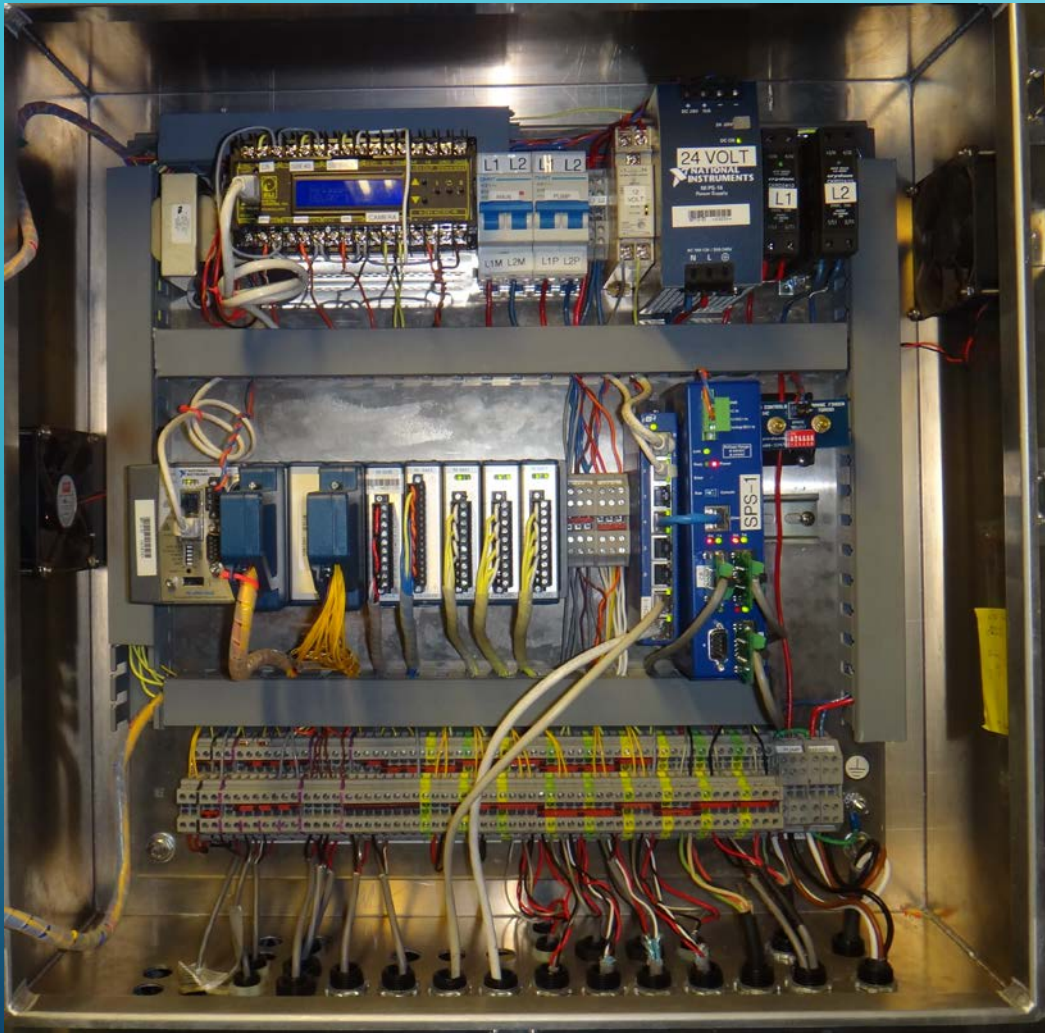


- Located in bow thruster space
- Dedicated through hull valves

## PARAMETERS

- Sea Surface Temperature
- Sea Surface Salinity
- Turner Designs C6
  - DOM
  - Chlorophyll *a*
  - Turbidity
  - Phycoerythrin (Cyanobacteri
  - Crude Oil
  - Optical brighteners (detergents)
- Auxiliary System
  - pCO<sub>2</sub> (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  $\pm 21.5$  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

# SYSTEM STATUS

UM RT Main.vi on 192.168.13.152 [Remote Panel] - Controller

File Edit View Project Operate Tools Window Help

1 System Time 19:10:23 2014/11/05

Control Mode Automatic

State Idle

Pump Power OFF

Pump State Off

Bow State Off

GPS Position Valid

RIP

Inside Exclusion Region

Fault Status DRY

User Info

(STOP) (AUTO) (RUN) (E-STOP) (RESET) (ALARM) Silence

FTP File (Direct) FTP File (Queued) System Halt

Region Open Water

Instrument Data

System Status

GPS Data

Configuration

Regions

Instrument Status

RT Data

Program Status

ftp

Analog Values

Pre-Strainer Pressure	0.00
Post-Strainer Pressure	0.00
Pump Flow	0.00
Motor Minder Out	0.00
Instrument Flow	0.00
Manifold Pressure	0.00
Aux Flow	0.00
Aux Pressure	0.00
Analog Leak Out	0.00
Bypass Feedback	0.000

Closed Open

Main Supply Valve

Discharge Valve

Fresh Water Valve

Aux Supply Valve

Aux Discharge Valve

Bypass Valve

Fault 0

Fault 1

Fault 2

Fault 3

Ship Ready 1

Ship Ready 2

Manifold Pressure

System Fault

0

Box Panel Button States

- Stop
- Auto Button
- Run
- EM Stop Button
- Reset Button
- Alarm Silence Button

Box Panel Light States

- Stop
- Auto
- Run
- Reset
- Alarm
- Silence

<C> Server: 192.168.13.152 <



# REMOTE PANEL

# CONFIGURATION ON DISPLAY

UM RT Main.vi on 192.168.13.152 [Remote Panel] - Controller

File Edit View Project Operate Tools Window Help

1 System Time 19:14:35 2014/11/05

Control Mode Automatic

State Idle

Pump Power OFF

Pump State Off

Bow State Off

GPS Position Valid

RIP

Inside Exclusion Region

Fault Status DRY

User Info

(STOP) (AUTO) (RUN) (E-STOP) (RESET) (ALARM) Silence

FTP File (Direct) FTP File (Queued) System Halt

Region Open Water

Instrument Data

Program Status

System Status GPS Data Configuration Regions Instrument Status RT Data

Auto Operation Enabled

In Port Reboot

Initial Flush Duration (S) 180

Backflush Duration (S) 60

Manifold Flush Duration (S) 180

Debubbler Flush Duration (S) 180

PCO2 Flush Duration (S) 180

Valve Timeout (S) 30

Bypass Valve Timeout (S) 20

Airbound Retry Wait (S) 30

Airbound Restart Wait (S) 600

Airbound Retry Limit 6

Airbound Reset Time (S) 1800

Airbound Persist Time (S) 60

Debubbler Enable

Auxiliary Enable

MAC Address 005C 3830 5C32

Pump On Timeout (S) 300

Message Timeout (S) 20

Enable At Sea Flush

Enable Flow Check

File Interval (M) 60

File Path c:\Data

Filename Root Bow

Log Interval (S) 10

NTP Time Server IP Address 129.6.15.30

NTP Time Server Port 123

Region Entry Lock Delay(S) 20

Region Exit Lock Delay(S) 20

Publish RT Data

State Log

GPS Delta T (s) 0

Use GPS Time

Config File Path

Manifold Overpressure 35.00

Bypass Open % 50

BypassMaxError 4

HLL Path

Pump Thresholds

Operational Settings

High Load Low Load Pump Off

110 25 4

Use GPS Time

In Port Reboot

GPS Delta T (S) 3

<C> Server: 192.168.13.152

# REMOTE PANEL

# EXCLUSION ZONES

UM RT Main.vi on 192.168.13.152 [Remote Panel] - Controller

File Edit View Project Operate Tools Window Help

1 System Time 19:13:04 2014/11/05

Control Mode Automatic

State Idle

Pump Power OFF

Pump State Off

Bow State Off

GPS Position Valid

RIP

Inside Exclusion Region

Fault Status DRY

User Info

(STOP) (AUTO) (RUN) (E-STOP) (RESET) (ALARM) Silence

FTP File (Direct) FTP File (Queued) System Halt

Region Open Water

Instrument Data Program Status ftp

System Status GPS Data Configuration Regions Instrument Status RT Data

Region Lock State

No Lock

Region Open Water Home Port

EndTime 2:08:59.286 PM 11/5/2014 Entry Time(S) 20 Exit Time(S) 20

Region Definition Array

Home Port	Port Description	Latitude	Longitude	Latitude 2	Longitude 2
<input type="checkbox"/>	Ireland Island, Bermuda	32.40700	-64.88300	32.21700	-64.63800
<input type="checkbox"/>	Freeport, Grand	26.52700	-78.77800	26.51200	-78.63400
<input type="checkbox"/>	George Town, Grand	19.31500	-81.39500	19.28500	-81.38500
<input type="checkbox"/>	Halifax, Nova Scotia	44.65500	-63.57500	44.56500	-63.45500
<input checked="" type="checkbox"/>	Ft. Lauderdale, FL	26.12685	-80.1385	26.06027	-80.0719
<input type="checkbox"/>	Maimi, FI, USA	25.78700	-80.18500	25.75200	-80.08300
<input type="checkbox"/>	Nassau, Bahama	25.09300	-77.35900	25.07800	-77.32800
<input type="checkbox"/>	New London, CT, USA	41.36200	-72.10500	41.30000	-72.06500

<C> Server: 192.168.13.152

# SEA-BIRD SBE 38 DIGITAL OCEANOGRAPHIC THERMOMETER



- Range:  $-5$  to  $+35$  °C
- Initial Accuracy <sup>1</sup>:  $\pm 0.001$  °C (1 mK)
- Resolution:  $0.00025$  °C (0.25 mK)
- Stability:  $0.001$  °C (1 mK) in six months, certified
- Response Time <sup>2</sup>: 500 milliseconds
- Self-heating Error: less than  $200$   $\mu$ K

# SEA-BIRD SBE 45 MICROTHERMOSALINOGRAPH



	Conductivity	Temperature (°C) *	Salinity (PSU), typical
<b>Measurement Range</b>	0–7 S/m (0–70 mS/cm)	–5 to 35	–
<b>Initial Accuracy</b>	± 0.0003 S/m (0.003 mS/cm)	± 0.002	± 0.005
<b>Typical Stability (per month)</b>	0.0003 S/m (0.003 mS/cm)	0.0002	0.003
<b>Resolution</b>	0.00001 S/m (0.0001 mS/cm)	0.0001	0.0002
<b>Calibration Range</b>	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)	+1 to +32 °C	



SBE 360  
CAROUSEL  
SAMPLER  
ABOARD  
ALLURE OF  
THE SEAS

# TURNER DESIGNS C6 MULTI-SENSOR PLATFORM WITH MECHANICAL WIPER



- 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.

# TURNER DESIGNS SENSORS AVAILABLE



Application	Minimum Detection Limit	Dynamic Range
CDOM/FDOM	0.15 ppb 0.5 ppb	0-1250 ppb 0-5000 ppb
Chlorophyll <i>in vivo</i> Blue Excitation Red Excitation	0.025 µg/L 0.5 µg/L	0-500 µg/L >500 µg/L
Fluorescein Dye	0.01 ppb	0-500 ppb
Oil - Crude	0.2 ppb	0-2700 ppb
Oil - Fine	10 ppb 10 ppm	>10,000 ppb >100 ppm
Optical Brighteners	0.6 ppb	0-15,000 ppb
Phycocyanin (Freshwater Cyanobacteria)	2 ppb	0-40,000 ppb
Phycoerythrin (Marine Cyanobacteria)	0.15 ppb	0-750 ppb
PTSA Dye	0.1 ppb	0-650 ppb
Rhodamine Dye	0.01 ppb	0-1000 ppb
Tryptophan	3 ppb	>20,000 ppb
Turbidity	0.05 NTU	0-3000 NTU

# 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](mailto: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

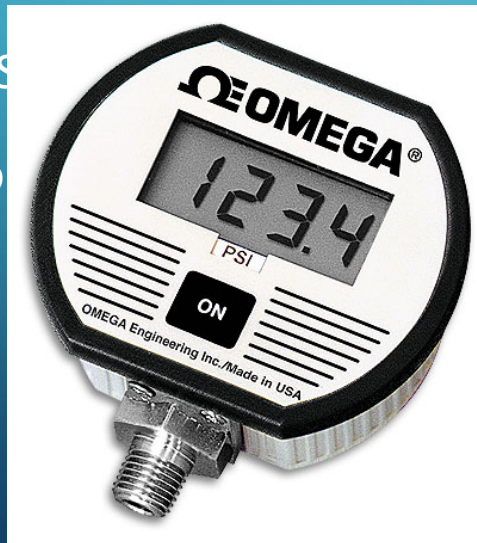


- Monitors Load on Pump
  - Dry Running
  - Overload
  - Cavitation
  - Bearing Failure

# PRESSURE AND FLOW

## Omega Absolute Pressure Gauge

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



## Dynasonics Clamp-On Transit Time Ultrasonic Flow



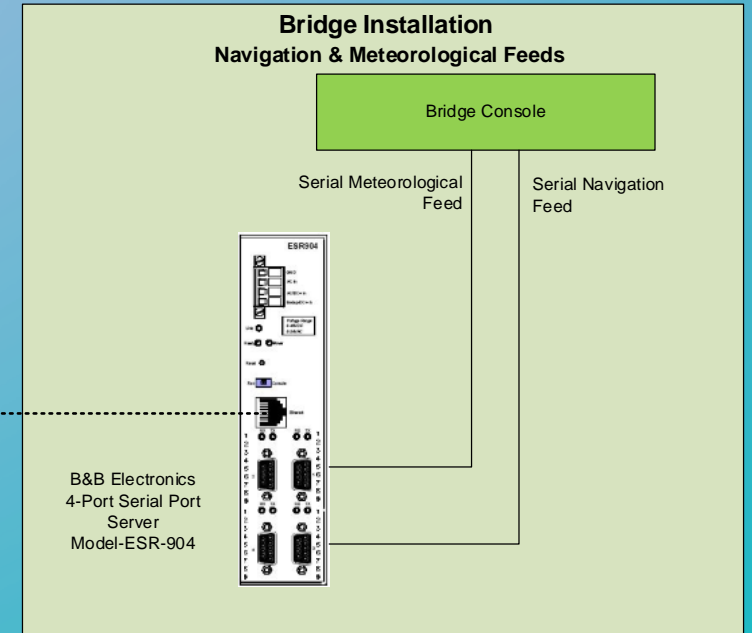
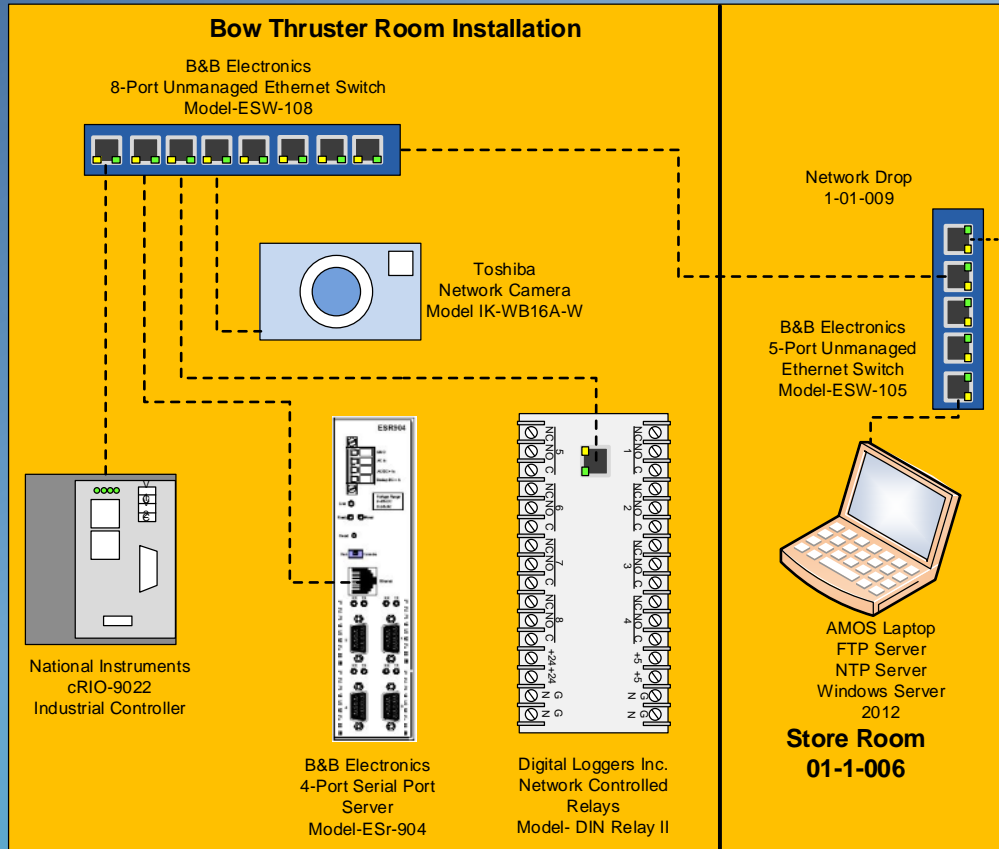
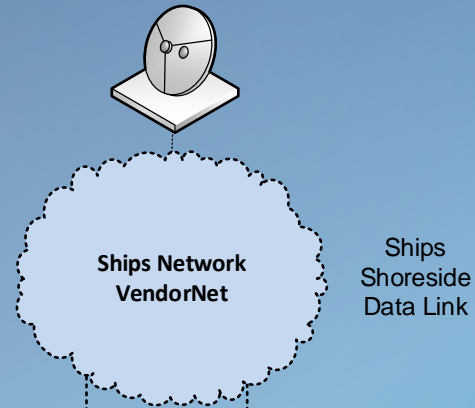
- Monitors pump and sensor flow externally
- No wet or moving parts (no fouling)
- Outputs
  - Serial

# B&B ELECTRONICS ESR904 ETHERNET TO SERIAL CONVERTER



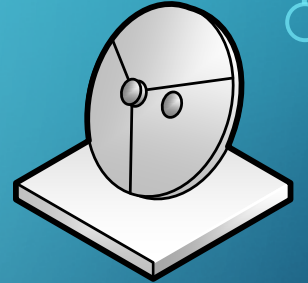
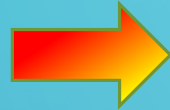
- Supports either UDP or TCP protocols
- Allows transmitting to and receiving from multiple IP addresses
- Used to interface ship's bridge sensors (GPS, Gyro & Meteorological) to AMOS
- Internal AMOS interface
  - SBE 38 Remote Temperature Sensor
  - SBE 45 Microthermosalinograph
  - Turner C6

# AMOS BLOCK DIAGRAM



Ship Supplied Network -----  
Science Supplied Network - - - - -

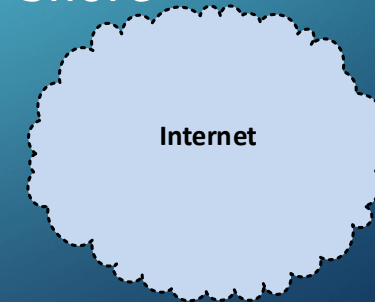
# DATA FLOW



Data stored locally on cRIO, transferred hourly by FTP to AMOS laptop

Data stored on AMOS laptop on a RAID drive

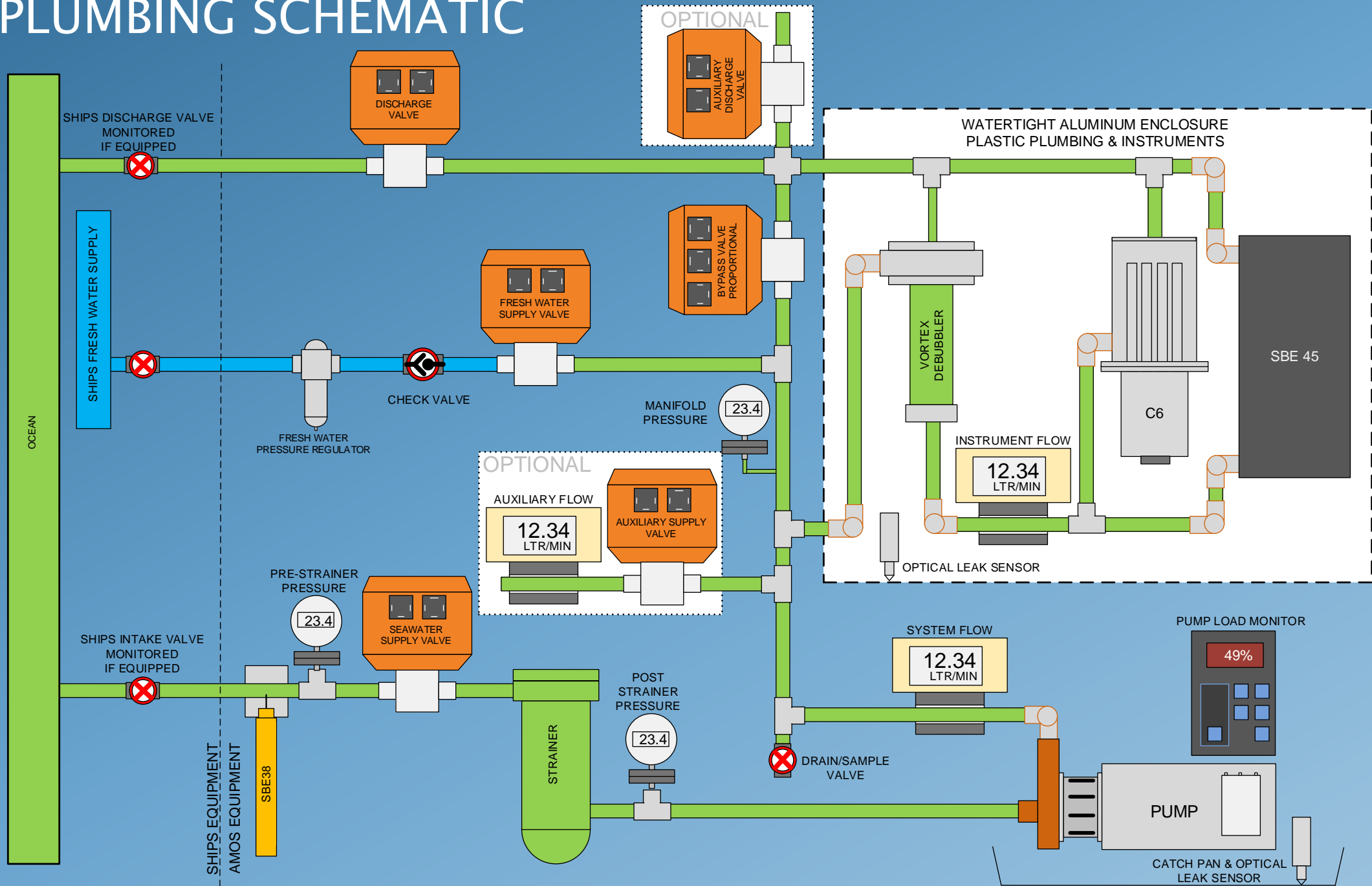
Satellite Connection – Ship to Shore



Data pulled by FTP from AMOS laptop to RSMAS Server

Data made available to registered science users

# PLUMBING SCHEMATIC



# 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



# CONTACTS

- Peter Ortner – OceanScope – [portner@rsmas.miami.edu](mailto:portner@rsmas.miami.edu)
- Rich Findley – Technical Director – [rfindley@rsmas.miami.edu](mailto:rfindley@rsmas.miami.edu)
- Aubri Vail – Technical Manager – [avail@rsmas.miami.edu](mailto:avail@rsmas.miami.edu)
- Elizabeth Williams – Program Manager – [ewilliams@rsmas.miami.edu](mailto:ewilliams@rsmas.miami.edu)
- Jim Lovin – Labview Programmer – [jlovin@rsmas.miami.edu](mailto:jlovin@rsmas.miami.edu)
- Miguel Izaguirre – MAERI – [mizaguirre@rsmas.miami.edu](mailto:mizaguirre@rsmas.miami.edu)
- Kevin Sullivan – pCO<sub>2</sub> – [kevin.sullivan@noaa.gov](mailto:kevin.sullivan@noaa.gov)