OCEAN EXPLORATION & RESEARCH

# NOAA Ship *Okeanos Explorer*

## Mission Capabilities

# VSAT System (Very Small Aperture Terminal)

3.7 m C-Band SeaTel Tracking Satellite Dish atop main mast in radome for real-time communications with shore. 20 Mbps (megabits per second) upload and 5 Mbps download capable. Non-ROV operations will generally use 5Mbps upload/ T1 download.  20 Mbps is primarily for live ROV ops when sending high-definition video, audio, and data streams to shore. Allows real-time voice intercom with ship at ECCs (shore-based control rooms). Real-time data distribution and archiving. Increases breadth of exposure and expertise brought to discoveries very quickly.

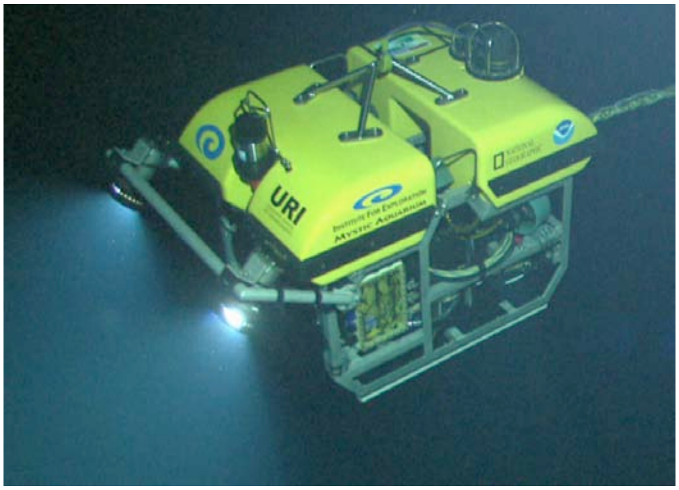
# Exploration Command Centers

There are currently five Exploration Command Centers (ECCs) located around the country that provide scientists and explorers the ability to participate in missions directly from shore. The ECCs are located at:

- NOAA PMEL, Sand Point, Seattle, WA
- NOAA HQ, Silver Spring, MD
- University of New Hampshire, New Durham, NH
- University of Rhode Island, Kingstown, RI
- Institute for Exploration, Mystic Aquarium, Mystic, CT

The ECCs are equipped with 3 large flat-screen LCD monitors for viewing live imagery from the ship; 3 computer workstations for receiving and viewing data feeds from the ship; and an IP telephony RTS system for real-time two-way audio communications with the ship control room. ECC technology evolves as industry changes standards and new technologies become affordable. The primary role of the ECCs is to provide a broader base of intellectual capital to exploration, and allow explorers to explore from shore. ECC are also education and outreach venues.

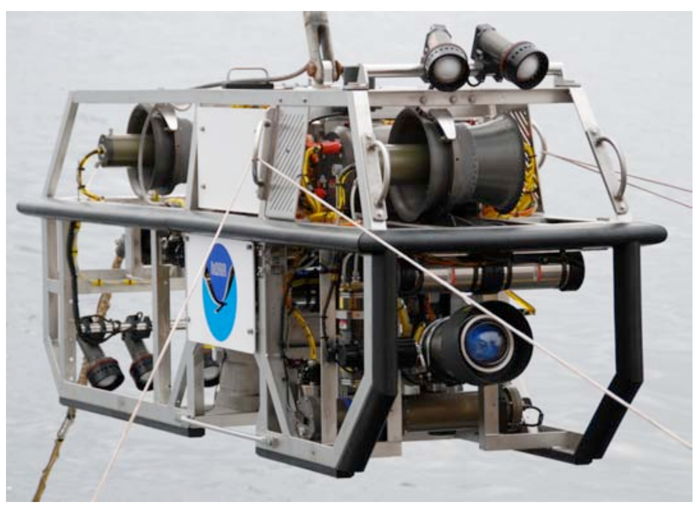
# NOAA
## Ocean Exploration & Research
## Remotely Operated Vehicle System




The NOAA Ship *Okeanos Explorer* utilizes the Little Hercules remotely operated vehicle (ROV). Originally developed by a team of engineers from the Institute for Exploration (IFE) at the University of Rhode Island (URI), "Little Herc" first came into the spotlight when he gave the world the first and only images of John Kennedy's PT Boat; PT-109. After several other successful missions for IFE, Little Herc stepped down, taking a back seat to the much larger "Hercules" ROV. After doing a short stint as an exhibit piece in the Mystic Aquarium, a new life was given to the veteran Little Herc "Explorer". Through a Joint Project Agreement (JPA) between NOAA, IFE and URI, a team of engineers from several institutions and companies recommissioned Little Herc.

During the four month overhaul, Little Herc received substantial upgrades including a new motor controller and power bottle system and an upgraded fiber optic multiplexer system. Four new thrusters allow the pilot to maneuver Little Hercules freely on a 30 meter (100 feet) tether. Little Herc carries 400 watt HMI lights, an Insite Pacific Zeus Plus High Definition video camera, several operational or pilot cameras, an RDI Workshorse Navigator DVL, Tritech Super SeaKing Sonar, Seabird SBE49 Conductivity, Temperature and Depth (CTD) system.

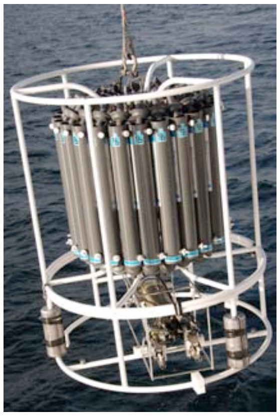
Little Herc is designed to operate with a new camera sled named Seirios. Seirios was also developed through a JPA. Seirios connects to the ship via the ship's main .68 cable. It is maneuvered by adjusting the position of the ship, raising and lowering the cable and using onboard thrusters. Seirios is equipped with 400 watt HMI lights and Zeus Plus high definition video camera and telescoping or retractable Mini Zeus high definition video camera to view Little Herc in its operating environment.



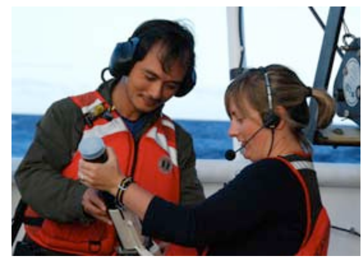
Both vehicles are tracked by the ship using a Linkquest TrackLink 10000HA Ultra-Short Baseline (USBL) tracking system, integrated with Hypack and CNAV DGPS.

**NOAA Ocean Exploration and Research**
**1315 East West Highway, Silver Spring, MD 20190**
**http://oceanexplorer.noaa.gov**

# NOAA
## Ocean Exploration & Research
### Water Column Capabilities



The NOAA Ship *Okeanos Explorer* has several systems for collecting and storing oceanographic data and water samples. Seabird Electronics Model 9/11+ **Conductivity Temperature Depth** (CTD**)** is installed in a 24-position rosette frame with a seabird SBE-32 carousel. There are 24 2.5L niskin bottles. The SBE 9+ underwater unit has a depth capability of 6800 meters and a dual conductivity/temperature sensor pair. This system has four ports available for up to 8 auxiliary sensors. Additional sensors installed on the CTD frame may include: Light Scattering, Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP) and Altimeter.



Lockheed Martin Sippican Mk-21 **expendable bathythermograph** (XBT**)** system with a portable hand-held launcher is used for obtaining sound velocity profiles while underway. These sound velocity profiles are processed and entered into the multibeam echosounder data acquisition software for accurate bathymetry data collection.

The scientific seawater system provides a continuous flow of water throught the SBE 38 **remote temperature probe** and the SBE 45 **micro-thermosalinograph** (TSG). This system provides temperature, conductivity, salinity and sound velocity of the sea surface. The sound velocity can also be used in real-time multibeam data acquisition.


The **wet lab** is the primary space for sample processing and storing. Samples can be stored in the lab cabinets, the refrigerator, **Thermo Scientific Ultima II** (-80° C) freezer, or the **Controlled Environment Room** as required. Any chemical analysis or preservation can be conducted in the chemical hood.

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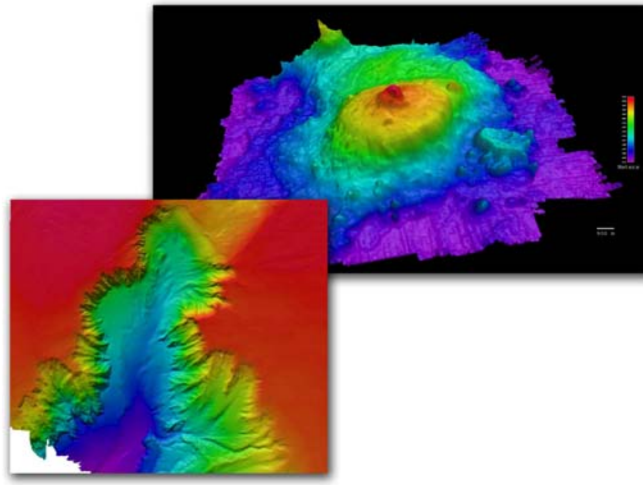
# BATHYMETRIC DATA ACQUISITION



**Multibeam Echosounder:**
**Kongsberg Maritime EM302, 30 kHz**

The state of the art 30 kHz EM 302 deep water multibeam sonar is manufactured by Kongsberg, Inc of Norway. The system is installed in a custom-designed hull transducer faring. The EM-302 provides the ship with high resolution deep-water mapping for reconnaissance and detailed site mapping to support ocean exploration and discovery.

The EM 302 transducers are modular linear arrays in a Mills cross configuration with separate units for transmit and receive. This sonar offers significantly larger swath width, increased data density and resolution. Beam focusing is applied both during reception and transmission. The system has up to 288 beams / 432 soundings per swath with pointing angles automatically adjusted according to achievable coverage or operator defined limits. In multi-ping mode, 2 swaths are generated per ping cycle, with up to 864 soundings. With multi-ping the transmit fan is duplicated and transmitted with a small difference in along track tilt.

The applied tilt takes into account depth, coverage and vessel speed to give a constant sounding separation along track. The beam spacing can be adjusted as equi-distant or equi-angular. EM 302 uses both CW pulses and FM sweep pulses with pulse compression on reception, in order to increase the maximum useful swath width. The transmit fan is split in several individual sectors with independent active steering according to accomplish compensation for the vessel movements: yaw, pitch and roll. The high density, high resolution, large coverage and water column capability makes EM 302 an ideal system to explore the sea bed and the water column for detection and characterization of a broad spectrum of features.

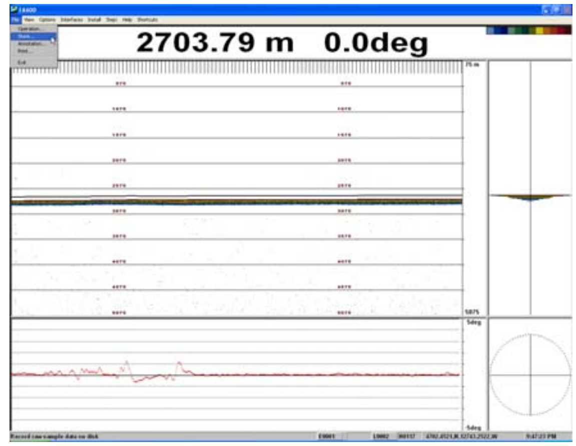
**EM302 Performance Data**

| | | |
|---|---|---|
| **Operating frequency** | 30 kHz | |
| **Depth range** | 10-7000 m | |
| **Swath width** | 5.5xDepth, to approx 8 km | |
| **Pulse forms** | CW and FM chirp | |
| **Swath profiles per ping** | 1 or 2 | |
| **Motion compensation:** | Yaw | ± 10 degrees |
| | Pitch | ± 10 degrees |
| | Roll | ± 15 degrees |
| **Sounding pattern** | Equi-distant /equiangular | |
| **Depth resolution** | 1 cm | |
| **Side lobe suppression** | > 25 dB | |
| **Beam focusing** | On transmit (per sector) and on reception (dynamic) | |
| **Beam forming method** | Time delay | |
| **Gain control** | Automatic | |
| **Swath width control** | Manual or automatic | |

| | |
|---|---|
| **Water column logging** | Yes |
| **Mammal protection** | Yes (Not implemented yes) |
| **Transmit array deg** | 150(Across track) x 0.5 (Along track) |
| **Receive array deg** | 1 (Across track) x 30 (Along track) |
| **No. of beams/swath** | 288 |
| **Max no. of soundings/swath** | 432 |
| **Max no. of swaths/pings** | 2 |
| **Max no. of soundings/ping** | 864 |
| **Approx. file sizes:** | |
| *Without water column* | 250 MB/hr (200m) - 80 MB/hr (3000m) |
| *With water column* | ~ 5 times file sizes @ 2000 m water depth |
| **Approx. beam foot print:** | @ 500 m (~ 4.5m x 9m) @ 3000 (~27m x 52m) |
| **Data format** | *.all for bottom bathymetry and backscatter<br>*.wcd for water column backscatter |
| **Data processing** | Caris HIPS/SIPS, Fledermaus |

**Single Beam Echosounder:**

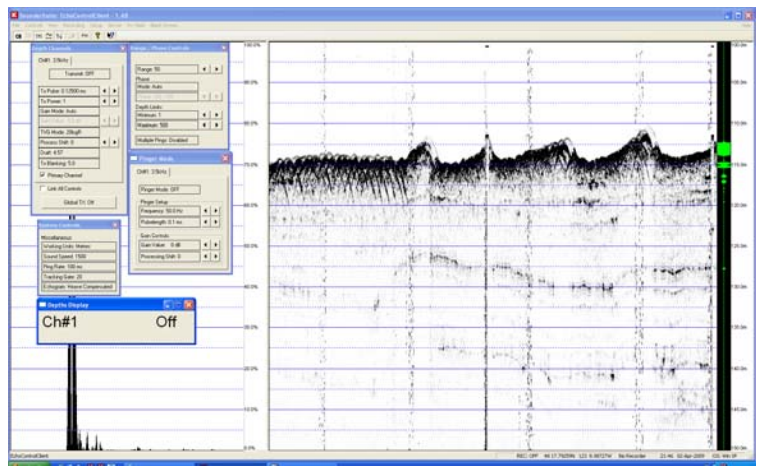
**Kongsberg Maritime EA600, 12 kHz, depth rated to 12 km**




The EA600 single beam is typically used while conducting a CTD cast to monitor the depth as the ship holds position, or as the CTD is being towed (Tow-yo). Since the Okeanos Explorer primarily maps with the multibeam sonar, the single beam data is only recorded when an interesting feature is observed, or during an operation where the bottom is beyond the EM 302 range (~ 7000 m).

**Subbottom Profiler:**

**Knudsen 3260 Chirp, 3.5 kHz**




The Subbottom Profiler is still being tested to determine its usefulness in exploration. The data from the Chirp can be processed with Sonar Whiz and overlaid with bathymetry data from the multibeam to visualize the bottom topography as well as the seafloor layer structure.

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# METEOROLOGICAL

The Remote Measurement & Research Company, LLC (RMRCo) ZMET Meteorological Sensor package is located on the flying bridge catwalk. The sensors are placed on the centerline (or as close to) of the ship. This package contains the following sensors, and each is recorded by SCS:

**Barometer**

Digital barometer outputs in millibars.

**Air Temperature/Relative Humidity**

Combination Vaisala air temperature and relative humidity sensor with radiation shield.

**Wind Direction and Speed**

RM Young wind bird measures vessel relative direction and speed.  SCS then calculates true wind direction and speed as a derived sensor, using the vessel's Course Over Ground (COG), Speed Over Ground (SOG), Heading (GYRO) .

**Radiometers**

There are two sensors in the RAD system.  The Precision Spectral Pyrometer (PSP), on the starboard side, measures the solar spectral region (shortwave). The Precision Infrared Radiometer (PIR), on the port side, measures terrestrial spectral region (longwave).

# NOAA's Office of Ocean Exploration and Research

## *End-to-end Data Management aboard the NOAA Ship Okeanos Explorer*


*CIMS automates metadata creation and data transformation in accordance with data management "Best Practices" and ensures timely archival and public access to data & information.*

NOAA's Office of Ocean Exploration & Research (OER) has partnered with NOAA's Data Centers in developing an end-to-end Data Management Plan for the wide range of data collected during OER's sea-going expeditions. The Cruise Information Management System (CIMS), a license-free software suite developed by NOAA's National Coastal Data Development Center (NCDDC), forms the foundation of the Plan's implementation. The CIMS is designed to:

- Streamline and automate expedition planning and operations
- Produce standard metadata records from digital activity logs
- Apply open source standards for efficiency and transparency
- Ensure broad accessibility and preservation of data and information

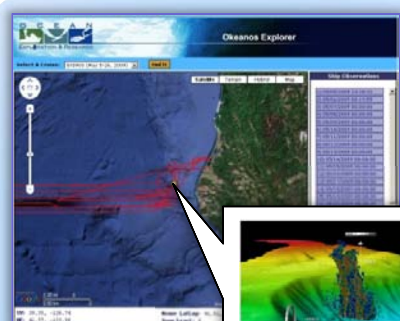
### A New Data Management Paradigm

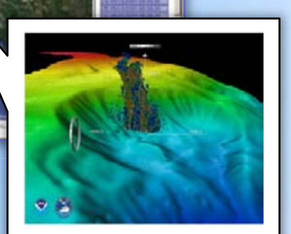
Since the 2008 commissioning of the NOAA Ship *Okeanos Explorer*, the Data Management Plan has been extended to address management requirements for data collected by shipboard systems. In cooperation with NOAA's Office of Marine and Aviation Operations, the CIMS has been modified to communicate directly with NOAA's Scientific Computing System (SCS). The CIMS/SCS software module will:

- Automate metadata creation from SCS and shipboard sensor files
- Transform sensor data to open-source, archive-ready formats
- Routinely transfer data / documentation to NOAA's archives
- Disseminate information via OPenDAP servers and Google™ maps

*NCDDC software engineers aboard ship work remotely with system architects on shore, taking advantage of the data assembly center's service architecture and technical capabilities.*

Enhanced CIMS functions are undergoing testing aboard the *Okeanos Explorer* during the current field season. CIMS software engineers aboard ship work remotely with NCDDC system architects on shore, taking advantage of the technical capabilities offered by the NCDDC data assembly center. The Center's service architecture enables automated data handling, format transformations, and timely distribution of data and information products to multiple access points. The CIMS ensures that scientific information resulting from OER's global, interdisciplinary explorations is broadly accessible to decision makers, scientists, educators, and the public.



*An easy-to-navigate Google™ map provides public access to geo-referenced data and Information-rich products developed aboard the Okeanos Explorer to highlight discoveries & unique findings.*

### Meeting Future Data Management Needs

When fully operational, CIMS may be transitioned to the NOAA Fleet to ensure that NOAA's investment in data collection is preserved and fully untilized. This technical approach, which emphasizes flexibility, adaptability, and transparency, is on course to meet NOAA's future information management needs.

For more information: explore.noaa.gov

Contact: Sharon Mesick, Federal Program Manager for OER Data Management
(228) 688-2256 / sharon.mesick@noaa.gov

OCEAN EXPLORATION & RESEARCH

# Exploration Vessel (E/V) *Nautilus*

*By Ian Kulin, Todd Gregory, and James Newman*

**FORMERLY:** *Alexander von Humboldt*

**LENGTH:** 64.23 meters (211 feet)

**BEAM:** 10.5 meters (34.5 feet)

**DRAFT:** 4.9 meters (14.75 feet)

**TONNAGE:** 1249 gross, 374 net

**MAIN PROPULSION:** Single 1286 kw (1700 HP) controllable pitch

**SPEED:** 10 knots service, 12 knots maximum

**DYNAMIC POSITIONING**

**CLASSIFICATION:** Germanischer Lloyd (GL) 100 A5 E1 (Ice Strengthened)

**BUILT:** 1967, Rostock, Germany

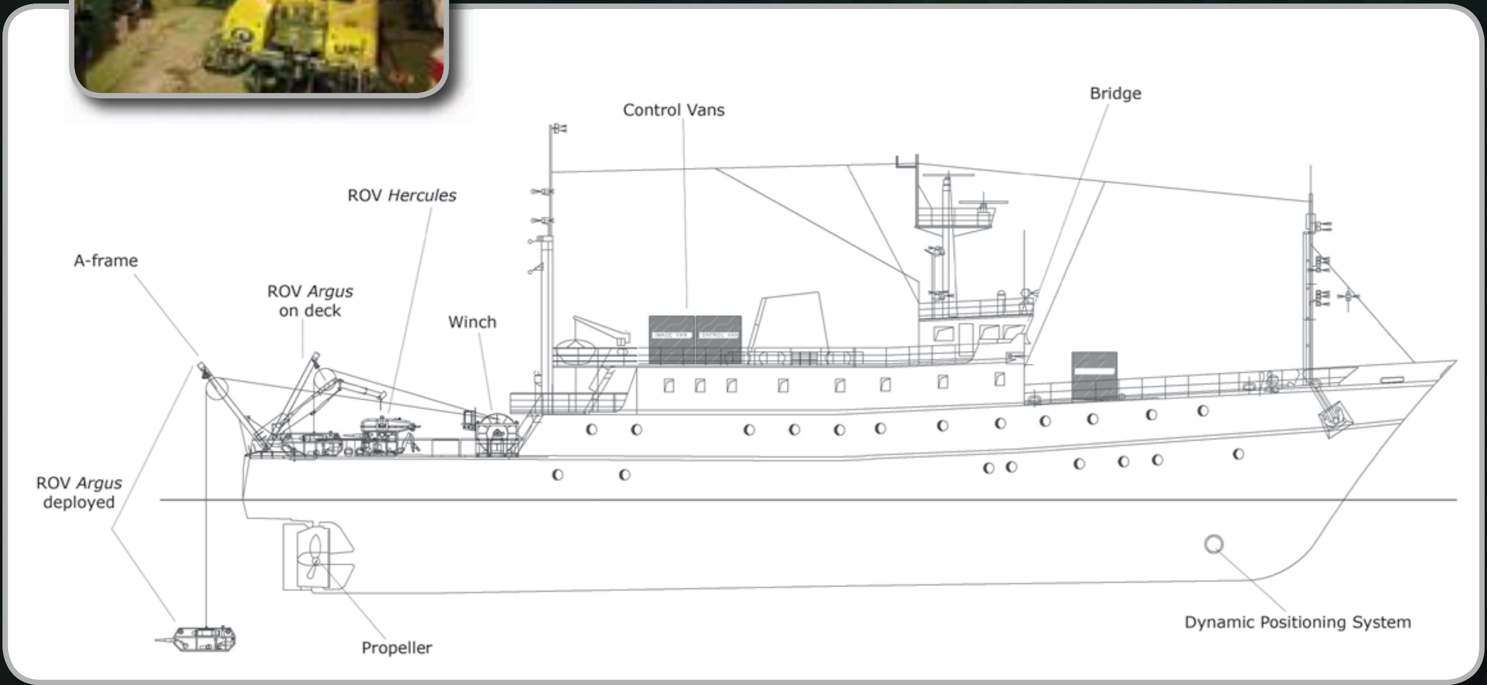
**BERTHING:** 36 bunks in single/double cabins and eight bunks in four-person cabins

**CREW:** 17

**SCIENCE PARTY:** 27

**FLAG:** St. Vincent and the Grenadines

**HOME BASE:** Yalikavak, Turkey



A 20-hp electric/hydraulic pump powers the mechanical functions on ***Hercules***. Two manipulator arms, one dexterous and the other strong, work together to sample and move equipment around on the seafloor. High-definition video cameras provide a clear, precise window to the world below…and create dazzling images.

Capable of working as a stand-alone system, ***Argus*** becomes a towed-body instrument for large-scale deepwater survey missions. Side-scan sonar looks out on either side of the vehicle up to 400 m away, identifying features as small as a brick. Powerful 1200-watt lamps provide light miles below where sunlight is absorbed by seawater.

# E/V *Nautilus* Vehicles

*By Brennan Phillips, Jim Newman, and Todd Gregory*

*Hercules* and *Argus* are state-of-the-art deep-sea robotic vehicle systems capable of exploring depths up to 4000 m. Each remotely operated vehicle (ROV) has its own suite of cameras and sensors that receive electrical power from the surface through a fiber-optic cable, which also transmits data and video. Engineers and scientists command the vehicles from a control room aboard *Nautilus*, with some dives lasting more than three days.

*Argus* was first launched in 2000 and was soon followed by *Hercules* in 2003. The systems are versatile, capable of supporting a wide range of oceanographic instrumentation and sampling equipment. They have surveyed ancient shipwrecks, discovered hydrothermal vents, and recovered lost equipment in oceans and seas around the world.

Several smaller remote systems complement *Hercules* and *Argus* for various exploration objectives.

***Echo*** is a side-scan and subbottom sonar towfish (100/400 kHz) capable of working at depths of up to 3000 m.

***Little Hercules*** is a 4000-m-rated inspection-class ROV that features the same high-definition video system as Hercules, along with several other oceanographic sensors.

***Diana*** is a side-scan sonar towfish capable of working as deep as 2000 m. The primary advantage of this 300/600 kHz system is the quality of data that is produced. ***Diana*** surveys create accurate, high-resolution maps of the ocean floor.

# The Development of Telepresence Technology for Remote Exploration and Education

*By Dwight Coleman and Robert Ballard*

The Inner Space Center (ISC) at the University of Rhode Island Graduate School of Oceanography is the hub for remote telepresence-enabled expeditions where teams of scientists, students, and educators participate in the exploration cruises remotely. The facility uses advanced telepresence technologies, including video production and broadcast systems, ship-to-shore telecommunication equipment, and real-time data processing and visualization systems to enable remote, shore-based ocean exploration operations. Using this technology, teams of scientists, students, and educators based at the ISC communicate with their counterparts on board the research vessels to support live shipboard operations, remotely operated vehicle dives, data processing and analysis, and educational outreach activities. The ISC supports two primary ships of exploration: the Ocean Exploration Trust's E/V *Nautilus* and NOAA's *Okeanos Explorer*. The mission control facility within the ISC is equipped for 24-hours-per-day operations where teams of remote participants stand watch to support the shipboard scientific investigations. The facility's layout mirrors the mission control spaces on board the ships of exploration, and the functionality of the telecommunication, video, and data systems are nearly identical to those onboard the ships. During the 2010 field season, the ISC was staffed to support both ships, the Doctors-on-Call program, and the Educators-at-Sea and Ashore programs.

The ISC supports a growing network of Remote Science Consoles for the Doctors-on-Call program that are nodes off the ISC hub, connected via Internet2 to the ISC and the ships of exploration. These consoles are equipped with video decoding systems, intercom telecommunication equipment, and data visualization systems. Presently, permanent Remote Science Consoles are installed at NOAA headquarters in Silver Spring, MD, the NOAA Pacific Marine Environmental Lab in Seattle, WA, the University of New Hampshire, the University of Haifa, the Institute for Exploration at Mystic Aquarium, and the University of Delaware, with one in development at Syracuse University. In addition, "mini-consoles" were installed at the Woods Hole Oceanographic Institution, the University of Washington, and Texas A&M University. The ISC supported the technical aspects of their installation and configuration on Internet2, and helped manage their operation.

Immediately adjacent to the mission control space is a video production studio and control room to support the creation and delivery of live educational broadcasts. During 2010, the live streaming video feeds from E/V *Nautilus* were converted and combined at the ISC into a multi-screen video feed that was viewable at *www.NautilusLive.org*. In addition, the ISC supports a data center with online video and data servers and archival systems. All streaming audio, data, and video from the ships are captured in real time and made accessible to remote users. The ISC facilitates and manages access to the live and recorded information through the ongoing development and maintenance of an online data portal, video data archive, content management system, and a collaborative Web-based gateway. This data portal hosts the raw, unprocessed versions of all video and data collected by the ships and represents a short-term archive until the final data sets are transferred to the national data archives. Finally, the mission control space at ISC can be used as an education and hands-on training facility for all users of the ships' data and cruise participants.

# The Doctors-on-Call Program: Maximizing the Interpretive Power of Telepresence

*By James A. Austin Jr., Robert Ballard, and Katherine L. Croff Bell*

During the 2010 *Nautilus* expeditions, telepresence was used to team up scientific expertise ashore with the shipboard scientific parties studying the biology, geology, and archaeology of the eastern Mediterranean. Because the ship offers a limited number of bunks, many of which are taken by the technical team operating the ROVs *Argus* and *Hercules*, experts ashore—known as Doctors on Call (DOC)—could be called on, often at short notice, to help those on *Nautilus* interpret and understand the video images streaming continuously from the seafloor.

Interactions from shore took a number of forms. For example, some scientists at URI's Inner Space Center literally stood watch right along with members of the shipboard parties studying Eratosthenes Seamount and the Santorini volcanic edifice. Other scientists and graduate students interacted using their own Remote Science Consoles (RSC). For example, personnel manning the RSC at Woods Hole Oceanographic Institution were fundamental to interpretations of biology encountered during the Anaximander Mountains expedition, while Israeli scientific personnel manning an RSC set up at the University of Haifa played a crucial role in interpreting videos collected along Israel's continental margin. At times, because *Nautilus* had direct phone and e-mail contact with shore-based institutions, diverse scientific expertise could be called upon at very short notice to collaborate with shipboard staff. One archaeological expert called upon by the University of Haifa used their RSC to judge the provenance (Roman) and age (3rd century CE) of an amphora in deep water off Israel, even as *Hercules* pilots were turning it gently for better views of its morphology. In more than one case, input from shore-based experts directly influenced how ROV dives were planned and conducted. Furthermore, interactions with such experts was continuously showcased on the *www.NautilusLive.org* Web site through emailed questions and verbal discussions between DOCs and members of the scientific and technical staff in the *Nautilus* control room.

Everyone agreed that while such ship-shore collaborations enhanced the value of interpretive information flowing out over the Internet, "situational awareness"—knowing exactly what the ship and ROVs were doing all the time and where—could be improved. That will be done in 2011 by displaying maps on a DOC Web site that show each day's game plan and real-time visualizations (i.e., navigation outputs) of vehicles in the water, superimposed on up-to-date maps of seafloor bathymetry. Furthermore, verbal communications between members of the shipboard parties and shore-based experts will be made clearer so that all who visit the Web site will be able to appreciate fully the power of telepresence to put technical and scientific expertise from various land-based locations at the immediate disposal of *Nautilus* shipboard teams.