RECOMMENDATIONS FOR A NATIONAL PROGRAM

2001 | President’s Panel on Ocean Exploration

2003 | National Research Council Report

2004 | President’s Commission on Ocean Policy

2004 | Final Recommendations of the Interagency Ocean Policy Task Force

2012 | Decadal Review of the Ocean Exploration Program

2013 | Ocean Exploration 2020: A National Forum
A NATIONAL PROGRAM SHOULD INCLUDE:

• The identification of **clear priorities by the exploration community**

• The creation of an extensive and dynamic **network of partnerships**

• **Private sector investments in technology** that exceed public sector investments

• Communication tools capable of **engaging ocean explorers with the public**

• **Citizens that are engaged** actively in ocean exploration

• **Data** from expeditions that are **readily and rapidly available**
NOAA Ship Okeanos Explorer

Exploration Vessel Nautilus

OCEAN EXPLORATION TRUST
MISSION

To explore the ocean, seeking out new discoveries in the fields of geology, biology, maritime history, archaeology, and chemistry while pushing the boundaries of STEM education and technological innovation.
OET’s Organizational Structure

Board of Directors

- Nautilus Advisory Board
- President

- Exploration & Research
- Technology & Innovation
- Education & Outreach
- Finance & Admin.
NAUTILUS ADVISORY BOARD

JESSE AUSUBEL  
The Rockefeller University

RUTH BLAKE  
Yale University

STEVE CAREY  
University of Rhode Island

CHUCK FISHER  
Penn State University

PETER GIRGUIS  
Harvard University

STEVE HAMMOND  
NOAA OER/PMEL

JEFF KARSON  
Syracuse University

LISA LEVIN  
Scripps/UC San Diego

LARRY MAYER  
University of NH

MARY MILLER  
Exploratorium

MIKE MOTTL  
University of Hawaii

KERRY-ANN ROYES  
YMCA of Broward County
CORPS OF EXPLORATION  798 since 2009
OET MILESTONES

- 2007: Incorporated as a 501(c)(3)
- 2008: Acquired R/V Alexander von Humboldt, renamed E/V Nautilus
- 2009: First 3-week expedition in Turkey
- 2010: First 4-month expedition in Mediterranean Sea
- 2011: 5-year MOA established with NOAA OER
- 2012: Workshop: Telepresence-enabled Exploration of the Caribbean Region
- 2013: Installation of multibeam sonar & transit across Atlantic Ocean
- 2014: First 6-month expedition including transit of the Panama Canal to explore the Eastern Pacific Ocean
- 2015: Workshop: Telepresence-enabled Exploration of the Eastern Pacific Ocean
SOURCES OF REVENUE

- Contributions
- Other Grants
- Education & Outreach
- Charters/Expedition
- NOAA OER
OET PARTNERSHIPS

- Museum/Aquarium
- K-12 School
- Out-of-School Program
- Media
- Academic
- Industry
- Government
- NGO

Since 2009, 342 organizations have been represented in OET programs, both aboard Nautilus and ashore.
NAUTILUS EXPLORATION PROGRAM

Since 2009, 798 people from 40 U.S. states...

...and 46 countries have sailed aboard Nautilus.
NAUTILUS EXPLORATION PROGRAM

The number of female participants has increased from 17% in 2010 to 40% in 2015.
Nautilus has explored in the waters of 24 countries:

Bahamas, Belize, British Virgin Islands, Canada, Cayman Islands, Cyprus, Dominica, Ecuador, France, Greece, Grenada, Haiti, Israel, Italy, Jamaica, Montserrat, Portugal, Puerto Rico, Spain, Syria, Trinidad & Tobago, Turkey, Ukraine
NAUTILUS EXPLORATION PROGRAM

While exploring those waters, ~80% of our ROV time has been spent on the seafloor.

449 ROV Hercules since 2009

217 days = total time in water
SCIENTIFIC & PROGRAM HIGHLIGHTS
UNPREDICTED GEOLOGICAL PROCESSES
3 NEW SPECIES OF SPONGE, WORM, & FISH

Chondrocladia robertballardi
SCIENTISTS ASHORE PROGRAM

# of Registered Participants

<table>
<thead>
<tr>
<th>Year</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>80</td>
</tr>
<tr>
<td>2014</td>
<td>120</td>
</tr>
<tr>
<td>2015</td>
<td>160</td>
</tr>
</tbody>
</table>

[Image of NAUTILUS LIVE website]
2,225 SAMPLES ARE ARCHIVED AT PARTNER REPOSITORIES
Life Onboard Nautilus

- Anaximander
- Underwater
- Mountain Range
- Three four-hour
- watches while running ops
- Completely full ship
- Language breakdowns

100+ SCIENTIFIC PUBLICATIONS, PRESENTATIONS & THESES
AT SEA PROGRAMS FOR STUDENTS & EDUCATORS

Education Program Participants

- SEIP
- SCF
- HRP
- Argonaut
- Ambassador

Number

Year

E/V Nautilus | 64 meters

COMPLEMENT | 17 crew; 31 science & operations
**RANGE** | 24,000 kilometers (13,000 nm)  
**SPEED** | 10 knots service, 12 knots max

**ENDURANCE** | 40 days at sea  
**FUEL CAPACITY** | 330 cubic meters
SHIP SERVICE GENERATORS | 500 kVA generators, 350 kVA generator, and 450 kVA shaft generator

PROPULSION | 250 kW bow thruster; 350 kW jet pump stern thruster; Single 1,286 kilowatt (1,700 hp) controllable pitch main thruster
GALLEY | Two cooks and one steward feed 48 people 3 meals per day

MESS | Seating for 32 people, 3 meals per day, with 24-hour snack bar
LOUNGE | Comfortable seating, monitors for ROV dive, or presentations; intercom for communications with other spaces on ship and shore; telephone.

SOCIAL DECK | Social area for meals and leisure time, equipped with wifi.
GYM ROOM | Elliptical trainer, ergometer, free weights for getting pumped up.

CABINS | Nautilus has berthing for 51, but lifeboat capacity is limited to 48.
**ROV HANGAR** | 258.3 sq ft ROV Hangar with 110/60 Hz and 220/50 Hz power

**WORKSHOP** | Complete set of hand tools, cordless tools, electrical and fiber optic test equipment, mill-drill combination machine, as well as storage for spares and other equipment
COMMAND CENTER | 301.4 sq ft Command Center with nine workstations

WET LAB | -80°C freezer, scientific freezer/fridge, misc scientific equipment
DATA PROCESSING & VISUALIZATION LAB | 480 sq ft lab with 7 workstations

RACK ROOM | 185 square feet; Two Omneon Mediadecks
PRODUCTION STUDIO | 130 sq ft studio with remote controllable HD camera

SATELLITE ANTENNA | Sea Tel 9711 IMA 2.4 meter integrated maritime tracking antenna
TOPSIDE VIDEO CAMERAS | HD cameras in Command Center, Fantail, ROV Hangar, & Wet Lab

INTERCOM | Ship-wide RTS Telex intercom system with integrated handheld UHF radios for communications
ISC MISSION CONTROL | supporting for telepresence operations

ISC PRODUCTION | The production facility is capable of supporting live interactions from sea
MULTIBEAM ECHOSOUNDER | 30 kHz Kongsberg EM302

Beam-width - 1° × 1°; Grid Resolution - 1% water depth
SUB-BOTTOM PROFILER & ECHOSOUNDER | Knudsen 3260

SIDESCAN TOWFISH | EdgeTech 4200 MP CHIRP 300 and 600 kHz
ULTRA SHORT BASELINE ROV NAVIGATION | TrackLink 5000MA system

MOONPOOL | Located in Gym Room for users’ through-hull instrumentation
LIGHTING | HD and SD video cameras; array of LED lamp heads

MAPRS | Miniature Autonomous Plume Recorders
MANIPULATORS | Kraft Predator & ISE Magnum

ARCHAEOLOGICAL SAMPLING | Several tools have been developed
BIOLOGICAL SAMPLING | A wide array of biological samples can be collected.

GEOLOGICAL SAMPLING | ROV capable of collecting rock samples up to 300 pounds.
GAS & FLUID SAMPLING | variety of instruments been used

SENSORS | Standard environmental sensors include a CTD, optode, temperature probe; a pH sensor
GAS & FLUID IMAGING

HIGH-RESOLUTION SEAFOOR IMAGING
LASER SPECTROMETER | CO2 and CH4 measurements in situ in deep sea

LANDERS | Elevators and other platforms are mission configurable
Conducted simultaneous operations with the AUV Sentry in ’13

ENGINEERING DESIGN CHALLENGE
CHALLENGES: UNFUNDED CHARGES FOR OET

- The identification of clear priorities by the exploration community
- The creation of an extensive and dynamic network of partnerships
- Private sector investments in technology that exceed public sector investments
- Communication tools capable of engaging ocean explorers with the public
- Citizens that are engaged actively in ocean exploration
- Data from expeditions that are readily and rapidly available
BASIC EXPLORATION  Fundamental exploration of the geological, biological, chemical, physical, archaeological and/or historical aspects of an unexplored part of the ocean

APPLIED EXPLORATION  Targeted research projects that are undertaken as a charter for a research group, university, government agency, or corporation
BASIC vs APPLIED EXPLORATION

Installed MBES

Number of Days


Mediterranean Sea  GoMex & Caribbean  Eastern Pacific

Applied Exploration

Basic Exploration
IDENTIFYING & PRIORITIZING BASIC EXPLORATION TARGETS

- PRE-WORKSHOP: Call for White Papers
- PRE-WORKSHOP: Invitations to selection of white paper authors
- WORKSHOP: Presentations on telepresence-enabled exploration
- WORKSHOP: Breakout groups based on (1) discipline and (2) region
- POST-WORKSHOP: Public comment period
- POST-WORKSHOP: Follow-up webinar to gather community input on results
- POST-WORKSHOP: Work with NAB to develop field programs
DISCIPLINE-BASED BREAKOUTS: 43 PRIORITY AREAS
OVERLAPPING PRIORITY AREAS
20 HIGH PRIORITY TARGET AREAS
2013-2015 NAUTILUS BASIC EXPLORATION TARGETS: 11/20
2014 EASTERN PACIFIC WORKSHOP

- 77 White Papers from 13 countries
- 35 Key Questions
- 50 Priority Areas
- 33 High Priority Target Areas
MULTIBEAM MAPPING SONAR
Rock samples collected on Noroit Seamount during a 2013 OER-funded Basic Exploration cruise were hornblende andesites and limestones.
OER funded a follow-up Applied Exploration cruise in 2014.

Observations & rock samples suggest that the origin of the seamounts is strongly controlled by the tectonics of the region, rather than simply volcanic activity.

First-ever characterization of diverse communities of deep-sea fishes, corals, and other invertebrates with the potential for several new records for the region.
APPLIED EXPLORATION

- Funded by external organizations for targeted research and/or educational outreach
- Supplement OET’s revenue to keep Basic Exploration costs low
- Provides additional content for our educational offerings; OET’s educational programs are required
We didn't go with you guys for the outreach and data management, but now having seen how good that was it will seem missing without it.

So I thought it was great, and I'm advocating we try to build on this cruise by following it up with another next year.

--Chip Breier, GISR Lead Scientist
CHALLENGES

- Limited funding limits community participation in Exploration Workshops.
- We have thus far not been able to coordinate response to the community-driven Exploration Workshops with *Okeanos Explorer*.
- As we move west farther from the continental United States, Applied Exploration funding will become more scarce.
DATA MANAGEMENT & DISSEMINATION
DATA MANAGEMENT & STAFF

**Shore Staff**
- Director of Science Operations
- Data Engineering (x2)
- Partnering Archival Institutions
  - Inner Space Center (URI)
  - GSO-Marine Geological Sampling Lab
  - Harvard Museum of Comparative Zoology
  - NCEI

**At Sea Staff**
- Science/Data Managers
- Data Managers in Training
- Science Interns/Data Loggers
- Data Engineer
DATA MANAGEMENT & DISSEMINATION

WHAT WE DO

• Collect interdisciplinary oceanographic datasets
  • QA/QC of data & metadata creation
  • Basic processing of data & repacking for rapid analysis

• Disseminate
  • Near real-time sharing of basic data vis Science Dashboard
  • Post-cruise digital data requests & provide information about partnering institutions
DATA MANAGEMENT & DISSEMINATION
WHAT WE DO

- Archive using widely accepted formats
  - Video & digital data repository at URI’s Inner Space Center
  - Physical samples curated & metadata generated on board ship
- Implement, develop, and maintain technical infrastructure on ship and shore
  - Full ship network and systems support from cable terminations to software engineering
  - Shore-side network and systems support from servers to software engineering
  - End-user support for internal OET, ship staff, and external users
DATA MANAGEMENT & DISSEMINATION
WHY WE DO IT

• Critical to OET’s mission & commitment to the community
• Creating a legacy of exploration for future explorers (e.g., archiving data publicly for future research & discovery)
• Learning environment and training the next generation of STEM workers
  • Data Managers & Interns gain hands-on training
  • Opportunity to learn beyond the ship
• Expanding the science team (Scientists Ashore) & impact of our discoveries
  • Shipboard science team ~3-6 can be infinitely extended to scientists on shore
DATA MANAGEMENT & DISSEMINATION
WHAT WE ACHIEVE

45 TB of underwater video/yr
1.5 TB of non-video data/yr
DATA MANAGEMENT & DISSEMINATION
WHAT WE ACHIEVE

Near real-time data sharing & ocean exploration from anywhere
DATA MANAGEMENT & DISSEMINATION
WHAT WE ACHIEVE

Rapid data analysis & dive replay tools
DATA MANAGEMENT & DISSEMINATION
WHAT WE ACHIEVE

Rapid data analysis & dive replay tools
DATA MANAGEMENT & DISSEMINATION
WHAT WE ACHIEVE

Rapid data analysis & dive replay tools
DATA MANAGEMENT & DISSEMINATION

DATA USE

>100 Scientific publications, theses & dissertations, conference abstracts

Follow-up requests & science proposals
CHALLENGES

• Limited number of personnel dedicated to data management & dissemination

• Data mining and use by the public (e.g., citizen science efforts)

• Data archival in NOAA databases

• Video/data accessibility and keeping up with data requests
EDUCATION & OUTREACH
EDUCATION & OUTREACH

GOALS

Expose the broader public to ocean exploration & research

Inspire young audiences to be lifelong learners and pursue interests, education, and careers in STEM disciplines

Provide students and educators with engaging learning opportunities and instructional materials. Increase their capacity to use those materials well.

Provide hands-on professional training & vocational skills development for students advancing through stem-focused degrees and careers.
NAUTILUS LIVE WEBSITE & OUTREACH

Nautilus Live Website Statistics

- Unique users
- Sessions
- Pageviews

Year:
- 2012: 45,606
- 2013: 110,735
- 2014: 460,951
- 2015 (YTD): 1,149,481

Pageviews:
- 2012: 470,745
- 2013: 1,622,828
- 2014: 2,202,567
- 2015 (YTD): 3,563,491

Sessions:
- 2012: 193,247
- 2013: 486,020
- 2014: 777,454
- 2015 (YTD): 480,510
NAUTILUS LIVE WEBSITE & OUTREACH

Social Media | Followers
--- | ---
2012 | 3,311
2013 | 11,164
2014 | 27,058
2015 (YTD) | 53,731

Twitter:
- 713,641 Views
- 49,587 Likes, Comments & Shares

Facebook:
- 2,653,587 People Reached
Over 750 stories in the media and press hits in both 2014 & 2015 in every major US market.
LIVE INTERACTIONS

2010 - 2015

13 | countries connected

3764 | live ship-to-shore interactions (2010 - 2015)

238 | venues & schools connected
LIVE INTERACTIONS

2010  4 states & 8 partner venues

2015  28 states & 120 venues

2010 - 2015

13 | countries connected
39 | US states connected
3764 | live ship-to-shore interactions
238 | venues & schools connected
4.8M+ | people reached
# STEM Learning Modules & Educator Workshops

## STEM Learning Modules: Foundational Themes

<table>
<thead>
<tr>
<th>Science</th>
<th>Technology</th>
<th>Engineering</th>
<th>Mathematics</th>
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</thead>
<tbody>
<tr>
<td>E/V NAUTILUS</td>
<td>REMOTELY OPERATED VEHICLES</td>
<td>SONAR MAPPING</td>
<td>OCEANOGRAPHY</td>
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</table>

<table>
<thead>
<tr>
<th>Biology of the Deep</th>
<th>Marine Geology</th>
<th>Marine Archaeology</th>
<th>The Corps of Exploration</th>
</tr>
</thead>
</table>

STEM topics include:
- E/V NAUTILUS
- Remotely Operated Vehicles
- Sonar Mapping
- Oceanography
- Biology of the Deep
- Marine Geology
- Marine Archaeology
- The Corps of Exploration
MODEL BEHAVIOR | EDUCATOR

Foundational Theme | Oceanography |
Rating: 6/7

Pacing: 1/2 class periods

Background Needed: Basic knowledge of scientific modeling and graphing

Assessment: Select provided

Materials/Resources:
- 4L large plastic clear tube filled with water
- 2L large plastic clear tube filled with water
- 8 pails of ice
- Several hot pots
- Paper towels, 600 ft roll or bowl of salt
- Various types of cooking oils such as peanut, vegetable, canola, etc.
- Plastic straws/spoons
- Thermometers
- Rulers
- Scales
- Sediments such as sand, gravel, etc.
- Laptops and graphing software such as Microsoft Excel (optional)

Overview
In this module, students will be exposed to the importance of developing models to predict behavior of substances such as oil in marine environments and will develop a model to test one variable that would influence the behavior of oil molecules when dispersed in water. Students will then use their developed models to make connections to questions about current research addressing these topics. This module could also serve as an introduction to scientific method and measurement.

Background
Oil spills are a major threat to marine ecosystems, costing many millions of dollars to clean up and threatening the livelihood of those who depend on the sea for income. In the oceans, these are usually caused by storm damage or overfishing, and the impact of such events is not fully understood. To address this issue, scientists are working on developing models of oil dispersion behavior in the water column to accurately inform policymakers, engineers, and scientists how to best manage and mitigate future spills. In this module, you will develop a model to test one factor affecting oil behavior in water. Check out http://www.nytimes.com/2015/06/15/earth/oil-spill-bubbles-critter-for-more-information.

Objectives & Learning Outcomes
- Students will understand impacts from hazardous events such as oil spills and actions companies are taking to study the impacts of such events
- Students will design a model to test a variable in a controlled setting
- Students will collect and graph data and use proper scientific measurement techniques
- Students will communicate their results to an appropriate audience

MODEL BEHAVIOR | ASSESSMENT

Objective
Evaluate competencies in Oceanography

Criteria
4: Exceptional
3: Compliant
2: Emerging
1: Developing

Knowledge & Understanding
- Students consistently answer all questions correctly. Using an abundance of relevant vocabulary and reference to literature, students are able to explain relationships within the context of the project. Students are able to answer most questions correctly. Using an adequate amount of relevant vocabulary. Students do not explain relationships within the context of the project.

Context
- Students are able to explain relationships within the context of the project.

Self-Directed Learner
- Students are engaged in the learning process and are able to organize ideas, concepts, and information to make connections and draw conclusions. Students are able to provide explanations and answers to questions. Students are engaging in the learning process. Students are able to provide explanations and answers to questions. Students are engaging in the learning process. Students are able to provide explanations and answers to questions.

Technological Tools
- Students are able to use digital resources to enhance their learning.

Collaboration Skills
- Students are able to work effectively and respectfully with a diverse group of learners.

Total Score: Comments

STEM Learning Modules

Полученной информации недостаточно для формирования чистого текста.
STEM LEARNING MODULES & EDUCATOR WORKSHOPS

- Since June 2015, OET has held 4 STEM workshops in TX, LA, FL, & CT and another is planned in October in IL.

- Estimated student reach through participating teachers to date is 100,000+.

- Feedback from participants has been extremely positive.
AT SEA PROGRAMS FOR STUDENTS & EDUCATORS
SCIENCE & ENGINEERING INTERNSHIP PROGRAM

2014 SEIP’s assessment of the impact of the program on their career plans are that it:

1. Confirmed or reaffirmed career plans
2. Positively influenced career plans
3. Provided professional experience
4. Provided a broader awareness of the interdisciplinary nature of STEM
<table>
<thead>
<tr>
<th>Year</th>
<th>Pre-Fellowship</th>
<th>Post-Fellowship</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>85%</td>
<td>100%</td>
</tr>
<tr>
<td>2013</td>
<td>85%</td>
<td>94%</td>
</tr>
<tr>
<td>2014</td>
<td>76%</td>
<td>100%</td>
</tr>
</tbody>
</table>

2014 SCF responses to “I am confident in my ability to teach students or public audiences about the value of ocean exploration.”
COMMUNITY STEM PROGRAM

SPONSORS/PARTNERS
Office of Naval Research
Bechtel
CITGO
Pfizer
Dominion
Ballard Exploration
University of New Hampshire
UC Santa Barbara
Ocean Networks Canada
Florida Panthers Foundation
Lyda Hill Foundation
Phil Stephenson Foundation
2016 & BEYOND

• Wintering over in Canada as guest of Victoria, BC and Ocean Networks Canada while discussing 2016/17 plans to winter over in San Pedro, CA at AltaSea.

• Begin Fabrication of new Command Center with donations from private individuals and ALCOA. Begin wiring installations between new Command Center and the recently renovated Data Lab and Rack Room.

• Work to expand Applied Exploration Program

• Expand scope and reach of OET STEM programs from 11 communities to 20

• Third “60-Minute” program with CBS News

• Explore use of E/V Nautilus in off-season to conduct multi beam operations as well as a dive platform