O C E A N
EXPLORATION & RESEARCH

Section 3: Multibeam Mapping for Volume 2: How Do We Explore?

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site:
http://oceanexplorer.noaa.gov/okeanos/welcome.html

Okeanos Explorer's prominent VSAT (Very small aperture terminal) dome enables satellite communications between explorers ashore and at sea and provides multiple high-definition video streams for widespread dissemination. Image credit: NOAA.

Wet Maps

Focus
Bathymetric mapping

Grade Level
5-6 (Physical Science/Earth Science)

Focus Question
What kinds of maps are used for ocean exploration, and how are these maps made?

Learning Objectives
- Students will describe three types of bathymetric maps, and discuss how each type may be used by ocean explorers.
- Students will explain why multibeam mapping is used aboard the *Okeanos Explorer*.
- Students will simulate a multibeam sonar system to create a three-dimensional map of a model seafloor.

Materials
For each student group:
- Copies of *Multibeam Mapping Simulation Activity Guide* and *Multibeam Mapping Simulation Activity Preparation Guide* (if you decide to have the students do the preparation) and (optionally) *Hands-On Activity Guide – Multibeam Mapping: PING)))™ Sonar Simulation* included with the *Mapping the Ocean Floor* lesson
- Cardboard box with lid, approximately 10 x 10 x 6 inches
- Pencils, unsharpened; or wood dowels approximately 1/4-inch diameter x 8 inches; two for each student
- Copies of Sounding Rod Scale (Figure 2); two for each student
- Clear tape
- Plaster of Paris, 1 – 2 lb
- Masking tape
- Colored pencils, six colors
- Ruler, one for each student group
- Graph paper

Audio Visual Materials
Optional – Images of exploration technologies and animations (see Learning Procedure, Step 1c)
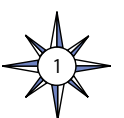
Teaching Time

Three to four 45-minute class periods, depending upon the availability of resources and activities assigned for out-of-class completion

Seating Arrangement

Groups of three to four students

Maximum Number of Students

30

Key Words and Concepts

Ocean Exploration
Okeanos Explorer
Bathymetric map
Multibeam sonar

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

On August 13, 2008, the NOAA Ship *Okeanos Explorer* was commissioned as "America's Ship for Ocean Exploration;" the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean. The strategy for accomplishing this mission is to use state-of-the-art technologies to search the ocean for anomalies; things that are unusual and unexpected. When an anomaly is found, the exploration strategy shifts to obtaining more detailed information about the anomaly and the surrounding area. An important concept underlying this strategy is the distinction between exploration and research. As a ship of discovery, the role of *Okeanos Explorer* is to locate new features in the deep ocean, and conduct preliminary investigations that provide enough data to justify follow-up by future expeditions.

The *Okeanos Explorer* strategy involves three major activities:
- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

Underway reconnaissance involves mapping the ocean floor and water column while the ship is underway, and using other sensors to measure chemical and physical properties of seawater. Water column exploration involves making measurements of chemical and physical properties "from top to bottom" while the ship is stopped. In some cases these measurements may be made routinely at pre-selected locations, while in other cases they may be made to decide whether an area with suspected anomalies should be more thoroughly investigated. Site characterization involves more detailed exploration of a specific region, including obtaining high quality imagery, making measurements of chemical and physical seawater properties, and obtaining appropriate samples.

In addition to state-of-the-art navigation and ship operation equipment, this strategy depends upon four types of technology:

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site:
http://oceanexplorer.noaa.gov/okeanos/welcome.html

Okeanos Explorer Vital Statistics:

Commissioned: August 13, 2008; Seattle, Washington
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46, including crew and mission support
Operations: Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation Operations (OMAO); Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit *http://oceanexplorer. noaa.gov/okeanos/welcome.html*.
Follow voyages of America's ship for ocean exploration with the *Okeanos Explorer* Atlas at
http://www.ncddc.noaa.gov/website/google_maps/ OkeanosExplorer/mapsOkeanos.htm

• Telepresence;
• Multibeam sonar mapping;
• CTD (an instrument that measures conductivity, temperature, and depth) and other electronic sensors to measure chemical and physical seawater properties; and
• A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 4,000 meters.

In many ways, telepresence is the key to the *Okeanos Explorer*'s exploration strategy. This technology allows people to observe and interact with events at a remote location. The *Okeanos Explorer*'s telepresence capability is based on advanced broadband satellite communication through which live images can be transmitted from the seafloor to scientists ashore, classrooms, and newsrooms, and opens new educational opportunities that are a major part of *Okeanos Explorer*'s mission for advancement of knowledge.

In the summer of 2010, years of planning, field trials, and state-of-the-art technology came together for the first time on the the ship's maiden voyage as part of the INDEX-SATAL 2010 Expedition. This expedition was an international collaboration between scientists from the United States and Indonesia to explore the deep ocean in the Sangihe Talaud Region. This region is located in the 'Coral Triangle', which is the global heart of shallow-water marine biodiversity. A major objective of the expedition was to advance our understanding of undersea ecosystems, particularly those associated with submarine volcanoes and hydrothermal vents. Among the Expedition's many "firsts," this was the first time scientists have been able to use an underwater robot to get a first-hand look at deepwater biodiversity in the waters of the Sangihe Talaud Region. For more information about the INDEX-SATAL 2010 Expedition, see *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*.

Map showing the Coral Triangle region – the most diverse and biologically complex marine ecosystem on the planet. The Coral Triangle covers 5.7 million square km, and matches the species richness and diversity of the Amazon rainforest. Although much of the diversity within the Coral Triangle is known, most still remains unknown and undocumented. Image courtesy of *www.reefbase.org*.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/coral_triangle_hires.jpg

Sonar (which is short for SOund NAvigation and Ranging) systems are used to determine water depth, as well as to locate and identify underwater objects. In use, an acoustic signal or pulse of sound is transmitted into the water by a sort of underwater speaker known as a transducer. The transducer may be mounted on the hull of a

ship, or may be towed in a container called a towfish. If the seafloor or other object is in the path of the sound pulse, the sound bounces off the object and returns an "echo" to the sonar transducer. The time elapsed between the emission of the sound pulse and the reception of the echo is used to calculate the distance of the object. Some sonar systems also measure the strength of the echo, and this information can be used to make inferences about some of the reflecting object's characteristics. Hard objects, for example, produce stronger echoes than softer objects. This is a general description of "active sonar". "Passive sonar" systems do not transmit sound pulses. Instead, they "listen" to sounds emitted from marine animals, ships, and other sources.

Multibeam sonar is one of the most powerful tools available for modern deep-sea exploration. A multibeam system uses multiple transducers pointing at different angles on either side of a ship to create a swath of signals. The *Okeanos Explorer* is equipped with a Kongsberg Simrad EM 302 multibeam system that can produce up to 864 depth soundings in a single swath. The time interval between signal transmission and return echo arrival is used to estimate depth over the area of the swath. In some systems, the intensity of the return echo is also used to infer bottom characteristics that can be used for habitat mapping. In addition to high-resolution maps, multibeam data can be used to create three dimensional models or even "fly-through" videos that simulate a trip across the area being mapped. For a fascinating example of this, see *http://oceanexplorer.noaa.gov/explorations/02fire/logs/jul08/media/sm2k.html*. This 3D fly-through movie shows the seafloor in the Magic Mountain area of Explorer Ridge (near the coast of Vancouver Island) where there are active hydrothermal vents. To see what the vents look like, you can view other fly-throughs of the same area at *http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain*.

Recently, a new generation of multibeam sonars has been developed that are able to map features in the water column as well as the seafloor. This ability will potentially allow multibeam sonars to map the location of fish and marine mammals, as well as a wide range of physical oceanographic processes. On May 17, 2009, the *Okeanos Explorer* was testing its multibeam sonar mapping system off the coast of California.

Multibeam Mapping Systems Aboard the *Okeanos Explorer*

Okeanos Explorer carries a Kongsberg Maritime EM302 deepwater multibeam sonar system. Transducers for the system are installed on the ship's hull in a custom-designed housing. The system can transmit up to 288 beams, can collect as many as 432 depth measurements in a single swath, and automatically compensates for movements of the ship. The EM302 operates in depths ranging between 10 m and 7,000 m. The width of the swath is about 5.5 times the depth, to a maximum of about 8 km. Depth resolution of the system is 1 cm. At a depth of 4,000 m, the system can resolve features with a dimension of approximately 50 m.

Software packages used to process data from the EM302 and to integrate these data with GPS information about geographic position and sensor data about ship movements to compensate for pitch and roll include:

Seafloor Information System
CARIS
Fledermaus
arcGIS
SonarWiz
Hypack
MapInfo
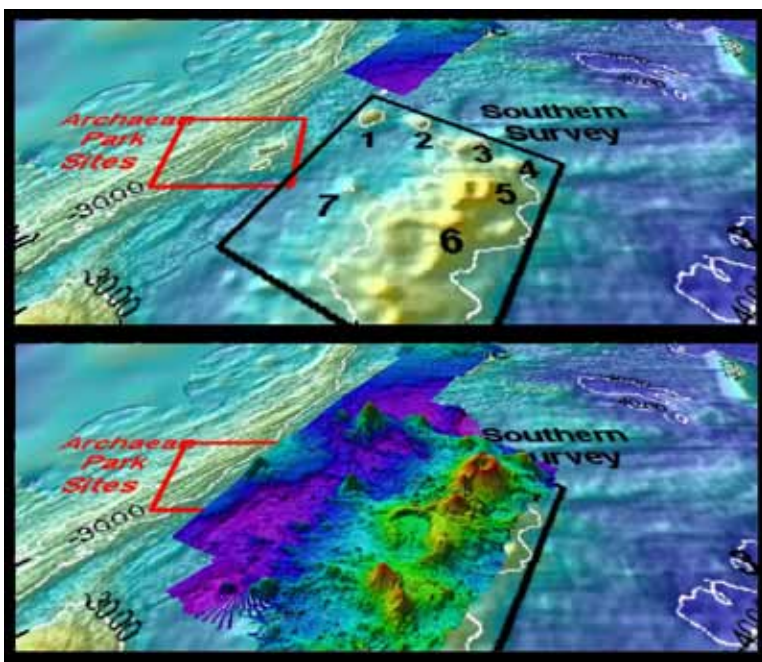
This "before and after" image provides a glimpse of *Okeanos Explorer*'s EM302 mapping system capabilities in deep water. The top image shows what we previously knew about the seafloor terrain in the southern Mariana region from satellite altimetry data. The bottom image includes an overlay of the information provided by the ship's EM302 multibeam system. Image courtesy of NOAA Office of Ocean Exploration and Research.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/em302_before_after_hires.jpg

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Suddenly, the multibeam image showed a plume of what scientists believe may be methane gas rising vertically 1,000 meters from the ocean floor. No such feature had ever been reported from this area before. You can see a video simulation that shows how multibeam sonar discovered this plume, and also provides a graphic overview of how multibeam works here: (*http://ccom.unh.edu/NOAA_oceanexploration/PlumePoints2.mov*). For more information about sonar systems, see *http://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html*.

An important technique for studying multibeam images uses a 3-dimensional data visualization system called Fledermaus (which is the German word for "bat," and is pronounced "FLEE-der-mouse"). The "Watching in 3-D" lesson includes a simple analysis of multibeam data using free viewing software for multibeam imagery in the Fledermaus file format.
Note: mention of proprietary names does not imply endorsement by NOAA.

In this lesson, students will learn about multibeam sonar, and use mock sonar set-ups to create a three-dimensional model of a simulated ocean floor.

STEM Connections

Ocean exploration aboard the *Okeanos Explorer* is a real-world example of STEM concepts in action:

Science provides the overall objective – to better understand Earth's ocean – as well as a methodology for systematically acquiring this understanding;

Technology includes the tools, systems and processes that have been made to make deep-ocean exploration possible;

Engineering designs the technologies that can function in the deep-ocean environment;

Mathematics provides the basis for measurements, data analysis, and engineering design.

With increasing attention to developing integrated approaches to STEM education and technological literacy, the *How Do We Explore?* theme offers an exciting context for educators who wish to bring more STEM content to their classrooms.

To assist with such efforts, most lessons developed for the *How Do We Explore?* theme identify opportunities to include specific benchmarks and standards for technological literacy that have been developed by the International Technology and Engineering Education Association (ITEA, 2007). While these standards have not been widely adopted, they provide useful guidance for efforts to enhance STEM content in advance of its inclusion in formal curricula.

In addition, the *How Do We Explore?* suite of lessons includes activities that are intended to provide opportunities to apply design processes, build technological devices, and develop some of the hands-on abilities that are an integral part of most concepts about STEM education. These activities are directly tied to the technologies and scientific methodologies used for ocean exploration aboard the *Okeanos Explorer*.

For more information, see: *http://www.iteaconnect.org/TAA/Publications/TAA_Publications.html*

Learning Procedure

1. To prepare for this lesson:
   a) Review:
      • Introductory essays for the INDEX-SATAL 2010 Expedition (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*);
      • Minding the Multibeam at Midnight by Colleen Peters (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/aug05/aug05.html*); and
      • State of the Art Seafloor Survey by Meme Lobecker and Elaine Stuart (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july31/july31.html*).
   (b) Review background information about the *Okeanos Explorer* exploration strategy and technologies.
   (c) If desired, download images to accompany discussions in Step 2. You may also want to download this "before and after" image to illustrate the capabilities of multibeam sonar:

      http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/em302_before_after_hires.jpg,

      as well as one or more of the animations referenced above to accompany discussions in Step 3:

      http://oceanexplorer.noaa.gov/explorations/02fire/logs/jul08/media/sm2k.html;

      http://oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain; and

      http://ccom.unh.edu/NOAA_oceanexploration/PlumePoints2.mov.

   (d) Review *Multibeam Mapping Simulation Activity Guide* and *Multibeam Mapping Simulation Activity Preparation Guide*, and decide how much preparation will be done by students. This activity may be varied, according to time available and individual education styles. For example, students may be divided into "Beam Teams," each of which constructs a mystery landscape that is kept hidden from other teams. Teams then exchange boxes and perform the mapping procedure to reveal the "mystery topography." This can become a competition between teams if points are awarded to teams that accurately predict the topography in the shortest amount of time.

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(e) Review *Hands-On Activity Guide – Multibeam Mapping: PING)))™ Sonar Simulation* included with the *Mapping the Ocean Floor* lesson, and decide whether you wish to include the activity as part of this lesson.

2. Briefly introduce the NOAA Ship *Okeanos Explorer* and the INDEX-SATAL 2010 Expedition. Briefly discuss why this kind of exploration is important (for background information, please see the lesson, *Earth's Ocean is 95% Unexplored: So What?*; *http://oceanexplorer.noaa.gov/okeanos/ explorations/10index/background/edu/media/so_what.pdf*). Highlight the overall exploration strategy used by *Okeanos Explorer*, including the following points:
   • The overall strategy is based on finding anomalies;
   • This strategy involves
      - Underway reconnaissance;
      - Water column exploration; and
      - Site characterization;
   • This strategy relies on four key technologies:
      - Multibeam sonar mapping system;
      - CTD and other electronic sensors to measure chemical and physical seawater properties;
      - A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 4,000 meters; and
      - Telepresence technologies that allow people to observe and interact with events at a remote location.
   You may want to show some or all of the images in the adjacent sidebar to accompany this review.

3. Ask students what they know about sonar, and provide additional information as necessary. Be sure students understand that sonar (which stands for SOund NAvigation and Ranging) uses an acoustic signal or pulse of sound that is transmitted into the water by a sort of underwater speaker known as a transducer. Transducers may be mounted on the hull of a ship, or may be towed in a container called a towfish. If the seafloor or other object is in the path of the sound pulse, the sound bounces off the object and returns an "echo" to the sonar transducer. The time elapsed between the emission of the sound pulse and the reception of the echo is used to calculate the distance of the object. Some sonar systems also measure the strength of the echo, and this information can be used to make inferences about some of the reflecting object's characteristics. Hard objects, for example, produce stronger echoes than softer objects. Sonar systems can be used to determine water depth, as well as to locate and identify underwater objects. A multibeam sonar system uses multiple transducers pointing at different angles on either side of a ship to create a swath of signals. The time interval between signal transmission and return echo arrival is used to estimate depth over the area of the swath. In addition to high-resolution maps, multibeam data can be used to create three dimensional models or even "fly-through" videos that simulate a trip across the area being mapped. You may want to show one or more of the video clips referenced in Step 1c.

Describe the role of multibeam sonar in ocean exploration aboard the *Okeanos Explorer*. Students should realize that this is the key technology for the "reconnaissance" component of the overall exploration strategy, and provides the "big picture" view as explorers look for anomalies. You may wish to have

The ROV Little Hercules descends through deep water to an undersea volcano in the Celebes Sea to search for hydrothermal vents and associated ecosystems. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/ logs/hires/1june29_hires.jpg
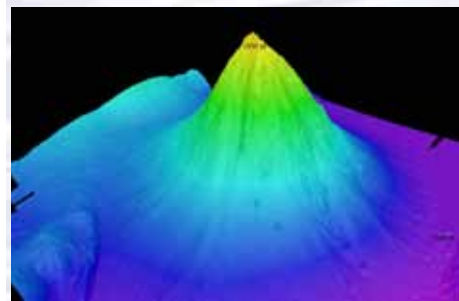
Okeanos Explorer's EM302 multibeam sonar mapping system produced this detailed image of the Kawio Barat seamount, which rises around 3800 meters from the seafloor. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/ logs/hires/june26fig1_hires.jpg

Scientists in the Exploration Command Center at NOAA's Pacific Marine Environmental Laboratory in Seattle view live video from the *Okeanos Explorer*'s ROV. Image courtesy NOAA
http://www.pmel.noaa.gov/images/headlines/ecc.jpg

Senior Survey Technician Elaine Stuart holds onto the CTD as it comes aboard the *Okeanos Explorer*. Image courtesy NOAA
http://www.moc.noaa.gov/oe/visitor/photos/photospage-b/CAP%20 015.jpg

students read the log entry "Minding the Multibeam at Midnight" (Step 1a). This image shows how much *Okeanos Explorer*'s EM302 mapping system adds to what we know about seafloor terrain: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/em302_before_after_hires.jpg*.

4. Tell students that their assignment is to map an unexplored and invisible landscape using methods that roughly simulate multibeam sonar technology. Divide students into "Beam Teams" of three or four students, and provide each team with a copy of *Multibeam Mapping Simulation Activity*, and access to necessary materials. Tell students that oceanographers like to graph depth so that the greatest depths are near the bottom of the graph, because this is how we imagine a vertical slice of the ocean would appear. So, the Y-axis on the bar graphs is made so that that largest depth values will be at the bottom of the graphs. You may want to have students color the depth contours on their graphs after they are cut out using the color scheme on the Sounding Rods (or any other scheme that you choose). Coloring the cutouts will make the final model more closely resemble a multibeam sonar image.

When students have completed their 3-D bathymetry models, have each group show their models to the entire class and report their conclusions about the mystery landscape. After each group has reported their conclusions, have them open their box, and compare the actual topography with their predictions.

5. When all groups have made their presentations, ask students how their investigations could be improved. Shortening the interval between "soundings" would improve detail in the models; but would also mean a lot more work since an additional graph cutout would have to be made for each row added to the sampling procedure. Having smaller graduations on the sounding rods would help improve the accuracy of "depth" measurements. This accuracy would also be improved by having a way to ensure that the sounding rods are exactly vertical when soundings are made.

Students should realize that a multibeam sonar system would provide an almost continuous record of depth in a swath on either side of the ship. The *Okeanos Explorer*'s EM302 multibeam system can produce swath widths as large as five times the water depth. Students should also realize that rough topography can obscure other topographic features, so better resolution is especially important when there are boulders, reefs, or other irregular objects in a search area.

Discussion of multibeam sonar technology may also include the following components of technological literacy:
- **Scope of technology –** Development of multibeam sonar technology provides detailed images of the ocean floor that were not possible before this technology was developed.
- **Core concepts of technology –** Multibeam sonar is an example of several technological systems connected together; including sonar systems to obtain depth data, global positioning systems for geographic location, sensors to detect ship motion so that data can be corrected for pitch and roll, and computer systems to analyze raw data and convert the data to accurate depth estimates and visual images.
- **Relationships between technologies and other fields of study –** Improvements to each of the technologies listed above improves the overall

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capability of bathymetric information from multibeam sonar systems; and this information is useful to geologists, biologists, and many other branches of science.

- **Effects of technology on the environment –** Some scientists are concerned that marine mammals may be harmed if they are close to ships using certain types of sonar technology. *Okeanos Explorer*'s EM 302 multibeam system is equipped with a function that reduces transmission power to avoid harming mammals if they are nearby.

6. If desired, have students complete the *PING)))™ Sonar Simulation Activity* (Step 1e). This activity addresses additional components of technological literacy, including:
- Attributes of design;
- Understanding of engineering design;
- Problem-solving approaches;
- Abilities to apply design processes; and
- Abilities to use and maintain technological products.

The BRIDGE Connection
www.vims.edu/bridge/ – Scroll over "Ocean Science Topics" in the menu on the left side of the page, then "Human Activities," then click on "Technology" for activities and links about satellite communications and other ocean exploration technologies.

The "Me" Connection
Have students write a short essay describing a situation (real or imaginary) in which the accuracy of a map was personally important.

Connections to Other Subjects
English/Language Arts, Mathematics, Social Studies

Assessment
Class discussions and students' work with the mapping simulation activity provide opportunities for assessment.

Extensions
See the *Calling All Explorers* lesson for an activity involving maps and GPS technology: *http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/10callingallexplorers.pdf*.

Multimedia Discovery Missions
http://oceanexplorer.noaa.gov/edu/learning/welcome.html – Click on the links to Lessons 5 and 6 for interactive multimedia presentations and Learning Activities on Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program
Earth's Ocean is 95% Unexplored: So What?
(from the INDEX-SATAL 2010 Expedition)
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf

Focus: Importance of deep-ocean exploration (Grades 5-6; Life Science/Earth Science)

Students describe at least three different deep-ocean ecosystems, explain at least three reasons for exploring Earth's deep ocean, and explain at least three ways that deep-ocean ecosystems may benefit humans, and create a wall magazine to communicate scientific ideas.

Sonar Simulation

(from the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition)

http://oceanexplorer.noaa.gov/explorations/10sanandreas/background/edu/media/sonarsim78.pdf

Focus: Side scan sonar (Grades 7-8; Earth Science/Physical Science)

Students describe side-scan sonar, compare and contrast side-scan sonar with other methods used to search for underwater objects, and make inferences about the topography of an unknown and invisible landscape based on systematic discontinuous measurements of surface relief.

Mapping the Ocean Floor

(from the INSPIRE: Chile Margin 2010 expedition)

http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/mapping.pdf

Focus: Bathymetric Mapping (Grades 7-8; Physical Science/Earth Science)

Students create a two-dimensional topographic map from bathymetric survey data, create a three-dimensional model of seafloor topography from a two-dimensional topographic map, and interpret two- and three-dimensional topographic data.

Sound Pictures

(from the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition)

http://oceanexplorer.noaa.gov/explorations/10sanandreas/background/edu/media/soundpics912.pdf

Focus: Sonar (Grades 9-12; Physical Science)

Students explain the concept of sonar, describe the major components of a sonar system, explain how multibeam and sidescan sonar systems are useful to ocean explorers, and simulate sonar operation using a motion detector and a graphing calculator.

Tools of Discovery - Multibeam Sonar

(from the INDEX SATAL 2010 Expedition)

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/multibeam.pdf

Focus: Technology for deep ocean exploration: Multibeam Sonar (Grades 9-12; Earth Science/Physical Science)

Students describe multibeam sonar, discuss the advantages of multibeam sonar bathymetry compared to two-dimensional topographic bathymetry, and interpret three-dimensional multibeam bathymetric data.

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Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

Anonymous. 2010. Web site for the INDEX-SATAL 2010 Expedition [Internet]. Office of Ocean Exploration and Research, NOAA [cited January 7, 2011]. Available from *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html* – Includes links to lesson plans, career connections, and other resources

Anonymous. Ocean Explorer [Internet]. NOAA Office of Ocean Exploration and Research [cited January 4, 2011]. Available from: *http://oceanexplorer.noaa.gov*.

Anonymous. Sonar [Internet]. NOAA Ocean Explorer [cited January 17, 2011]. Available from: *http://www.oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html*

Lobecker, M. and E. Stuart. 2010. State of the Art Seafloor Survey [Internet]. NOAA Ocean Explorer [cited January 10, 2011]. Available from: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july31/july31.html*

Peters, C. 2010. Minding the Multibeam at Midnight [Internet]. NOAA Ocean Explorer [cited January 10, 2011]. Available from: *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/aug05/aug05.html*

National Science Education Standards
Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Transfer of energy

Content Standard D: Earth and Space Science
- Energy in the Earth system
- Earth's history
- Earth in the solar system

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in society

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Nature of science

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Ocean Literacy Essential Principles and Fundamental Concepts

Because most Fundamental Concepts are broad in scope, some aspects of some Concepts may not be explicitly addressed in this lesson. Such aspects, however, can be easily included at the discretion of the individual educator.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept g. There are deep-ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

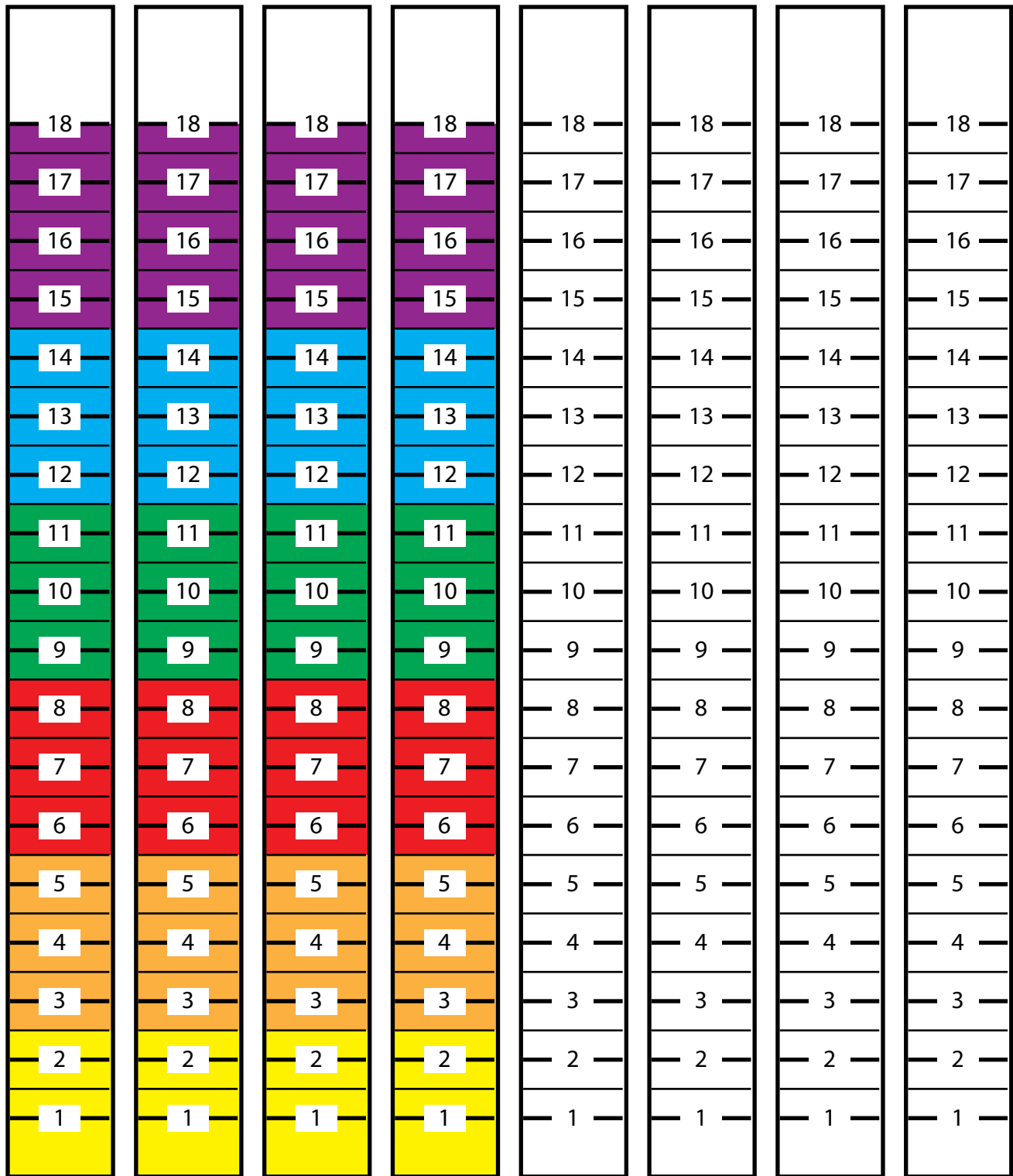# Multibeam Mapping Simulation Activity
Preparation Guide

Materials
Each student group will need (assuming four students per group):
- 1- Cardboard box with lid, approximately 10 x 10 x 6 inches
- 8 - Pencils, unsharpened; or wood dowels approximately 1/4-inch diameter x 8 inches; two for each student
- 1 - Copy of Sounding Rod Scale (Figure 2); two for each student
- Clear tape
- Plaster of Paris, 1 − 2 lb
- Masking tape
- Colored pencils, six colors
- Ruler
- Graph paper, at least ten sheets
- Awl, icepick or sharp nail

Figure 1. Box Preparation

BOX

BOX TOP
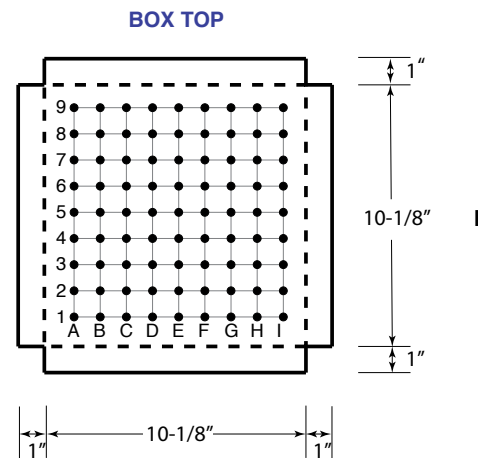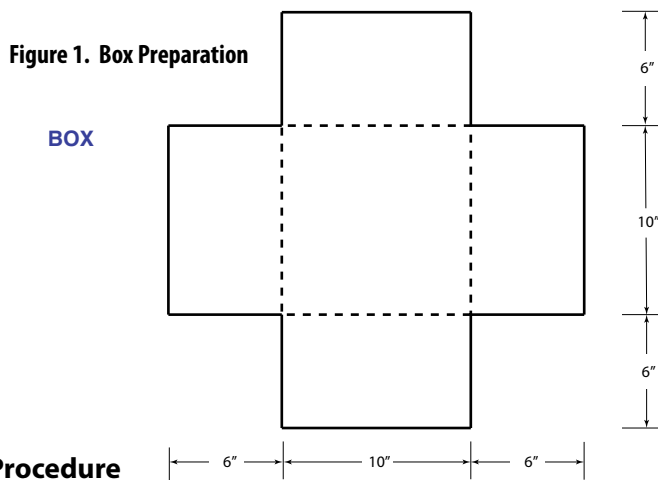
Procedure
1. If cardboard boxes of an appropriate size are not available, they can be constructed from poster board using Figure 1 as a guide. Fold along the dotted lines and tape the corners with masking tape.
2. Mark a grid of 1-inch squares on the top of the box. Make a hole at each junction point large enough so that the pencil or dowel can easily be inserted. TIP: Make a hole in the cardboard with an awl, icepick or nail; then enlarge the hole with a sharpened pencil or dowel. Label each row of holes with a number, and each column of holes with a letter (see Figure 1).
3. Cut out the Sounding Rod Scales, so that each student has two scales. If you are using the uncolored scales, color each interval with a colored pencil using the colored scales as a guide. Tape each scale onto a pencil or dowel to make two Sounding Rods for each student. The bottom of the scale should be even with one end of the pencil or dowel.
4. Prepare a "mystery landscape" in the bottom of each box. If students are doing this step, they should keep their work out of the sight of other groups. Mix plaster of Paris, and pour a 1 − 2 cm thick layer into the bottom of each box. Pile up some of the plaster to make irregular mounds that simulate rough topography. Do not completely cover the bottom of the box, because that will reduce the overall depth range, and we want a lot of variation in these landscapes! Allow plaster to harden. Temporarily fasten lids to the boxes with masking tape.

Volume 2: How Do We Explore?
Inquiry Topic: Multibeam Mapping – Wet Maps (5-6)

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Figure 2. Sounding Rod Scale

Multibeam Mapping Simulation Activity Guide

1. Your Beam Team should include three or four students, and each student should have two Sounding Rods. You will use these Rods to measure the depth under each of the holes in the lid of your box, then you will plot these depths to create a three-dimensional model of the landscape hidden inside the box. Each student will be responsible for measuring the depth of two or three of the holes in each row. If you stand in a circle (or part of a circle) around the box, you should all be able to make your measurements at the same time.

2. When your teacher tells you to begin, each member of your team should measure the depth in their assigned holes in the first row using a Sounding Rod. Leave the Rods in place until you have recorded your measurements on the Data Sheet. It will probably be easiest if one team member does the recording while the other members call out the depth measurements.

3. When you have finished measuring the depths in the first row, use the same procedure to measure depths of the remaining holes, recording the data from your measurements one row at a time.

4. When you have measured all of the depths, and entered all the values, plot the results for each row on a bar graph as directed by your teacher. Figure 3 shows an example of the graph that resulted from plotting one row of depth data. It will probably be quickest if each team member is responsible for plotting specific rows of data.

5. When your graphs are completed, cut them out as shown in Figure 3. Be sure to leave the border at the bottom of each graph! Fold as shown, and tape each graph onto the top of the box so that the folded edge of each graph lies on its corresponding row on the box top. Stand the graphs up so that they are perpendicular to the top of the box (additional tape may be needed to keep the graphs upright).

   Now you should have a three-dimensional model of the mystery landscape inside the box. Wait for further instructions from your teacher.

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Multibeam Mapping Simulation Data Sheet

COLUMNS	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

ROWS

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Figure 3. Example of graph of data from Row 1.

DATA

COLUMNS

ROWS		A	B	C	D	E	F	G	H	I	J
	1	16	12	7	4	3	5	8	11	14.5	

CUT

FOLD