MARINE NAVIGATION LESSON PLAN

See That Sound?

Theme

Hydrographic Survey

Links to Overview Essays and Resources Needed for Student Research

http://oceanservice.noaa.gov/topics/navops/hydrosurvey/
http://chartmaker.ncd.noaa.gov/hsd/hydrog.htm

Subject Area

Physical Science/Earth Science

Grade Level

9-12

Focus Question

How can scientists obtain information about the bathymetry of the seafloor to help mariners navigate safely in coastal areas?

Learning Objectives

- Students will explain the concept of sonar, and describe the major components of a sonar system.
- Students will compare and contrast multibeam and sidescan sonar systems.
- Students will design a relatively low-cost sidescan sonar system that could be built by an amateur ocean explorer.

Materials Needed

- Computers with internet access; if students do not have access to the internet, see suggestions under Learning Procedure Step 1
- Copies of "Guidance for Research on Hydrographic Sonar" Worksheet, one copy for each student or student group
- (Optional) Materials for sonar simulation activity (see Learning Procedure Step 4):
  - Graphing calculator, data logger, and motion sensor; ideally, one for each student group
  - String

– Boxes, cans, and other objects to create a model "seafloor"
– Meter stick
– Felt tip marker for marking string

Audio/Visual Materials Needed

None

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Groups of 2-3 students

Maximum Number of Students

30

Key Words

Hydrography
Sonar
Sidescan sonar
Multibeam sonar
Bathymetry

Background Information

Hydrography is the science of measuring and describing the physical features of bodies of water and adjacent land areas that are periodically underwater (such as areas that are covered and uncovered by rising and falling tides). Hydrographic surveys are undertaken to obtain information needed for ship navigation, harbor maintenance (e.g., dredging), coastal engineering (e.g., erosion control), coastal resource management (location of various habitat types), and other activities; but the most common use of hydrographic data is as an aid to safe navigation. All hydrographic surveys involve bathymetry (the measurement of depth in large bodies of water). In addition, most surveys also collect information about the types of material found on the sea floor (sand, mud, rock, etc.) since this knowledge is important to vessels anchoring, dredging, engineering projects and to understanding the ecology of biological communities.

NOAA's National Ocean Service (NOS) conducts hydrographic surveys through its Office of Coast Survey (OCS). The OCS is the oldest scientific organization in the U.S., created in 1807 to fulfill President Thomas Jefferson's order for a complete survey of the U.S. coast. Since its formation, the OCS has conducted over 10,600 hydrographic surveys. The OCS Historical Map & Chart Collection contains over 20,000 maps and charts from the late 1700s to present day (visit *http://historicals.ncd.noaa.gov/historicals/histmap.asp* for an Image catalog and link to software for viewing downloaded maps; see *http://chartmaker.ncd.noaa.gov/staff/charts.htm* for more information about NOAA's nautical charts).

Modern hydrographic surveys often use sidescan sonar to depict bathymetry and locate other significant features (such as shipwrecks). Sonar (which stands for SOund NAvigation and Ranging) systems consist of a transmitter that sends pulses of sound energy through the water and a receiver that detects return signals (echoes) that are reflected back from the seafloor or other objects. In a sidescan sonar system, the transmitter is typically towed behind the survey vessel in a torpedo-shaped container called a "towfish." The energy transmission from the towfish is a fan-shaped signal that sweeps the seafloor from directly under the towfish to either side, typically out to a distance of about 100 meters. The strength of the return echo is continuously recorded and analyzed by a computer to create a "picture" in which objects that reflect more acoustic energy are shown as lighter areas on the image, while objects that reflect less energy are shown as darker areas. If an object extends into the water column, a shadow will be created that will show up as a white area on the "picture."

Multibeam sonar systems also are frequently used by hydrographers. These systems provide fan shaped coverage similar to sidescan sonars, but do not continuously record the strength of the return echo. Instead, the multibeam system records depth by measuring the time elapsed between transmission of a sound signal and detection of the reflected signal by the sonar's receiver. Multibeam sonar transmitters are generally attached to a vessel, rather than being towed as in sidescan systems. Surveys usually are carried out by steering the survey vessel on a series of parallel tracks (courses) that are close enough to ensure that the area covered by the sidescan or multibeam sonar overlaps on adjacent tracks.

In this lesson, students will research sonar technology, and use the results of their research to design a sidescan sonar system that could be constructed on a limited budget. Optionally, students may also simulate sonar operation using a motion detector, graphing calculator, and a data logging system (such as the Texas Instruments "calculator based laboratory" (CBL) system or "calculator based ranger" (CBR) system).

Learning Procedure

1.

To prepare for this lesson, review the questions on the "Guidance for Research on Hydrographic Sonar" Worksheet, and the answers to questions provided in Step 3. If students do not have classroom internet access, this Worksheet may be completed as a homework assignment using home, library, or other internet resources.

2.

Introduce the science of hydrography by briefly reviewing the historical and present-day importance of marine navigation, and asking students to brainstorm the types of information needed to safely navigate the Earth's oceans. In addition to weather, students should recognize the importance of information about depth and physical characteristics of the seafloor, particularly in coastal areas. Tell students that the Office of Coast Survey is the oldest scientific organization in the U.S. and was created in 1807 to prepare a hydrographic survey of the entire U.S. coast by order of President Thomas Jefferson. At that time, depths were commonly measured using a "lead line", which was simply a rope marked at fixed intervals (usually fathoms; one fathom equals six feet) attached to a lead cylinder which was lowered to the bottom. When the line went slack, depth was estimated from the marks on the rope. Often, the bottom of the lead cylinder was hollowed out and filled with wax. When the lead was brought back on board the survey ship, bits of sand, shell, mud, etc. stuck in the wax gave the surveyors clues about the materials present on the seafloor.

Ask students how hydrographic data on depth bottom topography are obtained by modern hydrographers. Some students will probably be familiar with the concept of sonar. If not, they may have heard about this technology in connection with submarine warfare.

Provide each student or student group with a copy of the "Guidance for Research on Hydrographic Sonar" worksheet, and tell students that their assignment is to prepare a written report that includes answers to questions on the worksheet, as well as a design for a sidescan sonar system that could be constructed with a maximum budget of $500. You may want to direct students to the OCS webpage on sidescan and multibeam sonar (http://chartmaker.ncd.noaa.gov/hsd/wrecks.htm) to get them started.

3.

Lead a discussion of students answers to worksheet questions, then have each group present their ideas for a low-cost sidescan sonar.

- "Sonar" is an acronym for "SOund NAvigation and Ranging"

- The basic components of a sonar system are:
  – A transmitter capable of emitting an acoustic signal;
  – A receiver capable of detecting echoes from the transmitted signal; and
  – A processing unit to interpret the reflected signal.
  Students may also mention:
  – A cable to connect the processor with the transmitter and receiver;
  – A transducer (which is analogous to the antenna on a radio transmitter or receiver); and
  – A towfish to allow the transducer(s) to be towed behind the survey vessel.

- Transducers for sidescan sonar are often towed behind the survey vessel because:
  – Being able to tow the transducer at some depth below the surface means that there is less water through which the acoustic signal must travel, so there is less absorption and

scattering of the acoustic energy, and consequently, the signal is stronger;
- The transducer is less affected by the surface motion of the survey vessel (particularly rolling motion); and
- The transducer can be towed beneath a thermocline (the boundary between two water masses of different temperature) which can interfere with the acoustic signal.

• Higher frequencies give better image resolution (more detail) but travel shorter distances than lower frequencies.

• sidescan and multibeam sonars both transmit a fan-shaped pattern of acoustic signals, sidescan systems continuously record the strength of the return echo caused by the transmitted signal bouncing off of the sea floor or other object. Multibeam systems, on the other hand, record depth by measuring the time elapsed between transmission of a sound signal and detection of the reflected signal by the sonar's receiver. Multibeam sonar transmitters are generally attached to a vessel, rather than being towed as is typical of sidescan systems.

The usual approach to creating a low cost sidescan sonar is to adapt a conventional "fish finder" type of depth sounder. The primary modification is to construct a towfish (e.g., from PVC pipe fitted with aluminum stabilizing fins) to carry the transducer so that it points to one side rather than straight down. Somewhat more advanced designs use multiple transducers. Some amateur-built sidescan sonars are capable of producing very good images, and have been used to locate shipwrecks.

4. (Optional)
Option A: Procedure Using CBL Systems –
Steven Stevenoski of Lincoln High School, Wisconsin Rapids, WI developed an activity as part of the Teachers Experiencing Antarctica and the Arctic Program (see *http://tea.armadaproject.org/teainfo/TEA_flyer_0203AA.pdf* for information on the TEA program, and *http://tea.armadaproject.org/activity/stevenoski/seeingtheseafloorusingsoundmultibeamsidescansonar_main.html*)] in which students demonstrate how sound waves can be used to create images of objects using a motion detector, data logger, and graphing calculator. The original activity is based on a Texas Instruments graphing calculator, CBL ("calculator based labo-

ratory") system, and Vernier motion detector. A CBR ("calculator based ranger") system would provide a lower cost alternative, and other calculators, data loggers, and motion detectors could be used in a similar way. The following is an outline of the activity. Specific instructions will depend upon the particular systems available, but manufacturers' instructions for typical activities using these systems (e.g., measuring the velocity of a toy car) can be easily adapted for the sonar simulation. If students will be using Texas Instruments systems, a variety of guidebooks for CBL, CBR, and graphing calculators can be downloaded from *http://education.ti.com/educationportal/sites/US/sectionHome/download.html*.

The basic set-up for the simulation consists of a variety of objects (at least six) of varying height and shape. These are arranged on the floor between two points two to four meters apart. A string is stretched between these points, 1.0 to 1.5 meters above the floor (in the original activity, a stool was placed to mark the location of the two points and to provide an attachment for the string).

The motion detector is connected to the data logger (and if necessary to the graphing calculator), and the system is set up to collect distance data as a function of time. One student holds the motion detector at one end of the string, triggers the system to begin data collection, and moves the motion detector smoothly along the string to the other end. It is important that the motion detector is moved at a constant rate of speed, which should be slow enough to allow the system to collect enough data points to adequately map the objects. If the motion detector is moved slowly, more data points (distance measurements) will be collected.

Finally the data points are graphed as a function of time. Since the elapsed time is proportional to the linear distance along the string, the series of distance measurements should create a profile of the objects beneath the string. Actually, a reverse profile will be created, since taller objects will be closer to the string, and hence the distance to tall objects will be smaller than the distance to shorter objects. A simple data transformation can be used to correct this distortion (e.g., object height = |(measured distance) – (height of string)|.

Option B: Procedure Without CBL Systems –
The following procedure is based on the "traditional" (i.e., pre-sonar) technique for measuring depth with a lead line.

Divide the class into an equal number of groups, and pair each group with another. One group in each pair will set up a series of objects to create a model sea bottom, and the other group will attempt to analyze lead line data to obtain an accurate picture of the "bottom." Objects should include a variety of shapes, including at least one with relatively high vertical relief (to simulate part of a ship sticking up from the bottom). Be sure the "Interpretation" group cannot see the objects. Mark a string at three-inch intervals, and arrange the string above the objects as described above. Mark a second string about 2 m long at one-inch intervals and attach a weight (fishing sinker, metal nut, etc) to one end of the string. The "Set-up" group should use the weighted string to obtain "depth" measurements at three-inch intervals, and call these measurements out to the "Interpretation" group. When all measurements have been collected, the "Interpretation" group should graph these and state their predictions about the model sea floor. Have groups switch roles and repeat the procedure with a new arrangement of objects.

These simulations illustrate the importance of sample intervals in obtaining an accurate "picture" of the bottom, as well as the difficulty of drawing inferences about three-dimensional shapes from two-dimensional data. You may want to introduce the concept of sidescan sonar, which provides three-dimensional bottom data (see *http://ocean.noaa.gov/technology/tools/sonar/sonar.html* for more information about sidescan sonar).

The Bridge Connection

http://www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Human Activities," then "Technology" for links to resources about marine technology.

The Me Connection

Have students write a brief essay describing real or imaginary circumstances in which new hydrographic surveys could be urgently important to people who have nothing to do with marine navigation. If they have trouble with this, you may suggest that they consider the aftermath of severe coastal storms.

Extensions

1. Visit *http://www.ocean-institute.org/edu_programs/materials/P/PDF/PDF_SFE/A_SONAR.pdf* and/or *http://www.education-world.com/a_lesson/00-2/lp2083.shtml* for other activities about sonar.

2. Replicate the use of tallow on traditional lead lines by adding small objects (rocks, shells, sand, etc) to the model "seafloor," and having students gather data about bottom type using a piece of modelling clay or wax attached to the bottom of a fishing weight (pyramid shapes, at least 2 oz, work best).

Resources

http://oceanservice.noaa.gov/topics/navops/hydrosurvey – National Ocean Service hydrographic survey Web site

http://www.oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html – NOAA's Ocean Explorer Web page about sonar

http://chartmaker.ncd.noaa.gov/hsd/wrecks.htm – Office of Coast Survey Web page about sonar

http://www.l-3klein.com/; http://www.c-max.co.uk/; http://www.geo-acoustics.co.uk/df-sonar.htm; *http://www.wesmar.com/* – Web sites for commercial sidescan sonar manufacturers

National Science Education Standards

Content Standard A: Science as Inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Structure and properties of matter

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

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Links to AAAS "Oceans Map" (aka benchmarks)

5D/H3 – Human beings are part of the Earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

MARINE NAVIGATION WORKSHEET

Guidance for Research on Hydrographic Sonar

Your assignment is to prepare a written report that includes answers to the following questions, and a design for a sidescan sonar system that could be constructed with a maximum budget of $500. Answering these questions should lead you to some useful approaches for the design problem.

1. "Sonar" is actually an acronym. What does it mean?

2. What are the basic components of a sonar system?

3. Why are transducers for sidescan sonar often contained in a "towfish" that is towed behind the survey vessel?

4. What are the advantages and disadvantages of high frequency (500 kHz and up) sonar signals compared to lower frequency (50 kHz or 100 kHz) signals?

5. What is the difference between sidescan sonar and multi-beam sonar?

6. Discuss the importance of sidescan sonar and multibeam sonar to one of the following areas: ocean transportation, oceanographic research, disaster response, or maritime archaeology.