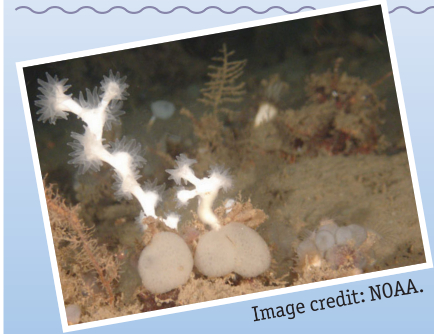
Lophelia II 2009:
Deepwater Coral Expedition: Reefs Rigs, and Wrecks

The Robot Ranger



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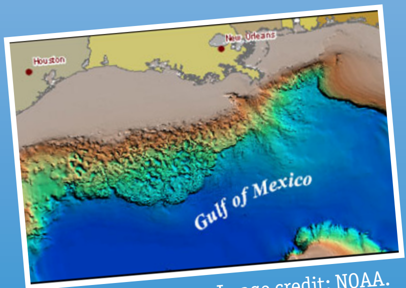

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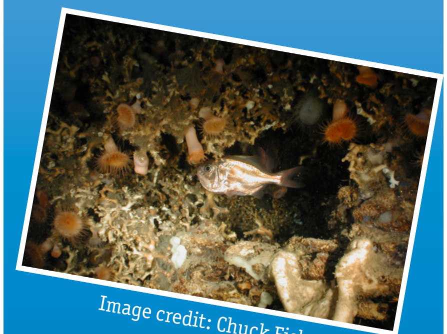

Image credit: Chuck Fisher, NOAA.

Image captions on Page 2.

lesson plan

Focus

Robotic Analogues for Human Structures (Vision, Distance Estimation)

Grade Level

5-6 (Life Science/Physical Science)

Focus Question

How can scientists build robotic systems that can estimate distance?

Learning Objectives

- Students will be able to explain how humans are able to estimate the distance to visible objects.
- Students will be able to explain the general principle of ultrasonic ranging.
- Students will be able to describe a robotic system capable of estimating the distance to nearby objects.

Materials

- Copies of *Robotic Ranging Inquiry Guide*; one copy for each student group
- Tennis balls; one for each student group
- Stopwatch or cell phone with stopwatch function; may be shared among several student groups
- (Optional) Ultrasonic sensors (see Learning Procedure, Step 1)

Audio-Visual Materials

- None

Teaching Time

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

Seating Arrangement

Groups of two to four students

Maximum Number of Students

32

Key Words

Ranging
Remotely Operated Vehicle
Robot
Ultrasonic sensor

Background Information

[*NOTE: Explanations and procedures in this lesson, except for the Inquiry Guide, are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators usually will need to adapt the language and instructional approach to styles that are best suited to specific student groups.*]

Deepwater coral ecosystems on hard substrates in the Gulf of Mexico are often found in locations where hydrocarbons are seeping through the seafloor. Hydrocarbon seeps may indicate the presence of undiscovered petroleum deposits, and make these locations potential sites for exploratory drilling and possible development of offshore oil wells. Responsibility for managing exploration and development of mineral resources on the Nation's outer continental shelf is a central mission of the U.S. Department of the Interior's Minerals Management Service (MMS). Besides managing the revenues from mineral resources, an integral part of this mission is to protect unique and sensitive environments where these resources are found.

For the past three years, NOAA's Office of Ocean Exploration and Research (OER) has collaborated with MMS on a series of expeditions to locate and explore deep-sea chemosynthetic communities in the Gulf of Mexico. These communities not only indicate the potential presence of hydrocarbons, but are also unique ecosystems whose importance is presently unknown. To protect these ecosystems from negative impacts associated with exploration and extraction of fossil fuels, MMS has developed rules that require the oil and gas industry to avoid any areas where geophysical survey data show that high-density chemosynthetic communities are likely to occur. Similar rules have been adopted to protect archeological sites and historic shipwrecks.

OER-sponsored expeditions in 2006, 2007, and 2008 were focused on discovering seafloor communities near seeping hydrocarbons on hard bottom in the deep Gulf of Mexico; detailed sampling and mapping at selected sites; studying relationships between coral communities on artificial and natural substrates; and gaining a better understanding of processes that control the occurrence and distribution of these communities. The *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks will take place aboard the NOAA Ship *Ronald H. Brown*, and is directed toward exploring deepwater natural and artificial hard bottom habitats in the northern Gulf of Mexico with emphasis on coral

Images from Page 1 top to bottom:
Lophelia pertusa colony with polyps extended.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

The ROV from SeaView Systems, Inc., is prepared for launch.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept20/media/rov_prep.html

Multibeam bathymetry allows terrain models to be created for large areas of the seafloor.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept21/media/gomex_multibeam.html

Lophelia pertusa create habitat for a number of other species at a site in Green Canyon.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

communities, as well as archeological studies of selected shipwrecks in the same region. Expedition scientists will:

- Make collections of *Lophelia*, other corals, and associated organisms from deepwater reefs;
- Collect quantitative digital imagery of characterization of deepwater reef sites and communities;
- Conduct archeological/ biological investigations on deep water shipwrecks.
- Deploy instruments to measure currents and sedimentation in several sites for a period of approximately one year.

Many of these activities depend upon a Remotely Operated Vehicle (ROV), which is an underwater robot that allows scientists to visit and work in deep-ocean sites without the expense and risk involved in using a manned submersible. The *Lophelia* II 2009 Expedition will use a ROV system named *Jason II/Medea*. This is a two-part system: *Jason II* is a mobile platform that carries sonar and video imaging equipment as well as manipulator arms for collecting samples. *Jason II* gives scientists a 'virtual presence' in deep ocean waters at depths up to 6,500 meters. A 35-meter cable connects *Jason II* to a second ROV named *Medea*, which is connected to the surface ship by a 10-kilometer fiber optic cable. This arrangement allows *Medea* to buffer *Jason II* from movements of the ship, and provides a second platform that allows scientists to observe *Jason II* during seafloor operations.

The *Jason II/Medea* system is operated from a control van that is loaded aboard the host ship along with the ROV. Additional equipment and supplies are carried in separate tool and rigging vans.

The advantage of the *Jason II/Medea* system is that it allows much longer observation periods than are possible with manned submersibles; the average *Jason* dive is 21 hours (compared to *Alvin* dives which are six to ten hours), though dives as long as 71 hours have been made on some occasions. The system is designed, built, and operated by the Deep Submergence Laboratory of Woods Hole Oceanographic Institution. See http://oceanexplorer.noaa.gov/technology/subs/jason/welcome.html for more information.

A key piece of information needed by ROV pilots is a reliable way to determine the distance to nearby objects. While video equipment aboard *Jason II* provides images of nearby objects, the images do not provide binocular vision that we ordinarily use to gauge distance. This lesson guides a student inquiry into robotic systems that can provide this kind of information.

Learning Procedure

1. To prepare for this lesson:
   - Review introductory essays for the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks at http://oceanexplorer.noaa.gov/explorations/09lophelia/welcome.html;
     - Visit http://oceanexplorer.noaa.gov/gallery/technology/technology_collection.html for images and discussions of various types of ROV used in ocean exploration; and
     - Review procedures and questions on the *Robotic Ranging Inquiry Guide* and make copies for student groups.
     - Find a suitable location where there is a large wall with at least 50 feet of open space in front of the wall.

   If your class has access to Lego® NXT or Calculator-Based Laboratory™ systems you may want to extend this inquiry by having students assemble and use an ultrasonic ranging device to measure the distance to nearby objects. Another, more involved, option is to construct a similar device using a Ping)))™ sensor and a microcontroller (see *Make* magazine, Volume 19 for detailed instructions; you can purchase the volume online at http://makezine.com/19/makey/).

2. Briefly introduce the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks. Emphasize that very little is known about deep-water coral communities, but these communities may be important to humans in a variety of ways, including their potential as sources for new drugs to treat human diseases (for more information on this point, see the 2003 Ocean Explorer Deep Sea Medicines expedition, http://oceanexplorer.noaa.gov/explorations/03bio/welcome.html).

   List some of the activities planned for the *Lophelia* II 2009 expedition: surveys of deep-ocean hard-bottom communities; collecting live corals and other organisms; and installing scientific instruments on the ocean floor. Ask students how they think scientists will accomplish these tasks. If students suggest manned submersibles, brainstorm advantages and disadvantages, and ask if there are alternatives that reduce problems such as cost and risk to human life. This should lead to the idea of using underwater robots. You may want to show some images of various ROVs at this point, from the Web site cited in Step #1. Tell students that ROVs used for underwater exploration have a cable that attaches them to a ship at the surface. The cable carries instructions to the ROV from a pilot, as well as video and other information from the ROV to scientists. Usually the pilot and scientists are aboard the surface ship, but the newest ocean exploration ships can exchange information via satellite between an ROV and control centers thousands of miles away. (See http://oceanexplorer.noaa.gov/okeanos/welcome.html.

Briefly discuss the definition of **robot**. Most definitions involve the concepts of a mechanical device performing human or near-human tasks, and /or behaving in a human-like manner. The key ideas are that a robot has a purpose, and mimics certain human or animal functions. Ask students to imagine they are ROV pilots on board the NOAA Ship *Ronald H. Brown*. Say that they are responsible for steering the ROV through completely unknown areas only a few feet from the ocean floor, and ask them as pilots to share their biggest concerns. Running into objects on the bottom will probably be mentioned. Ask how ROV pilots could deal with this problem. Video cameras are likely to be mentioned, but remind students that it could be hard to estimate the distance to an object from a video image. This is because the pilots would not have a binocular view of the object, and human depth perception depends upon binocular vision. You can demonstrate this by instructing students to hold two pencils by the eraser end, one pencil in each hand, then close one eye and try to touch the ends of the pencils together. Trying again with both eyes open should reveal the importance of binocular vision to depth perception.

3. Provide each group with a copy of the *Robotic Ranging Inquiry Guide*, a tennis ball, and a stopwatch (or cell phone with a stopwatch function). Tell students that the activities in the *Inquiry Guide* are designed to help them invent a way to estimate the distance to an object that involves ranging instead of binocular vision (if ranging is an unfamiliar term, say they will understand what this means when they have completed the inquiry activities). Provide additional instructions that they will use for the inquiry activity, related to the wall location that they will use. You may also want to suggest that they have a few "trial runs" to become familiar with the procedures before they start recording data. The success of the tennis ball ranging activity depends heavily upon cooperation between students and their ability to replicate test conditions over several trials.

   Now on with the Inquiry!

4. Lead a discussion of students' results for the tennis ball ranging activity. This activity offers an opportunity to discuss sources of variability in experimental data, and the importance of replicates in experimental procedures. If time permits, you may want to brainstorm ways that the accuracy of this activity could be improved.

   Discuss students' ideas for how an underwater robot could estimate distance to an object using some type of ranging. The hints should suggest that the solution might involve sound. Some students may be familiar with sonar, radar detectors, backup warning signals, or other devices that measure distance with sound, light, or other types of electromagnetic energy. Some of these do not work very well under water, but the underlying principle is similar: The time required for a pulse of energy to travel to a target object and back is measured, and the distance is calculated based on the speed at which the pulse travels.

Tennis balls travel slowly enough to be measured with a stopwatch, but sound and electromagnetic energy pulses travel much more rapidly and require timing devices capable of measuring thousandths or millionths of a second. Motion and ultrasonic ranging sensors found in teaching systems such as Lego® NXT or Calculator-Based Laboratory™ use ultrasonic pulses with a frequency of around 40 khz - 50 khz (the upper limit of human hearing is about 20 khz). A computer or microcontroller triggers an ultrasonic speaker to emit a pulse, then records the time that elapses before the reflected echo of the pulse returns to an ultrasonic microphone (the time would be about 900 microseconds for an object 15 cm away). If your class has access to a teaching system with an ultrasonic ranging sensor, at this point you may want to have students assemble and use the sensor in a ranging device that can measure distance to nearby objects.

The Bridge Connection

http://www.vims.edu/bridge/ – Scroll over "Ocean Science Topics," then "Human Activities," then click on "Technology" for links to resources about submersibles, ROVs, and other technologies used in underwater exploration.

The "Me" Connection

Have students write a brief essay describing how robots are (or may be) of personal benefit.

Connections to Other Subjects

English/Language Arts, Mathematics

Assessment

Students' *Inquiry Guide* reports and class discussions provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/09lophelia/welcome.html to find out more about the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks.

2. Build your own underwater robot! See "ROV's in a Bucket" and books by Harry Bohm (See Resources, below).

3. For additional activities involving ROVs, see the Ocean Explorer lesson plan, **I, Robot, Can Do That!** (http://oceanexplorer.noaa.

gov/explorations/05lostcity/background/edu/media/lostcity05_i_robot.pdf)

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html
Click on the links to Lessons 3, 5, and 6 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

(*All of the following Lesson Plans are targeted toward grades 5-6*)

Call to Arms
(PDF, 329 kb) (from the Lophelia II 2008 Expedition)
http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/calltoarms.pdf

Focus: Robotic Analogues for Human Structures (Physical Science)

Students will describe the types of motion found in the human arm, and describe four common robotic arm designs that mimic some or all of these functions.

Entering the Twilight Zone
(8 pages, 352k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/zone.pdf

Focus: Deep-sea habitats (Life Science)

In this activity, students will be able to describe major features of cold seep communities, list at least five organisms typical of these communities and infer probable trophic relationships within and between major deep-sea habitats. Students will also be able to describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, and describe major deep-sea habitats and list at least three organisms typical of each habitat.

Animals of the Fire Ice
(5 pages, 364k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/animals.pdf

Focus: Methane hydrate ice worms and hydrate shrimp (Life Science)

In this activity, students will be able to define and describe methane hydrate ice worms and hydrate shrimp, infer how methane hydrate ice worms and hydrate shrimp obtain their food, and infer how methane hydrate ice worms and hydrate shrimp may interact with other species in the biological communities of which they are part.

A Piece of Cake
(7 pages; 282kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/cake.pdf

Focus: Spatial heterogeneity in deepwater coral communities (Life Science)

In this activity, students will be able to explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of deepwater hard bottom communities. Students will also be able to explain how organisms, such as deep-water corals and sponges, add to the variety of habitats in areas such as the Charleston Bump.

Deep Gardens
(11 pages; 331kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/deepgardens.pdf

Focus: Comparison of deep-sea and shallow-water tropical coral communities (Life Science)

In this activity, students will compare and contrast deep-sea coral communities with their shallow-water counterparts, describe three types of deep-sea corals and explain three benefits associated with deep-sea corals. Students will explain why many scientists are concerned about the future of deep-sea coral communities.

Let’s Make a Tubeworm!
(6 pages, 464k) (from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_tube_gr56.pdf

Focus: Symbiotic relationships in cold-seep communities (Life Science)

In this activity, students will be able to describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, describe major features of cold seep communities, and list at least five organisms typical of these communities. Students will also be able to define symbiosis, describe two examples of symbiosis in cold seep communities, describe the anatomy of vestimentiferans, and explain how these organisms obtain their food.

What's In That Cake?
(9 pages, 276k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Cake.pdf

Focus: Exploration of deep-sea habitats (Life Science)

In this activity, students will be able to explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of the Gulf of Mexico. Students will also be able to describe and discuss at least three difficulties involved in studying deep-sea habitats and describe and explain at least three techniques scientists use to sample habitats, such as those found on the Gulf of Mexico.

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.

http://oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration Program

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://www.marinetech.org/ – Web site for the Marine Advanced Technology Education (MATE) Center, with information on making ROVs and ROV competitions

http://monitor.noaa.gov/publications/education/rov_manual.pdf – "ROV's in a Bucket;" directions for a simple underwater ROV that can be built by grade-school children using off-the-shelf and off-the-Internet parts; by Doug Levin, Krista Trono, and Christine Arrasate, NOAA Chesapeake Bay Office

Bohm, H. and V. Jensen. 1998. Build Your Own Programmable Lego® Submersible: Project: Sea Angel AUV (Autonomous Underwater Vehicle). Westcoast Words. 39 pages

Bohm, H. 1997. Build your own underwater robot and other wet projects. Westcoast Words. 148 pages http://www.gomr.mms.gov/index_common.html - Minerals Management Service Web site

http://www.gomr.mms.gov/homepg/lagniapp/chemcomp.pdf (PDF) - *Chemosynthetic Communities in the Gulf of Mexico* teaching guide to accompany a poster with the same title, introducing the topic of chemosynthetic communities and other ecological concepts to middle and high school students

http://www.coast-nopp.org/ - Resource Guide from the Consortium for Oceanographic Activities for Students and Teachers, containing modules, guides, and lesson plans covering topics related to oceanography and coastal processes

http://cosee-central-gom.org/ - Web site for The Center for Ocean Sciences Education Excellence: Central Gulf of Mexico collaborative

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
- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

Content Standard C: Life Science
- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science
- Structure of the Earth 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
- Populations, resources, and environments
- Science and technology in society

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

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
Fundamental Concept c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.
Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
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 e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
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.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

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Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov

The Robot Ranger

Robot Ranging Inquiry Guide

Problem

How can an underwater robot estimate the distance to an object?

Idea

Measure the time it takes for something to travel to an object and back. It will take less time to travel to an object that is close than to travel to an object that is farther away.

Experiment & Observe

1. Your teacher will identify a location where there is a large wall for this experiment.

2. The overall plan: One member of your group will throw a tennis ball against the wall and catch the ball when it bounces back. Another group member will measure the time it takes for the ball to travel to the wall and back. A third member will keep a record of the distance and time.

Important Instructions for the Thrower:

- Don't throw the ball as hard as you can! You must be able to catch the ball.
- Stand in the same spot for throwing and catching.
- Throw the ball at the same speed each time.
- Throw the ball so that it bounces once on its way back.

3. The step-by-step procedure:

a. Stand against the wall, then walk 15 steps directly away (perpendicular) from the wall.

b. When the Timekeeper says "Go!" the Thrower should throw the tennis ball against the wall, and catch it after one bounce. The Timekeeper should watch the ball, and stop the stopwatch as soon as the ball touches the Thrower's hand.

c. The Recorder writes down the time it took for the tennis ball to travel to the wall and back.

d. Repeat Steps b and c two more times so you have three measurements of how long it took the tennis ball to travel 15 steps.

e. Repeat Steps a through d for distances of 10 steps and 5 steps from the wall. You should have a total of nine measurements when you are finished. The Thrower should try to throw the ball exactly the same way each time.

f. Before you leave the wall, stand 15 steps away again and clap your hands once as loudly as you can. Record your observations.

The Robot Ranger
Robotic Ranging Inquiry Guide

4. Find the average time it took the tennis ball to travel 5 steps, 10 steps, and 15 steps. Plot these data with distance on the X axis and time on the Y axis.

5. From your graph, predict how long it would take the tennis ball to travel to the wall and back if the Thrower was standing 8 steps from the wall.

Estimating distance in this way is an example of ranging.

Invent a Solution

Obviously, an underwater robot could not estimate the distance to an object by throwing a tennis ball. But could the robot send something else that would bounce off the object, and then measure the travel time to estimate distance?

Hints:
- What did you observe when you clapped your hands?
- Sound travels at a speed of about 1125 feet per second in air.

Describe your solution that would allow an underwater robot to estimate the distance to an object using some type of ranging.

Tennis Ball Ranging Data Sheet

Distance (steps)	Time			Average Time
	Trial 1	Trial 2	Trial 3	
5				
10				
15				