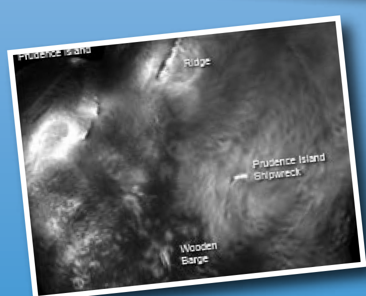
Thunder Bay 2010:
Cutting-Edge Technology and the Hunt for Lake Huron's Lost Ships

My Wet Robot

(adapted from the Bonaire 2008 Coral Reefs and New Technologies Expedition)



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lesson plan

Focus

Underwater Robotic Vehicles

Grade Level

9-12 (Physical Science)

Focus Question

What are some workable solutions to typical problems involved with the design of practical underwater robots?

Learning Objectives

- Students will be able to discuss the advantages and disadvantages of using underwater robots in scientific explorations.
- Given a specific exploration task, students will be able to identify key design requirements for a robotic vehicle that is capable of carrying out this task.
- Students will be able to describe practical approaches to meet identified design requirements.
- (Optional) Students will be able to construct a robotic vehicle capable of carrying out an assigned task.

Materials

- ❑ (Optional, if students will be required to construct a robotic vehicle) Materials to build a robotic vehicle, such as PVC pipe, batteries, propellers for model boats, floats, Lego® Robotics components, and other materials identified by student groups
- ❑ (Optional, if students will be required to construct a robotic vehicle) A place to test students' robots, such as a swimming pool or child's wading pool filled with clear, fresh water

Audio-Visual Materials

- ❑ None

Teaching Time

Two or three 45-minute class periods, plus time for students to complete their projects

Seating Arrangement

Groups of 2-4 students

Maximum Number of Students

32

Key Words

Lake Huron
Shipwreck
Robot
AUV
ROV
Robotic vehicle

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.

The area surrounding Thunder Bay in Lake Huron is so dangerous to shipping that it has earned the nickname Shipwreck Alley. Lake Huron is notorious for dense fog banks, violent storms, and rocky shoreline; hazards that have brought disaster to hundreds of ships. As a result, Thunder Bay represents one of the nation's most historically significant collections of shipwrecks. The Thunder Bay National Marine Sanctuary (TBNMS) was established in 2000 to protect this important cultural resource. The present boundaries of the TBNMS enclose 448 square miles that contain 40 known historic shipwrecks. Plans are well underway, however, to expand these boundaries to include 3,662 square miles (Figure 1). Archival records indicate that the expanded boundaries include more than 100 undiscovered shipwrecks which can provide unique opportunities for historians and archaeologists to study the maritime and cultural history of the Great Lakes region, as well as for recreational explorers. Finding the exact location of these shipwrecks is obviously essential to these kinds of uses, as well as to protecting these resources.

To help meet this need, in 2008 a remote sensing survey was undertaken in the northern portion of the proposed expansion area. This survey used a side scan sonar towed from a research vessel, as well as a conventional sonar system mounted on an autonomous underwater vehicle (AUV). The 2008 survey covered an area of about 100 square miles and located two new shipwrecks. The total proposed expansion area is much larger, though, so a third survey strategy is needed to efficiently cover large areas of deep water. As its name suggests, the Thunder Bay 2010: Cutting Edge-Technology and the Hunt for Lake Huron's Lost Ships Expedition will use state-of-the-art technology that includes a sophisticated AUV carrying a one-of-a-kind precision sonar system to survey up to 200 square nautical miles

Images from Page 1 top to bottom:
Existing (yellow) and proposed (green) boundaries of the Thunder Bay National Marine Sanctuary. Locations of some known shipwrecks are indicated. Source: Thunder Bay National Marine Sanctuary

A crew in a support boat releases the line from the Naval Undersea Warfare Center (NUWC) REMUS 600 unmanned underwater vehicle equipped with the Integrated Precision Underwater Mapping (iPUMA) subsystem in Narragansett Bay during the Autonomous Vehicle Fest in May 2008.
http://www.militaryaerospace.com/index/display/article-display/337291/articles/military-aerospace-electronics/volume-19/issue-8/features/special-report/swimming-robots.html

This image was captured by iPUMA, a wide-swath forward-looking sonar used to identify possible targets. Here we see the two wrecks off Prudence Island, as well as features on the surrounding seafloor. To get a sense of scale, consider that the wooden barge is 120 feet long.
http://oceanexplorer.noaa.gov/explorations/08auvfest/logs/summary/media/ipuma_s2_3_sonar.html

Once a shipwreck has been located on a sonar image, archaeologists don SCUBA gear to "ground truth" the discovery. Dives deeper than about 40 m require the use of special breathing mixtures containing helium, oxygen, and nitrogen to reduce some of the safety hazards that accompany breathing ordinary air during deep dives. Source: Thunder Bay National Marine Sanctuary in the proposed expansion area. Further investigation of shipwrecks located during the survey will be done by marine archaeologists using technical diving procedures. If particularly interesting wrecks are discovered, these "ground truthing" dives may be done during the Thunder Bay 2010 Expedition. Most of these investigations, however, will be done after the expedition's conclusion.

The Integrated Precision Mapping (iPUMA) system used to search for shipwrecks in Lake Huron is based on the principles on which all sonar systems operate. 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 that 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. There are many specialized varieties of sonar, including the widely used side-scan sonar and multibeam sonar. For more information about these systems, visit http://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html.

The iPUMA system is a type of forward-looking sonar that provides an image of objects in front of the vessel on which the sonar is mounted. This system, developed by the Applied Research Laboratory at the University of Texas, uses cell phone technology to make the system smaller than earlier types of forward-looking sonar. In addition, the iPUMA system provides intelligent control of the AUV that carries the system using software currently in use on Mars Rover robots. Mounted on a REMUS 600 AUV, the iPUMA system can efficiently search large deep-water areas with approximately ten (10) times the coverage of traditional sonar.

Like all AUVs, the REMUS 600 is an underwater robot that operates without a pilot or cable to a ship or submersible. This independence allows AUVs to cover large areas of the ocean floor, as well as to monitor a specific underwater area over a long period of time. Typical AUVs can follow the contours of underwater mountain ranges, fly around sheer pinnacles, dive into narrow trenches, take photographs, and collect data and samples. Basic systems found on most AUVs

Map 1. Great Lakes region, with Thunder Bay National Marine Sanctuary marked with a red dot.

US Army Corps of Engineers, Detroit District. From Wikipedia.

Figure 1. Existing (yellow) and proposed (green) boundaries of the Thunder Bay National Marine Sanctuary. Locations of some known shipwrecks are indicated. Source: Thunder Bay National Marine Sanctuary

include: propulsion, usually propellers or thrusters (water jets); power sources such as batteries or fuel cells; environmental sensors such as video and devices for measuring water chemistry; computer to control the robot's movement and data gathering functions; and a navigation system.

The REMUS (which stands for Remote Environmental Measuring UnitS) 600 AUV operates to depths of 600 meters (with modifications its depth range can be extended 1500 meters), and can operate for missions lasting up to 70 hours. REMUS AUVs were designed as low-cost vehicles that can be operated with a laptop computer. Instruments typically include an Acoustic Doppler Current Profiler, sidescan sonar, conductivity and temperature profiler, and a light scattering sensor. Many other instruments can be carried depending upon mission needs, including fluorometers, bioluminescence sensors, radiometers, acoustic modems, forward-looking sonar, altimeters, and Acoustic Doppler Velocimeters, video plankton recorder, and a variety of digital cameras. For more information, see http://www.whoi.edu/page.do?pid=29856.

In this activity, students will design and, optionally, build an underwater robotic vehicle capable of performing specified tasks.

Learning Procedure

1. To prepare for this lesson:
   (a) Review introductory essays for the Thunder Bay 2010: Cutting-Edge Technology and the Hunt for Lake Huron's Lost Ships Expedition at http://oceanexplorer.noaa.gov/10thunderbay/welcome.html
   (b) Decide on the desired level of complexity for this lesson. The simplest, quickest, and least expensive approach is to simply have students design robotic vehicles that could be capable of performing prescribed tasks. A more involved approach would be to require the robotic vehicles to be capable of autonomous activity, so that students would have to incorporate programmable robotics such as Lego® Mindstorms components. The most involved (and also the most fun and rewarding) approach is to require students to actually construct the robots they design. If you plan to have students construct their robotic vehicles, you may also want to review the books by Harry Bohm listed under "Resources." If you opt for one of the more complex approaches, at least a month should be available for students to complete their assignment; more time would be better.

   If students do not have access to the internet, make copies of relevant materials on underwater robotic vehicles from the Web site referenced above.

2. Briefly introduce students to "Shipwreck Alley" and the Thunder Bay 2010: Cutting-Edge Technology and the Hunt for Lake Huron's Lost Ships Expedition, and discuss the role of underwater robots on the expedition. Briefly discuss the advantages and disadvantages of underwater robots compared to free divers or manned submersibles. You may want to show students some images of the REMUS AUV from http://www.whoi.edu/page.do?pid=29856.

3. Tell students that their assignment is to design an underwater robotic vehicle that they could construct and that would be capable of moving in a horizontal direction at a fixed depth. You may also want to include a requirement that the robot must collect some type of information about the surrounding environment such as temperature or visual images. If you want to require that the vehicles be capable of autonomous activity and/or actually constructed, add those instructions as well.

   To help students get started, lead a brainstorming session of key components or systems that would have to be included in this kind of vehicle, such as:
   - power system
   - propulsion system
   - communication system
   - buoyancy control system
   - information gathering system(s)

   Discuss specific requirements for each of these systems. Emphasize that the intention of this assignment is for students to design an underwater robotic vehicle that they could construct (whether you actually require them to do so or not), so students' solutions to these requirements should be practical and involve materials to which they have access. Assign "milestone" dates by which certain tasks should have been completed. Have each group present a periodic progress report, identifying problems that have been encountered and proposed solutions.

   There are numerous reports and case studies on the internet about underwater robotics projects, and students should be encouraged to locate these and learn from prior experience. Procedures for waterproofing motors and other components, programs for autonomous control of simple movements, and many other "lessons learned" are available. Tell students to be sure to document the sources for any "prior knowledge" that they use in designing their robots, and to keep a notebook in which they record the assigned requirements for their robot, their approaches to providing key systems, and (if their assignment includes constructing a robot) test procedures and results for each of these systems as well as for the assembled robotic vehicle.

On the date assigned for project completion, each group should present a report of their design solutions and demonstrate their assembled robotic vehicle (if this was part of their assignment).

The BRIDGE Connection

www.vims.edu/bridge/archive1200.html/ – Links to information and activities about shipwrecks; from the main Web page (www.vims.edu/bridge/) click "Ocean Science Topics," on the left side of the page, then "Human Activities," then "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

Notebooks, project reports, and completed robots (if assigned) provide opportunities for assessment.

Extensions

Visit http://oceanexplorer.noaa.gov/10thunderbay/welcome.html to keep up to date with the latest Thunder Bay 2010: Cutting Edge-Technology and the Hunt for Lake Huron's Lost Ships Expedition discoveries.

Other Relevant Lesson Plans from NOAA's Office of Ocean Exploration and Research

The Robot Archaeologist
(17 pages, 518k) (from AUVfest 2008)
http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/robot.pdf

Focus: Marine Archaeology/Marine Navigation (Earth Science/Mathematics)

In this activity, students will design an archaeological survey strategy for an autonomous underwater vehicle (AUV); calculate expected position of the AUV based on speed and direction of travel; and calculate course correction required to compensate for the set and drift of currents.

Where Am I?
(7 pages, 264 kb) (from the 2003 Steamship Portland Expedition)

http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandwhereami.pdf

Focus: Marine navigation and position-finding

In this activity students will be able to identify and explain at least seven different techniques that have been used for marine navigation and position finding, explain the purpose of a marine sextant, and use an astrolabe to solve practical trigonometric problems.

By Land or By Sea or Both?
(14 pages, 1.1 Mb) (from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/landsea.pdf

Focus: Watercraft in Paleoamerican Migrations

In this activity, students will describe evidence that supports the idea that the initial settlement of North and South America involved watercraft, discuss types of watercraft that might have been involved in new world settlement, and explain at least three advantages and three disadvantages of coastal settlements compared to inland settlements.

The Ridge Exploring Robot
(27 pages, 1.6 mb) (from the INSPIRE: Chile Margin 2010 expedition)
http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/robot.pdf

Focus: Autonomous Underwater Vehicles/Marine Navigation

Students will explain a three-phase strategy that uses an autonomous underwater vehicle (AUV) to locate, map, and photograph previously undiscovered hydrothermal vents, design a survey program to provide a photomosaic of a hypothetical hydrothermal vent field, and calculate the expected position of the AUV based on speed and direction of travel.

X-Storms
(5 pages, 384k) (from the 2003 Steamship *Portland* Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandstorm.pdf

Focus: Extreme storms (Earth Science)

In this activity, students identify and explain three factors that contributed to extreme storm conditions during the Halloween Nor'easter of 1991, discover how to obtain real-time and historical meteorological data, and compare and contrast extra-tropical cyclones, tropical cyclones, and hybrid storms.

Now Take a Deep Breath
(14 pages, 548 Kb) (from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/breath.pdf

Focus: Physics and physiology of SCUBA diving (Physical Science/Life Science)

In this activity, students will be able to define Henry's Law, Boyle's Law, and Dalton's Law of Partial Pressures, and explain their relevance to SCUBA diving; discuss the causes of air embolism, decompression sickness, nitrogen narcosis, and oxygen toxicity in SCUBA divers; and explain the advantages of gas mixtures such as Nitrox and Trimix and closed-circuit rebreather systems.

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/10thunderbay/welcome.html – Web site for the Thunder Bay 2010: Cutting-Edge Technology and the Hunt for Lake Huron's Lost Ships Expedition

http://thunderbay.noaa.gov/welcome.html – Web site for the Thunder Bay National Marine Sanctuary

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://thunderbay.noaa.gov/welcome.html – Links to Lesson Plans from the Thunder Bay National Marine Sanctuary; includes grades K - 2 Boat Builder Activity, grades 3 - 5 Photomosaic Activity, grades 3 - 5 Mapping Activity, grades 6+ Mapping Activities, Steamships and Energy Conversions, and Make Your Own Putt-Putt Boat

http://monitor.noaa.gov/publications/education/rov_manual.pdf – Directions for making a simple underwater robot; from NOAA's Monitor National Marine Sanctuary

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.

National Science Education Standards

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

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

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

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 2.
The ocean and life in the ocean shape the features of the Earth.
Fundamental Concept Fundamental Concept b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.

Essential Principle 4.
The ocean makes Earth habitable.
Fundamental Concept a. Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean.
Fundamental Concept b. The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
Fundamental Concept d. Much of the world's population lives in coastal areas.
Fundamental Concept f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

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 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.

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Please send your comments to:
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Acknowledgements

This lesson was developed by Mel Goodwin, PhD, Marine Biologist and Science Writer. Design/layout by Coastal Images Graphic Design, Charleston, SC. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov/