www.oceanexplorer.noaa.gov

Bermuda: Search for Deep Water Caves 2009

The Robot Explorer

Image captions/credits on Page 2.

lesson plan

Focus
Robotic vehicles for exploring anchialine caves

Grade Level
9-12 (Physics/Earth Science/Technology)

Focus Question
What is needed to construct a robotic vehicle that is capable of exploring a cave?

Learning Objectives
- Students will be able to discuss systems needed for a robotic vehicle capable of cave exploration.

- Students will be able to explain the design and construction process for a simple robot explorer.

Materials
- ❑ Copies of *Robot Explorer Inquiry Guide,* one for each student

Audio-Visual Materials
- ❑ (Optional) Computer projector or other equipment for showing images of underwater caves

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of 3-4 students

Maximum Number of Students
32

Key Words
Anchialine cave
Remotely operated vehicle
Robot
Technology

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.

Anchialine caves are partially or totally submerged caves in coastal areas. Anchialine (pronounced "AN-key-ah-lin") is a Greek term meaning "near the sea," and anchialine caves often contain freshwater and/or brackish water in addition to seawater. These caves may be formed in karst landscapes as well as in rock tubes produced by volcanic activity. Karst landscapes are areas where limestone is the major rock underlying the land surface, and often contain caves and sinkholes formed when acidic rainwater dissolves portions of the limestone rock. Volcanic caves are formed when the surface of flowing volcanic lava cools and hardens, while molten lava continue to flow underneath. If the molten lava continues to flow away from the hardened surface, a hollow tube will be formed that becomes a lava tube cave.

Water in anchialine caves tends to stratify according to salinity, with the heavier seawater below the level of fresh and brackish water. This stratification produces distinctive habitats occupied by a variety of species that are endemic to these locations. (Endemic means that these species are not found anywhere else). Some of these species are "living fossils" known as relict species, which means that they have survived while other related species have become extinct.

Animals that live only in anchialine habitats are called stygofauna or stygobites. Investigations of these species have revealed some puzzling relationships, including:

- Some stygobite species appear to have been in existence longer than the caves they inhabit, which implies that these species must have arrived in the caves from somewhere else; but how could this happen if these species are only found in caves?
- Some stygobite species are found in caves that are widely separated, such as crustacean species found in caves on opposite sides of the Atlantic Ocean and species in Australian anchialine caves that are also found Atlantic and Caribbean caves.
- Geographic distribution of some species suggests a possible connection with mid-ocean ridges. For example, shrimps belonging to the genus *Procaris* are only known from anchialine habitats in the Hawaiian Islands, Ascension Island in the South Atlantic, and Bermuda in the North Atlantic.
- Some anchialine species are most closely related to organisms that live in the very deep ocean.
- Some anchialine species are most closely related to organisms that live in deep sea hydrothermal vent habitats.

Images from Page 1 top to bottom:
Water in inland tidal cave pools in Bermuda is brackish at the surface, but reaches fully marine salinity by a depth of several meters. Image credit: NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/bermudaorigin/media/bermudaorigin_5.html

Divers swim between massive submerged stalagmites in Crystal Cave, Bermuda. Such stalactites and stalagmites were formed during glacial periods of lowered sea level when the caves were dry and air-filled. Image credit: NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/bermudaorigin/media/bermudaorigin_3.html

Ostracods are small, bivalve crustaceans that can inhabit underwater caves. The ostracod genus *Spelaeoecia* is know only from marine caves and occurs in Bermuda, the Bahamas, Cuba, Jamaica and Yucatan (Mexico). Image credit: Tom Iliffe, NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/plan/media/spelaeoecia.html

Prof. Tom Iliffe, diving with a Megalodon closed-circuit rebreather, tows a plankton net through an underwater cave to collect small animals. Image credit: Jill Heinerth, NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/plan/media/plankton.html

- An unusually large proportion of anchialine cave species in Bermuda are endemic to these caves, suggesting that these habitats have been stable for a long period of time.

Most investigations of anchialine caves have been confined to relatively shallow depths; yet, the observations described above suggest that connections with deeper habitats may also be important to understanding the distribution of stygobite species. Bermuda is a group of mid-ocean islands composed of limestone lying on top of a volcanic seamount. Because they are karst landscapes, the islands of Bermuda have one of the highest concentrations of cave systems in the world. Typical Bermuda caves have inland entrances, interior cave pools, underwater passages, and tidal spring outlets to the ocean. Bermuda's underwater caves contain an exceptional variety of endemic species, most of which are crustaceans. Most of these organisms are relict species with distinctive morphological, physiological, and behavioral adaptations to the cave environment that suggest these species have been living in caves for many millions of years. Yet, all known anchialine caves in Bermuda were completely dry only 18,000 years ago when sea levels were at least 100 m lower than present because of water contained in glaciers. Such observations suggest the possibility of additional caves in deeper water that would have provided habitat for anchialine species when presently-known caves were dry.

To help find undiscovered caves, the Bermuda: Search for Deep Water Caves 2009 expedition will use a SeaBotix LBV200L underwater robot, also called a remotely operated vehicle (ROV). Underwater ROVs are linked to an operator aboard a surface ship by a group of cables. Most are equipped with one or more video cameras and lights, and may also carry other equipment such as a manipulator or cutting arm, water samplers, and measuring instruments to expand the vehicle's capabilities. For more information about the SeaBotix LBV200L, visit http://www.seabotix.com/products/lbv200l_overview.htm.

ROVs offer a variety of advantages for exploring confined spaces such as shipwrecks and caves. In particular, ROVs can explore spaces too small for human divers, and also remove the serious element of risk involved when human divers work in deep waters or hazardous settings. A desirable feature for ROVs used to explore underwater caves is the ability to detect and avoid obstacles. In this activity, students will design and, optionally, build a robotic vehicle capable of sensing objects in its path and taking appropriate action to avoid these objects.

Learning Procedure

1. To prepare for this lesson:
   (a) Review introductory essays for the Bermuda: Search for Deep Water Caves 2009 expedition at http://oceanexplorer.noaa.gov/explorations/09bermuda/welcome.html. You may also want to

visit http://oceanexplorer.noaa.gov/technology/subs/rov/rov.html for images and discussions of various types of ROVs used in ocean exploration. If you want to explain multibeam sonar, you may also want to review information and images at http://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.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 the prescribed tasks. A more involved approach is to have students construct one or more of the systems in their design (such as the distance sensing system, or the propulsion system). The most involved (and also most fun and rewarding) approach is to require students to actually construct the robots they design. A variation of the latter approach would be to have different student groups construct different systems, and integrate these into a working vehicle. If you plan to have students construct robotic vehicles, you may also want to review the books and other resources listed under Extensions. 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.

(c) Review the *Robot Explorer Inquiry Guide*. You may also want to review Magri (2009), which provides detailed instructions for one design that meets the requirements for the design specified in this lesson.

2. Briefly introduce the Bermuda: Search for Deep Water Caves 2009 expedition, emphasizing that very little is known about deep water anchialine caves. Describe how anchialine caves are formed. Show students a few images of underwater caves, and explain that scientists plan to search the vertical underwater cliffs beneath the island of Bermuda for evidence of deepwater caves. The first step in the search is to map the cliff face with multibeam sonar, an instrument that uses sound waves to create pictures of underwater features. The next step is to use an underwater robot called a remotely operated vehicle (ROV) to explore areas where multibeam sonar surveys suggest there may be deep water caves. Ask students why they think scientists chose to use a ROV instead of SCUBA divers or a manned submersible vehicle.

3. Tell students that their assignment is to design a robotic vehicle that they could construct which would be capable of sensing objects in its path and taking appropriate action to avoid these objects. You may want to require that the vehicle be capable of operating underwater; but terrestrial vehicles will be easier to construct, test, and modify.

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;
- obstacle detection system; and
- command system to integrate information from the obstacle detection system and provide appropriate instructions to the propulsion system to avoid obstacles.

4. Provide each student group with a copy of the *Robot Explorer Inquiry Guide*, and explain other details such as whether they will be required to construct all or part of their vehicle, milestone dates by which certain tasks should have been completed, etc.

   When students have completed their research on the topics discussed in the *Inquiry Guide*, you may want to discuss their results with the entire class before groups continue with the design process. Emphasize that the intention of this assignment is for students to design a 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.

   There are numerous reports, case studies, etc. on the internet about robotics projects, and students should be encouraged to locate these and learn from prior experience. Procedures for using motors and other components, programs for microcontrollers, 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/ – Scroll over "Ocean Science Topics," 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 and societal benefit.

Connections to Other Subjects

English/Language Arts, Mathematics

Assessment

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

Extensions

1. Visit http://oceanexplorer.noaa.gov/explorations/09bermuda/welcome.html for more about the Bermuda: Search for Deep Water Caves 2009 expedition.
2. Some sources for ideas, designs, and materials for robotic vehicles:
   - See “ROV’s in a Bucket” and books by Harry Bohm under Other Resources.
   - Parallax, Inc. – microcontrollers, sensors, parts, tutorials, and education-oriented forums; http://www.parallax.com/.
   - MakerShed – microcontrollers, parts, kits, publications; http://www.makershed.com/.
     {NOTE: Mention of commercial entities and products does not imply endorsement by NOAA.}
3. For additional activities with ROVs, see I, Robot, Can Do That! (http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_i_robot.pdf).

Other Relevant Lesson Plans from NOAA’s Ocean Exploration Program

Now Take a Deep Breath
(from 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.

The Robot Archaeologist
(from the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/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.

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/explorations/09bermuda/welcome.html – Bermuda: Search for Deep Water Caves 2009 expedition

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.

Magri, K. 2009. My Robot, Makey. Make 19:77-87; available online at http://www.make-digital.com/make/vol19/?pg=78

National Science Education Standards

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

Content Standard D: Earth and Space Science
- Geochemical cycles

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 local, national, and global challenges

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
Fundamental Concept g. The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean.

Essential Principle 2.
The ocean and life in the ocean shape the features of the Earth.
Fundamental Concept a. Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.
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 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 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.

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.

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:
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Robot Explorer

Robot Explorer Inquiry Guide

Your assignment is to design a robotic vehicle that your group could construct which would be capable of sensing objects in its path and taking appropriate action to avoid these objects. Your teacher may have assigned some additional requirements.

At a minimum, your robot will need four systems for:

- Power;
- Propulsion;
- Obstacle detection; and
- Integration and Control to receive information from the obstacle detection system and provide appropriate instructions to the propulsion system to avoid obstacles.

Here are some ideas to help you get started:

- Electric power systems are used for most robots. Robots may be attached to a power source with a cable (often called an umbilical), but this adds weight and can limit mobility. Batteries are an alternative, but can become very heavy if a large amount of power is needed. The amount of power needed is usually determined by the propulsion system.

- Robotic propulsion systems use some type of motor. You should investigate the advantages and disadvantages of DC motors vs. AC motors.

- A variety of devices may be used to detect obstacles, but the simplest for this type of robot is an ultrasonic rangefinder. One such device is the Ping)))™ rangefinder produced by Parallax, Inc. A lot of information about this device is available on the Internet. If you want to have your rangefinder scan or look around, you should also get some information on devices called servos.

- Most small robots use microcontrollers for integration and control. Commonly used microcontrollers include Lego™ NXT and RCX bricks, BASIC Stamp, Arduino, and PICAXE microcontrollers. Searching these terms together with “robot” will produce MANY useful references.