OCEAN EXPLORATION & RESEARCH

Section 5: Underwater Robots for Volume 2: How Do We Explore?

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

Invent a Robot

Focus
Engineering design

Grade Level
5-6 (Physical Science/Technology)

Focus Question
How can scientists design and build robotic arms that are capable of specific movements?

Learning Objectives
- Students will discuss advantages and disadvantages of using underwater robots in scientific explorations, and how underwater robots are used aboard *Okeanos Explorer.*
- Students will use the process of engineering design to develop potential solutions for an ocean exploration problem.
- Students will explain the principle of hydraulic power transfer systems, and construct a robotic arm that demonstrates this principle.

Materials
For each student group:
- Copy of *Student Worksheet*
- Cardboard or heavy poster board, five pieces, each approximately 12" x 12" (the stiffer the better)
- Duct tape, approximately 2" x 25'
- 10 - Machine screws with nuts, #8 x 1"
- 4 - Machine screws with nuts, #8 x 3"
- 20 - Flat washers, #8 hole
- 4 - Oral syringes
- Plastic tubing, approximately 3/16" inside diameter; two pieces, each approximate 12" long (should fit snugly over the end of the syringes)
- Water
- Small container, such as a 9-oz drinking cup

Tools (may be shared by several student groups)
- Heavy scissors to cut cardboard ("bandage scissors" are inexpensive and work well)
- Nail or Phillips screwdriver to punch holes in cardboard
- Screwdriver to fit machine screw

Audio Visual Materials

- (Optional) Video projector or other equipment to display downloaded images (see Learning Procedure, Step 1d)

Teaching Time

Two or three 45-minute class periods, plus time for students to construct their robotic arm

Seating Arrangement

Groups of two to four students

Maximum Number of Students

30

Key Words and Concepts

Ocean Exploration
Okeanos Explorer
Robot
Remotely operated vehicle
Engineering design

Background Information

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

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

The *Okeanos Explorer* strategy involves three major activities:

- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

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

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

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

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

imagery, making measurements of chemical and physical seawater properties, and obtaining appropriate samples.

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

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

In the summer of 2010, years of planning, field trials, and state-of-the-art technology came together for the first time on the ship's maiden voyage as part of the INDEX-SATAL 2010 Expedition. This expedition was an international collaboration between scientists from the United States and Indonesia to explore the deep ocean in the Sangihe Talaud Region. This region is located in the 'Coral Triangle', which is the global heart of shallow-water marine biodiversity. A major objective of the INDEX-SATAL 2010 Expedition was to locate submarine volcanoes, hydrothermal vents, chemosynthetic ecosystems, and seamounts associated with active geologic processes in Indonesia's deep sea. A key component in the expedition's quest for anomalies was to look for changes in chemical properties of seawater that can indicate the presence of these features. For more information about the INDEX-SATAL 2010 Expedition, see *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*.

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

The site characterization component of the *Okeanos Explorer* exploration strategy depends heavily upon remotely operated vehicles (ROVs). These are unoccupied robots usually linked to an operator aboard a surface ship by a group of cables. Most ROVs 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, equipment for collecting samples, and measuring instruments to expand the vehicle's capabilities for gathering data about the deep-ocean environment.

For the INDEX-SATAL 2010 Expedition, the NOAA Ship *Okeanos Explorer* carried *Little Hercules*, an ROV originally developed by a team of engineers at Dr. Robert Ballard's Institute for Exploration (IFE) at the University of Rhode Island for the primary purpose of gathering high quality video imagery. Nicknamed "*Little Herc*," the ROV proved to be well-suited to this purpose on a variety of successful missions for IFE, including providing the first and only images of John Kennedy's PT Boat, *PT-109*. Eventually, a much larger ROV named "*Hercules*" took over these tasks, and *Little Herc* became part of an exhibit at the Mystic Aquarium. This shore duty came to an end, however, when it became clear that *Okeanos Explorer*'s primary ROV would not be ready in time for the INDEX-SATAL 2010 Expedition. Through a collaboration between IFE and NOAA's Office of Ocean Exploration and Research, *Little Herc* was brought out of retirement and refitted specifically to meet the expedition's needs.

Little Herc is operated in tandem with a camera platform that carries 2,400 watts of lighting provided by HMI (hydrargyrum medium-arc iodide) arc lamps. This lighting illuminates the total darkness of the deep ocean, helps guide *Little Hercules*, and provides lighting for the high-definition video images of the ROV at work. The camera platform is named *Seirios*, after the name of the brightest star in the night sky (also called the Dog Star, sometimes spelled "Sirius"). *Little Herc* is attached to *Seirios* by a 30-m cable called the Remotely Operated Vehicle Tether, while the camera platform is attached to the *Okeanos Explorer*'s traction winch by a 17 mm Oceanographic Instrumentation and Control Cable which has an armored outer jacket with 3 power conductors and 3 optical fibers for transmitting data and control signals.

A variety of sensors are aboard the ROV for navigation and data collection. These include depth and altitude sensors, an Ultra Short Baseline Tracking System, full color imaging sonar, and a Seabird SBE 49 FastCAT CTD. Video equipment includes two Insite Pacific single CCD (charge-coupled device) high-resolution miniature color video cameras, one Insite Pacific triple CCD high-definition Zeus Plus video camera, two Deep Sea Power and Light 250-watt LED matrix lights, and two Deep Sea Power and Light 400-watt HMI arc lamps. For additional details about *Little Herc*, see the sidebar, The *Little Hercules* Remotely Operated Vehicle. For more information about other ROVs, visit *http://oceanexplorer.noaa.gov/technology/subs/rov/rov.html*.

This lesson introduces students to remotely operated vehicles and video imagery as they are used for ocean exploration aboard the *Okeanos Explorer*. In the future, students will have access to additional video imagery collected by ROVs as the *Okeanos Explorer* continues its voyages of discovery in Earth's deep ocean.

Learning Procedure

1. To prepare for this lesson:
   a) Review:
   - Introductory essays for the INDEX-SATAL 2010 Expedition (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*); including *Little Hercules* ROV (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/rov/rov.html*);
   - Daily log entries for
     July 7 (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july07/july07.html*);
     July 24 (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july24/july24.html*); and

The *Little Hercules* Remotely Operated Vehicle

Little Hercules was developed by a team of engineers at Dr. Robert Ballard's Institute for Exploration (IFE) at the University of Rhode Island. Its primary purpose is to gather high quality video imagery in support of scientific research and ocean exploration. Major systems include:

- **Power** – 2,800 volts (AC) supplied from the surface; stepped down to 120 VAC by a transformer aboard *Little Herc;* further converted in the electronics pressure housing to 24 VDC (8A maximum load) and 12 VDC (0.6A maximum load)
- **Propulsion** – Four Technadyne 1020 electric thrusters; two oriented horizontally to provide forward, backward, and rotational motion, and two mounted to form a V when viewed from the front (vertran configuration) which provides up, down, and lateral movement
- **Onboard Control** – PC104 computer
- **Imaging** – Main Camera: One Insite Pacific triple CCD high-definition Zeus Plus HDTV camera with zoom and macro; Utility Cameras: Two Insite Pacific single CCD high-resolution miniature color video cameras
- **Lighting** – Two Deep Sea Power and Light 250-watt-equivalent LED matrix lights; Two Deep Sea Power and Light 400-watt HMI arc lamps
- **Navigation** – Ultrashort Baseline acoustic transponder (works in concert with ship-based system that calculates the ROV's underwater position)
- **Sensors** – Paroscientific 8B7000 pressure/depth sensor; Seabird SBE 49 FastCAT CTD; Tritech PA500 altimeter; Tritech Super SeaKing scanning sonar

These components are integrated within an aluminum frame that is supported in water by a flotation package of syntactic foam, which provides slightly positive buoyancy that is trimmed to neutral by the ROV's vertical thrusters. Most electronics are contained in a 10-inch diameter titanium pressure housing. The ROV is rated to a depth of 4,000 meters, and in air weighs 1,200 pounds.

Little Hercules is operated in tandem with a camera platform named *Seirios* that is equipped with a HD video camera identical to that on the ROV, as well as six HMI (hydrargyrum medium-arc iodide) arc lamps that provide a total of 2,400 watts of lighting. *Seirios* has no buoyancy module, and is intentionally much heavier than water to provide a buffer between the ROV and surface motion of the ship. *Little Hercules* is attached to *Seirios* by a 30-m cable called the Remotely Operated Vehicle Tether. *Seirios* is attached to the *Okeanos Explorer*'s traction winch by a 17 mm Oceanographic Instrumentation and Control Cable which has an armored outer jacket with 3 power conductors and 3 optical fibers for transmitting data and control signals. A traction winch has large diameter grooved drums that are designed to protect cables from excessive friction and bending under heavy load conditions.

Prior to every dive, the ROV crew reviews multibeam sonar maps of the proposed dive area, and develops a track-line that is the initial path that the ROV will follow. During a dive, the ROV pilots may modify the track-line as they receive requests from scientists aboard the ship and in Exploration Command Centers to obtain video images of certain features and organisms that the ROV encounters during its exploration.

August 6 (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/aug06/aug06.html*).

You may want to assign one or more of these essays as background reading prior to beginning the rest of the lesson.

(b) Review background information about the *Okeanos Explorer* exploration strategy and technologies.

(c) Copy the *Student Worksheet*, one copy for each student group.

(d) Download images referenced in Step 2. You may also want to download examples of imagery from underwater robots (*http://oceanexplorer.noaa.gov/okeanos/media/slideshow/flash_slideshow.html* and *http://oceanexplorer.noaa.gov/okeanos/media/slideshow/video_playlist.html*).

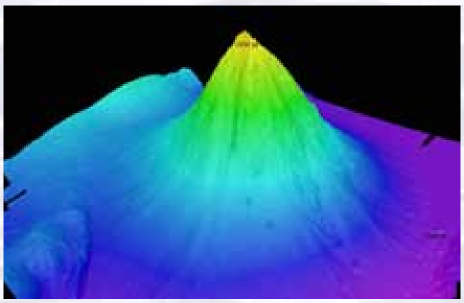
(e) (Optional) Review the *Hands-On Activity Guides* included with the *Through Robot Eyes* lesson and decide whether you wish to have students complete one or more of these in addition to the Engineering Design activity described below. *Hands-On Activity Guides* are provided to introduce some basic systems used in many underwater robots to gather information for ocean exploration:
- *Getting Control with Microcontrollers;*
- *Making Things Happen with Servos*; and
- *Exploring with Sensors*.

The purpose of these activities is to introduce students and educators to materials, methods, and technologies that they can use for a wide variety of inquiries, activities, and projects that integrate skills in science, technology, engineering, and mathematics. These activities may be used at any grade level, depending upon available resources, curriculum content, and individual student needs. Unless students are already familiar with microcontrollers, the *Getting Control with Microcontrollers* activity should precede the other two.

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

You may want to show some or all of the images in the adjacent sidebar to accompany this review.

The ROV *Little Hercules* descends through deep water to an undersea volcano in the Celebes Sea to search for hydrothermal vents and associated ecosystems. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/1june29_hires.jpg



Okeanos Explorer's EM302 multibeam sonar mapping system produced this detailed image of the Kawio Barat seamount, which rises around 3800 meters from the seafloor. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june26fig1_hires.jpg

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

Senior Survey Technician Elaine Stuart holds onto the CTD as it comes aboard the *Okeanos Explorer*. Image courtesy NOAA
http://www.moc.noaa.gov/oe/visitor/photos/photospage-b/CAP%20015.jpg

3. Explain that building complicated ROVs such as *Little Hercules* involves a process called Engineering Design. If students are not already familiar with this concept, explain that Engineering Design is a process that engineers use to create solutions to problems. There are many versions of the process, but the basic steps are:
   - Define the problem;
   - Gather relevant information;
   - Brainstorm possible solutions;
   - Analyze possible solutions and select the most promising; and
   - Test the solution.

   Testing the solution often involves building models of simplified designs to be sure an idea will work before investing a lot of time and money to construct something more elaborate. This step is sometimes called prototyping or "proof of concept." If the prototype works, the designers will continue to develop their solution with the same materials and techniques. If the prototype does not work, then designers must go back to a previous step and consider solutions that use other materials and techniques. This entire process may be repeated several times to improve the solution until results are satisfactory. For complex projects, these steps may be done by teams that work on different parts of the problem. An ROV such as *Little Herc* might have a design team working on the video system, another team working on propulsion, and another responsible for electronics.

   You may also want to point out that explorers often encounter unexpected problems or challenges during an expedition. A famous example is the Apollo 13 mission during which engineers on Earth had to design a "scrubber" that would remove carbon dioxide from the air that the astronauts had to breathe, using only materials that were already aboard the spacecraft. To find solutions for these kinds of challenges, explorers often turn to Engineering Design.

   Remind students that *Little Hercules* is designed to obtain high quality video images in ocean environments as deep as 4,000 meters. It can also carry electronic instruments to measure environmental features such as temperature, but has no way to bring anything back to the ship except images. Tell students that their task is to use the methods of Engineering Design to develop a robotic arm that is able to pick up objects that are about the size of a soda can.

   Say that other teams working on this problem have decided that a hydraulic control system may be part of the solution to the robotic arm design task. So to begin their design process, students need to review some basic concepts of hydraulics and simple mechanics.

4. Be sure students are familiar with the following concepts related to simple machines:
   - The exact number of "simple machines" depends to some extent upon your perspective, but the list typically includes levers, pulleys, wheel-and-axles, inclined planes, wedges, and screws. In some ways, through pulleys and wheel-and-axles are variations of the lever; and the wedge and screw are alternative forms of the inclined plane.

   - Levers are divided into three classes, depending upon the positions of the input lever arm, the fulcrum, and the output arm (or load). In a Class I lever the fulcrum is between the input arm and the output arm (such as a crowbar). In a Class II lever, the output force is between the input force and the fulcrum (as in a wheelbarrow). In a Class III lever, the input force is between the output force and the fulcrum (as in a human arm).

- Mechanical advantage is the ratio of force output to force input. One of the big advantages of many simple machines is that they have high mechanical advantages, such as a crowbar that essentially multiplies the force applied by a human by a factor of 2, 3, or more. But in some machines the mechanical advantage is less than 1, because the machine's purpose is not to increase the input force but rather to change the direction or distance over which the force operates.

5. Provide each student group with a copy of the *Student Worksheet*, and the materials listed on the worksheet. Have each group complete Parts A and B of the Worksheet. Then lead a discussion of students' results. Students should understand that
   - Hydraulic refers to the use of confined liquid to transmit power, multiply force, or produce motion;
   - Hydraulic systems use a liquid while pneumatic systems use air or other gases: and
   - An actuator is a mechanical device that converts energy into some kind of motion.
   - The energy that operates the actuators they built in Part B is mechanical energy from their own muscles, that is transferred to the moving arm by the hydraulic system of the actuator.

   Provide Additional Materials listed on the *Worksheet*, and any additional instructions or advice that may be needed. You may want to require each group to present the concept for their model before they actually begin construction; if this is a requirement you may want to provide the additional materials after the concept has been approved.

6. When students have completed Part C of the *Worksheet*, have each group present their model and explain its operation to the rest of the class. There are many ways to construct a model that meets the design requirements. The essential points are:
   - Design requirements are clearly identified. For instance, the model must be able to grasp an object, such as an empty plastic cup, and lift the object at least one inch.
   - Several options are considered.
   - The selected option fulfills the design requirements.
   - If the model does not fulfill the design requirements, students identify necessary modifications.

   When all groups have presented their results, lead a class discussion about the next steps in designing a robotic arm that would be able to retrieve objects from the ocean floor, and what additional design decisions would be needed. The list of decisions includes:
   - Materials for constructing the arm, considering environmental conditions in the deep ocean;
   - Number of movements needed (this is called "degrees of freedom;" the actuator in Part B of the *Worksheet* has one degree of freedom; the human arm has more than 26 degrees of freedom);

- How the arm will be powered (are hydraulics the best solution; what are some other options);
- How the arm will be controlled from the surface; and
- What other sensors might be needed (such as a video camera mounted on the arm to show what is being lifted, or a pressure sensor on the gripper to know how much an object is being squeezed).

Be sure students realize that in a real hydraulic system, their hand muscles would be replaced by a pump to move hydraulic fluid in and out of actuators.

7. (Optional) **Some Math Connections** – Have students calculate the volume of hydraulic fluid (water in this case) needed to fill the system in their design. This will involve measuring the length and diameter of the syringes and tubing, and calculating volume as

$$V = \pi \bullet r^2 \bullet L$$

where V is volume, r is the radius of the tubing or syringe, and L is its length.

You may also have students verify their calculations by measuring the volume of water actually contained in their system.

8. These activities and discussions may also address the following components of technological literacy (ITEA, 2007):
   - Usefulness of technology
   - Development of technology
   - Process of inventions and innovations
   - Attributes of design
   - Understanding of engineering design and the design process
   - Problem-solving approaches
   - Abilities to apply design processes
   - Abilities to use and maintain technological products

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics" in the menu on the left side of the page, then "Human Activities," then "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 they might personally use the process of Engineering Design.

Connections to Other Subjects

English/Language Arts, Life Science, Mathematics, Physics

Assessment

Students' models and class discussions provide opportunities for assessment.

Extensions

1. Visit the *Okeanos Explorer* Digital Atlas (*http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm*) and Web page (*http://oceanexplorer.noaa.gov/okeanos/welcome.html*) for reports, images, and other products from *Okeanos Explorer* cruises.

2. Visit *http://www.marinetech.org/rov_competition/rov_video_2007.php* for a video from the Marine Technology Society's student ROV competition, and links to other sites about underwater robots.
3. For ideas about building your own underwater robots, see Bohm and Jensen (1998), Bohm (1997), and the Sea Perch Program (see Other Resources).

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html – Click on the links to Lessons 1, 5, and 6 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

What's That? (from the The Lost City 2005 Expedition)
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_whatsthat.pdf
Focus - Investigating Lost City hydrothermal field ecosystems by remotely operated vehicles (Grades 5-6; Life Science/Physical Science)
Students describe a sampling strategy for investigating an unknown area, and explain why this strategy is appropriate for such an investigation; identify and discuss some of the limitations faced by scientists investigating unexplored areas of the deep ocean, and discuss how an autonomous underwater vehicle such as the Autonomous Benthic Explorer (ABE) can contribute to discoveries such as the Lost City Hydrothermal Field.

Call to Arms
(from the Lessons from the Deep: Exploring the Gulf of Mexico's Deep-Sea Ecosystems Education Materials Collection)
http://oceanexplorer.noaa.gov/edu/guide/media/gomdse11calltoarms56.pdf
Focus - Robotic analogues for human structures (Grades 5-6; Life Science/Physical Science)
Students describe the types of motion found in the human arm; design and construct a model of a mechanical arm that mimics some or all of the motion capabilities of the human arm; describe combinations of simple machines that are used in their mechanical arm models; define mechanical advantage, and discuss the importance of mechanical advantage in robotic arm designs; and describe four common robotic arm designs that mimic motion capabilities of the human arm.

The Robot Ranger
(from the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks Expedition)
http://oceanexplorer.noaa.gov/explorations/09lophelia/background/edu/media/09ranger.pdf
Focus - Robotic Analogues for Human Structures (Vision, Distance Estimation) (Grades 5-6; Life Science/Physical Science)
Students describe how humans are able to estimate the distance to visible objects, and describe a robotic system with a similar capability.

Big Enough?
(from the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks Expedition)

STEM Connections

Ocean exploration aboard the *Okeanos Explorer* is a real-world example of STEM concepts in action:
Science provides the overall objective – to better understand Earth's ocean – as well as a methodology for systematically acquiring this understanding;
Technology includes the tools, systems and processes that have been made to make deep-ocean exploration possible;
Engineering designs the technologies that can function in the deep-ocean environment;
Mathematics provides the basis for measurements, data analysis, and engineering design.

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

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

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

For more information, see: *http://www.iteaconnect.org/TAA/Publications/TAA_Publications.html* *http://oceanexplorer.noaa.gov/explorations/09lophelia/background/edu/media/09bigenough.pdf*

Focus - Buoyancy (Grades 5-6; Physical Science)

Students define buoyancy, mass, volume, and density, and explain the relationships between these properties. Given the mass and volume of an object, students calculate the minimum buoyancy required to keep the object afloat in seawater. Students also explain why objects in seawater are more buoyant than the same objects in fresh water.

Other Resources

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

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

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

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

Anonymous. *Okeanos Explorer* America's Ship For Ocean Exploration [Internet]. NOAA Office of Ocean Exploration and Research [cited January 24, 2011]. Available from: *http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Okeanos_Explorer_for_WOC_-_FINAL.pdf*; NOAA Fact Sheet about *Okeanos Explorer*

Anonymous. Sea Perch Program [Internet]. Massachusetts Institute of Technology Sea Grant Program. [cited January 12, 2011]. Available from *http://seaperch.mit.edu/* – Includes detailed instructions for building a simple remotely operated underwater vehicle; based on designs from "Build Your Own Under Water Robot and Other Wet Projects" by Harry Bohm and Vickie Jensen

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.

International Technology Education Association. 2007. Standards for Technological Literacy: Content for the Study of Technology. Reston, VA. 260 pages.

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 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

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

Essential Principle 1.
The Earth has one big ocean with many features.

Fundamental Concept b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

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

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

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

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

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

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

Essential Principle 7.
The ocean is largely unexplored.

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

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

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

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

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

Send Us Your Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education settings.
Please send your comments to:
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Student Worksheet

Your group is one of several teams working to design a robotic arm that is able to pick up objects that are about the size of a soda can from the ocean floor. One of the other design teams has suggested that hydraulic actuators may be part of the final design. Your team's task is to build a model that demonstrates how this could be done.

A. Review of Background Information

1. What does "hydraulic" mean?

2. What is the difference between "hydraulic" and "pneumatic?"

3. What is an actuator?

B. Build a Simple Hydraulic Actuator

Materials

- Cardboard or heavy poster board, approximately 12" x 12" (the stiffer the better)
- Duct tape, approximately 2" x 60"
- Machine screw with nut, #8 x 1"
- 2 - Flat washers, #8 hole
- 2 - Oral syringes
- Plastic tubing, approximately 3/16" inside diameter x 12" (should fit snugly over the end of the syringes)
- Water
- Small container, such as a 9-oz drinking cup

Tools

- Heavy scissors to cut cardboard ("bandage scissors" are inexpensive and work well)
- Nail or Phillips screwdriver to punch holes in cardboard
- Screwdriver to fit machine screw

Procedure

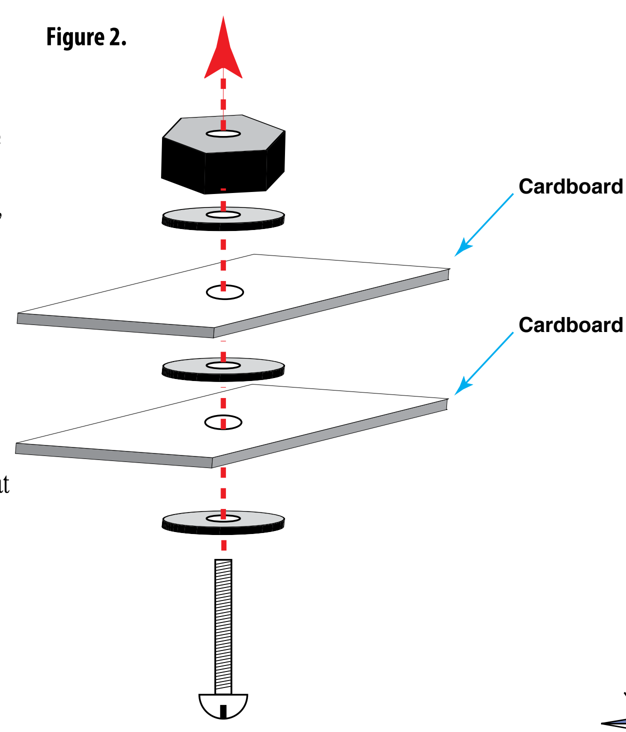
1. Cut two pieces of cardboard using the pattern on page 16 (Figure 1).

2. Reinforce the cardboard pieces: Put a piece of duct tape on one side, then cut off the excess tape around the edges. Put a second piece of duct tape on the other side, and trim the edges. Repeat this process, if necessary, until the pieces are very stiff.

3. Punch a hole in each of the pieces as shown on the pattern. The hole should be large enough for the #8 machine screw, but not much larger.

4. Attach the two pieces with a #8 machine screw, three flat washers, and a #8 nut as shown in Figure 2. You may need a screwdriver to twist the machine screw through the holes. Do not tighten the machine screw assembly too much; the pieces need to be able to move freely around the machine screw.

Figure 2.



5. Take a piece of duct tape 6'' long, and tear it in half lengthwise, and then tear one of these pieces in half lengthwise again. These narrower pieces of duct tape will be useful for attaching a syringe to the shorter piece of cardboard.

6. Attach the plunger of one syringe to the shorter piece of cardboard as indicated on the pattern. Tear one of the narrower pieces of duct tape in half, and wrap it around the plunger and cardboard as shown in Figure 3. Now wrap a second narrow piece of duct tape around the plunger at right angles to the first piece of tape. Add more tape if necessary, but you do not want the joint between the plunger and cardboard to be too tight.

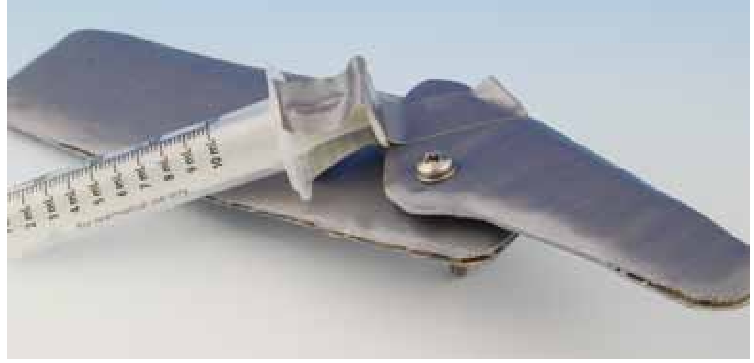


Figure 3.

7. Tape the syringe onto the larger piece of cardboard as shown in Figure 4. Be sure the plunger is fully inserted into the barrel of the syringe.

Figure 4.

8. Press one end of the plastic tubing onto the end of the other syringe so it is firmly attached. Place the other end of the plastic tubing into a small container of water, and pull the plunger back so that water is drawn into the tubing and syringe. Fill the syringe as full as possible, then hold the end of the plastic tubing so that it is higher than the end of the syringe, and slowly push on the plunger until the syringe is about half-full, and there is no air in the syringe or plastic tubing. You may have to refill the syringe with more water and repeat this procedure a few times to get rid of all the air.

9. Attach the open end of the plastic tubing to the syringe that is taped to the cardboard assembly. Slowly press the plunger on the unattached syringe, and you should see the small arm on the cardboard assembly rotate around the machine screw. Pull out slowly on the plunger to reverse this motion. Your hydraulic actuator is completed!

C. Design and Build a Hydraulic Mechanism for a Robotic Arm

Remember that your team's task is to build a model that demonstrates how hydraulic actuators could be used for a robotic arm that is able to pick up objects that are about the size of a soda can from the ocean floor. This model does NOT have to have all of the features that will be needed in the final robotic arm. You only need to show that a design using hydraulic actuators could produce the movements that would be needed to accomplish the purpose of the robotic arm. Your model needs to be able to do two things:

- Grasp an object (such as an empty plastic cup); and
- Lift the object at least one inch.

So that other teams can learn from your experience, it is very important to document how you apply the process of Engineering Design. In addition to creating a model that meets the two requirements, your team should produce a report that:

1. Defines the problem;
2. Describes your solution, including a drawing of your model;
3. Explains your construction procedure; and
4. Reports the results of your tests of the model.

If your model cannot meet the design requirements, describe the modifications that you think are necessary to make it work.

Additional Materials

- Cardboard or heavy poster board, four pieces, each approximately 12" x 12"
- Duct tape, approximately 2" x 20'
- 9 - Machine screws with nuts, #8 x 1"
- 4 - Machine screws with nuts, #8 x 3"
- 18 - Flat washers, #8 hole
- 2 - Oral syringes
- Plastic tubing, approximately 3/16" inside diameter x 12"

Note: These materials are sufficient to construct many models that will meet the design requirements, but your model may not need all of them.

Tip: Cardboard arms and supports are much stronger if they are folded and taped to form beams with square or triangular cross-sections (see Figure 5).

Figure 5.

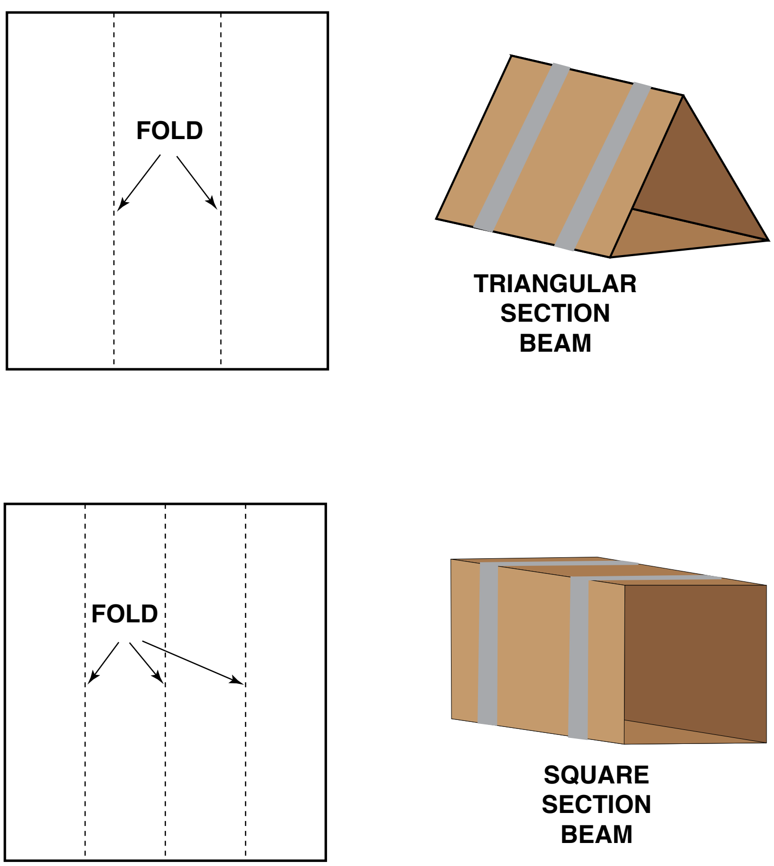


Figure 1.