SONAR At Sea

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Sonar Exhibit: Historic Ship Nautilus and the Submarine Force Museum, Groton, Connecticut

Background:

SONAR (**SO**und **N**Avigation and **R**anging) is used for a variety of purposes by submarines and other ships around the world. SONAR works using two different methods. **Passive SONAR** simply monitors for the presence of sound waves approaching the vessel and sensed by a hydrophone. Passive SONAR can determine the direction (bearing) to the source of the sound. Using passive sonar bearings, range to the sound source can also be determined under certain circumstances. **Active SONAR** releases a sound wave (called a "ping") from a sonar hydrophone and measures the time it takes for the sound reflected from the target (ship, sub, ocean feature) to return to the hydrophone. This provides a range and bearing to the target, very much like echolocation used by sea mammals and bats.

Instructional Goals:

- Students investigate how SONAR operates and how it can be used to navigate.
- Students will build a topographic map of a facsimile seafloor they have not seen to model SONAR operations.
- Students will use SONAR signal return times at three different locations to determine the location of an unseen object.

Science Standard links:

- MS-PS4.B Electromagnetic Radiation (Next Generation Science Standards), which includes mechanical sound waves.
- CCSS.ELA-Literacy.6-8.1 (Common Core State Standards for Literacy in Science and Technical Subjects)

Preliminary Knowledge:

1. Students should be familiar with wave energy and sound.
2. Students should be familiar with d = s * t, distance = speed x time

Introductory Activities:

1. Study how SONAR (**SO**und **N**avigation **A**nd **R**anging) functions using sound waves and the speed of sound in sea water (speed approximately 1500 m/s) to navigate and map the sea floor.
    a. Watch this video: http://www.youtube.com/watch?v=c-_SlJ71u5U
    b. There is a detailed description of submarine operations, including SONAR at: http://www.history.navy.mil/branches/teach/dive/elem.htm

2. Study how topographic maps are made and show examples: http://oceanexplorer.noaa.gov/explorations/02davidson/logs/may23/media/divetracks.html .

Activity One: Construct a Sea Floor Model

Objective:

- To map the depth of a model sea floor without seeing it visually.

Materials:

- Shoe box
- Paper clip
- Metric ruler
- Graph paper
- Pencil
- Paper mache
- Tissue paper

Procedures:

1. Have students, in groups of two, form a model sea floor in a shoebox, with at least on seamount and trench. (Set aside to dry overnight)
2. Students should then tape tissue over there shoebox in enough thickness to be opaque.
3. Trade boxes with another group.
4. Students should then map the sea floor by poking a straightened paper clip and measure the depth (in cm) at set grid distances. Suggested to use the area of your graph paper as a guide.
5. Draw contour lines connecting similar depths (remember to not cross lines)
6. Once your map is done, bring map and box to teacher to unveil your “seafloor” and see how accurate your map was.

Questions: Individual or for discussion

1. In what ways was this activity similar to how SONAR maps the ocean floor? How was it different?
2. Why was it important to not see the floor you were mapping prior to completing the activity?
3. How accurate was you map? How could you improve your results if we did this again?
4. In step #5, why was it important to not cross contour lines?
5. Would this type of mapping use active or passive SONAR? How do you know this?
6. What is the common name for this type of SONAR?

Answers To Activity One:

1. It was similar in that the seafloor was mapped without seeing it. One way it was different is that the measuring device measured the exact distance, not twice the distance as SONAR would.
2. So the only data was that collected and not influenced by any recollections.
3. Various answers accepted
4. Various answers accepted
5. Active SONAR, a signal needs to be created, travel to the seafloor, and return to be measured.
6. Fathometer on a ship or "fish finder" on your boat.

Activity Two: SONAR Triangulation

Objective:

- To find the position of a target by calculating distances from three points and triangulating using graph paper and a compass.

Materials:

- Graph paper
- Metric ruler
- compass

Procedures:

1. Prepare in advance or have students prepare graph paper 0.25 inch square with an x-axis labeled 0 through 25, and the y-axis labeled a-z (going up). For this activity 0.25 inches equals 1500 ft.

2. Have students record the following data
    a. Position 1, U-4, Active SONAR signal time 10.65 seconds
    b. Position 2, Y-13, Active SONAR signal time 6.3 seconds
    c. Position 3, T-14, Active SONAR signal time 2.25 seconds

3. Students should divide this time in two to account for the time out and the return time, where d = (time/2) x speed, using speed of sound in water as 5000 ft/sec.

4. On the graph paper students should plot each of the positions and calculate the distance to **TARGET 1**

   a. Using the following formula (converts distance from ft to inches on the graph for analysis):

Distance in inches = (time in seconds / 2) x (5000ft/sec) /6000ft/inch
= (time/2) x (5000) / 6000

      i. Point A: 26625 ft
      ii. Point B: 15750 ft
      iii. Point C: 5625 ft

   b. Once the distance is determined have students use a compass to draw circles centered on each point. Where all three intersect is the target location.
   c. **Target should be at Q-21**

5. More Coordinates to determine a targets location:

Target 2

      i. Position 1, Q-3, Active SONAR signal time 5.55 seconds
      ii. Position 2, L-11, Active SONAR signal time 4.2 seconds
      iii. Position 3, E-14, Active SONAR signal time 6 seconds

Target 3

      iv. Position 1, U-14, Active SONAR signal time 1.8 seconds
      v. Position 2, T-16, Active SONAR signal time 1.35 seconds
      vi. Position 3, L-14, Active SONAR signal time 3.6 seconds

Target 4

      vii. Position 1, U-7, Active SONAR signal time 2.7 seconds
      viii. Position 2, S-11, Active SONAR signal time 6 seconds
      ix. Position 3, Q-15, Active SONAR signal time 8.1 seconds

Questions:

1. Why does the formula include the dividing of the signal time by 2?
2. How would you change the formula if you found a target with passive sonar only, using sound from the target?
3. If the bearing of the target from each position is known, what device could be used to help determine the exact target point?

Answers To Activity Two:

- Target 1 – Q-21
- Target 2 – H-5
- Target 3 – R-15
- Target 4 – W-3

1. To account for the time traveled to and from the target.
2. You would not divide the time by 2.
3. A compass, to provide the direction to graph a straight line with a ruler in the direction of the target (between 0 and 360 degrees) from the sonar's position. Where the range arc and direction line (called a bearing) intersect, is the target's position. So you need only ONE active sonar "ping" to find the target's position.