XIII...How to Catch a Speeding Cloud in Space

Introduction:

What does the Radio Plasma Imager on the IMAGE satellite do? Scientists can not go into all areas of space to collect information, so a process called remote sensing is used. Remote sensing is defined as collecting information about an object without touching that object. Remote sensing is also used frequently here on Earth. When a traffic officer wants to determine the speed of a car, a radar gun is aimed at the vehicle. The radar sends radio waves to the car, which are reflected off the metal in the car, and sent back to the radar gun's receiver. The radar gun then figures out the distance the car has traveled and the speed of the car. The IMAGE satellite's Radio Plasma Imager (RPI) calculates the distance and velocity of electrically charged clouds (called plasmas) and their densities (how many particles) in much the same way. The activities below begin to explore how radar works through echoes, wave patterns, and finally how the data is collected and organized to form images.

Materials:

Slinky - (two of the same size)
Stopwatch
Meter stick or measuring tape
Clear dish or plastic bowl
Water
Clay
BB, ball bearing or rock
Hot plate or overhead projector
Students

Objectives:

- The students will explore how waves move away from, and then bounce back to the source, in the form of echoes.
- The students will explore how the elapsed time of the echo waves can be used to determine distance.
- The students will explore how scientists use this information to produce images that represent the distances of things in space.

Key Terms:

Magnetopause- The boundary of a region surrounding the Earth where the pressure from the solar wind is just as strong as the pressure of the Earth's magnetic field.

Plasmapause- The boundary of a region surrounding the Earth in the shape of a donut with the Earth in the center. This region contains fast moving atoms trapped in the Earth's magnetic field, that rotate with the Earth every 24 hours.

Note to Teacher:

*Always make it very clear to students that sound waves and light waves are **not** physically the same. Sound waves are created by pressure changes in a gas and travel at the speed of sound. Light waves and radio are caused by changes in electric and magnetic fields and travel at the speed of light. It is very common for students and adults to think of these as the same phenomena.*

Procedures:

- The students are going to participate in a game where the use of echoes will help them determine another child's location. Choose one student to be the "bat" and the rest of the students will be the "insects". Set up a perimeter boundary to limit the distance the bat and the insects will be from each other. Place a blindfold on the bat and have the insects select a spot within the boundaries to stand still. The bat will begin to "chirp" and the insects will "buzz". Each time the bat makes its chirping noise, the insects must respond by buzzing. Direct the bat to find his meal of an insect by moving in the direction of a buzz. The students should be discouraged from harming each other. Allow several students to be the bats, saving time for discussion at the end. How were the bats able to find the insects without seeing them? The students should be able to explain how they followed the sounds they heard to the location of the "insects", and describe the experience in their learning logs.

- To further the students experiences with echolocation and remote sensing go to the "Echo the Bat" site at http://imagers.gsfc.nasa.gov//index.html . This site offers a story of a bat that uses echolocation to find his food. This site also has the students go on an interactive journey to find Echo, who can not find the cave with the rest of his family. During the journey to find the cave, the students use radar images of the ground and learn to identify geographic features from these satellite pictures.

- How do the sounds get from one place to another? Have two students kneel on the ground facing each other. It is best if it is a bare floor - no carpeting. (The distance will depend on the length of the slinky that you are using.) The slinky should be stretched out on the floor between the two students, but not so taunt that it doesn't have flexibility. Have one student gently start to move his arm back and forth parallel to the floor creating waves in the slinky. Help the students see that this "wave" motion represents how sound moves from one place to another. When the students were playing the bat and insect game, they were able to hear the insects because the sound traveled in waves to the bat. Since the sound waves traveled in a straight path, the bat could determine what direction the insects' sounds were coming from and move toward the food. As a further example of waves moving in straight lines, place some water in a clear glass or plastic dish. Place the dish on an overhead projector, allowing the water to become calm. Drop a BB or rock into the water, and have the students observe the path of the waves. How do the waves move? What is the path that they take? The students should record their findings in their learning logs.

- When scientists are using remote sensing to explore areas in space, they need to "fine tune" the use of echolocation to include speed, distance and elapsed time. The students will use the slinky to determine how the elapsed time in which a wave travels gives some information about the distance the wave has traveled. Once again, the two students will need to kneel apart, keeping the slinky taunt. One student will need to begin a single wave that can travel across the slinky, bounce off the other student and return to the originating student. This time the students will need to time how long it takes for the wave to travel from one student to the other and back to the originating student. What would the students' predictions be if the ends of the slinky were farther apart or closer together? The students should be made to see that the distance is covered in half the round trip time.

- So how does the Radio Plasma Imager really use this echolocation to study distant locations within the Earth's magnetosphere? The students will use the slinky in the same way again. This time, have a student grab the slinky (without picking it up) at midpoint and allow the wave to bounce back from that point to the originating student. The students should record the time it takes for the wave to bounce back to the originating student. Did this take more or less time than having the wave move across the length of the slinky? Have the students repeat this part of the activity creating a new "object" for the wave to bounce off of by grabbing the slinky at different places. The students should still be recording the elapsed time. Initiate a discussion with the children about what they have seen; what would happen if there were no "object" where the wave was sent, would there be an echo? The students should gain an understanding that the closer the object is, the quicker the echo wave can return. Conversely if an object were further away, the echo wave would need more time to reach you. The satellite knows how fast the radar signal travels in space, so if we time how long takes for the signal to return, we can figure out how far it traveled and use this information to get a image of the object. The RPI instrument is constantly sending out waves and receiving echoes. From the return of the echoes, it can determine where specific clouds of particles are located in the magnetosphere and how many particles are in a certain area.

- When the RPI is sending out its waves, the waves are sent in all directions. Sometimes, there may be multiple boundaries of particles that will send echoes back from two different directions. Both of the waves will bounce back in straight lines, to the original transmitter. This can be demonstrated by using a clear glass or plastic dish, overhead, BB's, clay and water. Set up the dish with water in it, but place two clumps of clay that will remain stationary. Drop the ball bearing into the water so that it is not equidistant from both clumps of clay, and have the students carefully watch the first wave to move out. The waves circling out from the BB's will bounce off the clay and move back to the source, but they will not reach it at the same time. Students should report their findings in their Science Learning Logs. The students may find it helpful to draw pictures of what they observed.

- When the RPI instrument sends out waves, it looks at location plots as well as the number of particles within an area (density). Have four students each grab an end of a slinky. Then have the students stretch the slinkys out to two different lengths, each group making waves at the same time and compare the apparent speeds of the wave. The more stretched out slinky can represent a less dense area of plasma, while the less stretched out area can represent a more dense area of plasma. Radio waves travel at slower speeds through dense plasmas than through less dense ones.

- By plotting the echoes, you can build up a map of what is around you. You will need to make a coordinate graph on the floor using tape or draw it outside with chalk. (Or purchase a shower curtain liner, make your coordinate graph on it with tape – fold up and save when done!) The graph should be 10 x 10 with directional words labeled outside the graph. In this activity, a student can play the role of the RPI instrument, by positioning him or herself at the satellite location given in the sample chart. The RPI instrument will state the direction that the wave will be sent and the "calculated" distance it traveled. A student playing the role of the wave will need to move in the direction stated, and the specified distance on the graph. The "wave" student can either remain in that spot or place an object on the spot. When all of the "data" has been recorded, a string or yarn can be wrapped around the objects to show the boundaries of the area being studied. (A sample data list is included) The students can then write the coordinates for the shape that is made.

- A variation of this activity would be to have the students who are not playing the role of the instrument or the "wave", plotting the coordinate points on a paper copy of the coordinate graph as the data is transmitted.

<u>What does the RPI's data tell us?</u>

When the RPI is sending out sound waves, there would be a returning echo only if there was something in that part of space to bounce the wave back. The RPI sends out its waves in all directions, and uses the speed of the returning echoes to determine the distances of objects. This next activity will be a simplified model of how the RPI emits radio waves, records the time and amplitude of the echoes, and utilizes the data to determine boundaries. The students will be using two different graphic models of the Earth, its magnetopause and its plasmapause to demonstrate how the RPI's data would reflect the effects of a solar storm on the earth. The emphasis on this lesson is for the students to draw conclusions and make assumptions by looking at the data plots of the echoes.

<u>Part 1</u>

1. Display Diagram 1 on the overhead, and have the students use desks to construct the magnetopause and chairs to construct the plasmapause as shown in the model. Four students will pretend to be four locations on the modified IMAGE orbit. Label the four students with their locations and give each a piece of colored paper. Each location on the orbit will be sending out two sound waves in opposite directions, which will be represented by two students.

2. Begin with Position A, have both sound waves move in opposite directions towards the established magnetopause and plasmapause in this model, with consistent speeds. As these waves reach an object, they should "bounce" back to their source. The student at that position should give the sound wave that returns first a piece of colored paper.

3. On the board or chart paper, draw a diagram of the waves similar to the ones on the next

page. The diagram uses the elapsed time and amplitude for its axis. For the purposes of this model, the amplitude is assumed to be greater as the distance is closer; objects further away would have fainter amplitude. As you are drawing in the waves, elicit the students input about which echo should be recorded first, what would be an appropriate height or amplitude, and the appropriate distance between the two echoes. Only complete as many diagrams as necessary for students to have an understanding.

4. Continue this same sequence with each of the remaining three positions. Have the students remain in their positions during the second part of this activity.

Part 2

1. Display Diagram 2 on the overhead, and have the students use desks to construct the magnetopause and chairs to construct the plasmapause as shown in the model. Four students will pretend to be four locations on the modified IMAGE orbit. Label the four students with their locations and give them each a piece of colored paper. Each location of the orbit will sending out two sound waves in opposite directions, which will be represented by two students.

2. Follow all of the steps listed above for the four locations on the IMAGE orbit for this diagram.

Part 3

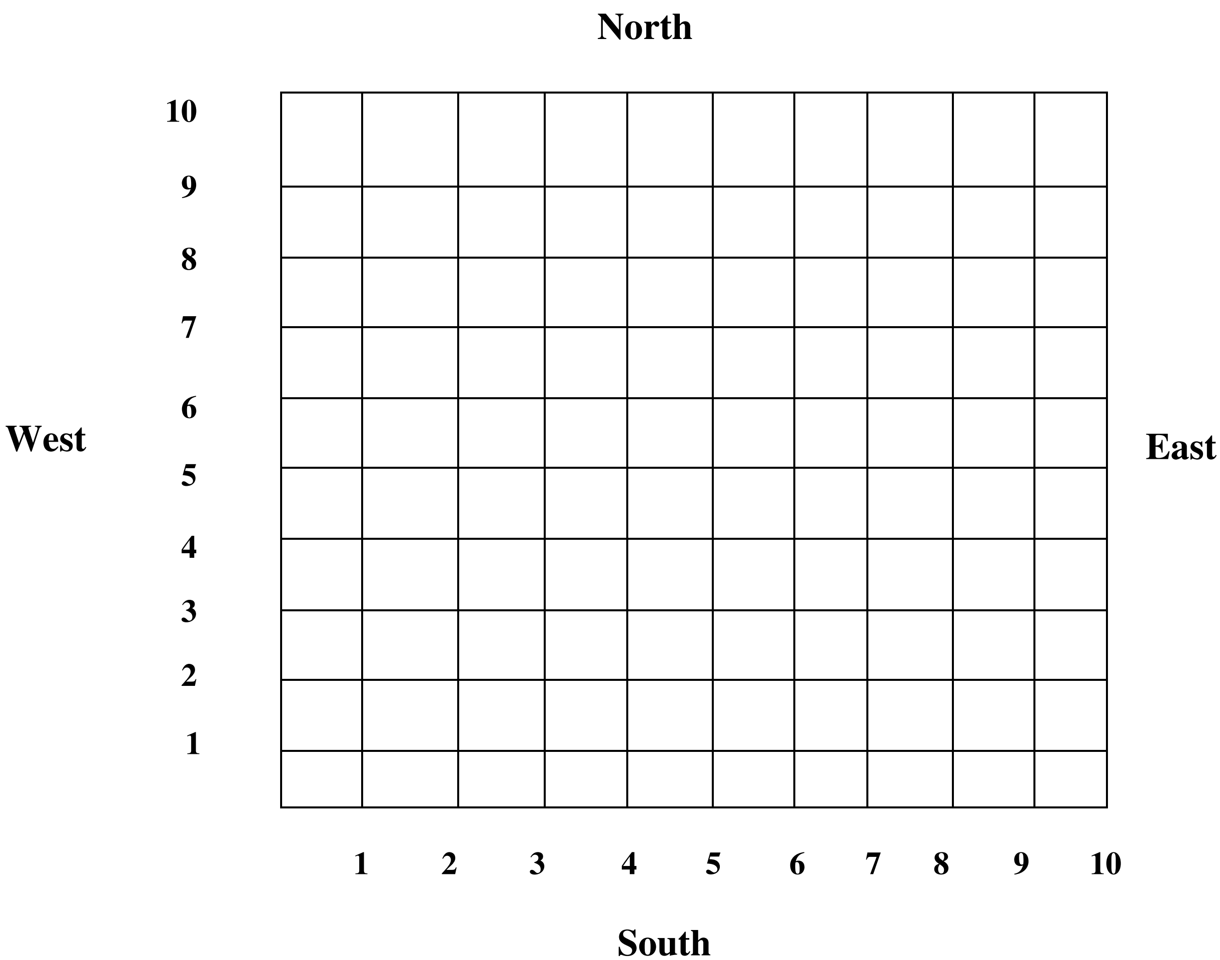
1. Display or distribute copies of the Amplitude/Time charts for Diagram 1. Have the students match each chart to the location on the IMAGE's orbit. The students should be able to support their choices with evidence from the data. These responses can be oral or written.

2. Display or distribute copies of the Amplitude/Time charts for Diagram 2. Have the students match each chart to the location on the IMAGE's orbit. The students should be able to support their choices with evidence from the data. These responses can be oral or written.

3. For students who enjoy a challenge, have them pick other locations on the IMAGE orbit or within the Magnetopause, draw and then defend their Amplitude/Time charts. There is also an activity for older students available at http://image.gsfc.nasa.gov/poetry/NASADocs/RPI.pdf called The Magnetosphere that has the students plot the boundaries of the magnetosphere by determining the speed and direction of the echoes.

Radio Plasma Imager Echo Plots

Directions: Use the location and echo data from the chart below to plot the boundaries of the object the Radio Plasma Imager is measuring. Begin by putting your finger on the location named by the coordinate pairs, then move your finger in the direction of the echo as indicated. Make an X when you have moved your finger the specified distance of the echo. When all of the echoes are plotted, connect the X's to image what the RPI has measured.



Data Table

Satellite Location	Echo Direction	Echo Distance
1,2	East	1
2,2	North	7
3,3	West	2
4,4	South	3
5,5	West	2
6,6	East	3
7,7	South	3
8,8	East	1