National Aeronautics and
Space Administration

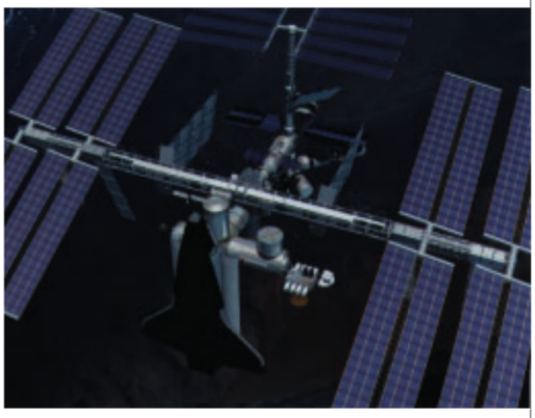
Office of Human Resources
and Education
Education Division

Educational Product	
Teachers and Students	Grades K–4

Amateur Radio in Space

A Teacher's Guide With Activities in Science, Mathematics, and Technology








Amateur Radio in Space—A Teacher's Guide with Activities in Science, Mathematics, and Technology is available in electronic format through NASA Spacelink—one of the Agency's electronic resources specifically developed for use by the educational community.

The system may be accessed at the following address: *http://spacelink.nasa.gov*

Amateur Radio in Space

National Aeronautics and Space Administration

Office of Human Resources and Education
Education Division

Acknowledgments

Writers
Sandy Peck
Clear Creek Independent School District
League City, TX

Rosalie White
American Radio Relay League (ARRL)
Newington, CT

Editor
Jane George
Teaching From Space Program
NASA Headquarters
Washington, DC

Special thanks to Pamela L. Mountjoy at NASA Headquarters and Nancy Robertson and Matthew Bordelon at NASA Johnson Space Center for all their help and support.

This publication is in the Public Domain and is not protected by copyright.
Permission is not required for duplication.

EG–1998–03–114–HQ

Table of Contents

Introduction 3

Activities

Waves, Waves, Everywhere 6

Can I Hear You? 13

"Hello Over There" 17

Say It With Space Talk 22

Appendices

A. How Can I Get Involved With the SAREX Program? 26

B. SAREX 27

NASA Resources for Educators 30

Introduction

The Space Amateur Radio EXperiment (SAREX) is designed to facilitate communication between astronauts in orbit with students on the ground. SAREX is sponsored by the American Radio Relay League (ARRL), the Radio Amateur Satellite Corporation (AMSAT), and the National Aeronautics and Space Administration (NASA). SAREX is also supported by the Federal Communications Commission (FCC).

Through SAREX, astronauts make scheduled and unscheduled Amateur Radio contacts from the Shuttle orbiter with schools selected through a proposal process (see Appendix for proposal process information) from around the world. These contacts energize students and families about science, technology, and learning.

The SAREX program will continue on the International Space Station (ISS). Ham radios provide a necessary secondary system component for communication between Shuttle orbiter (and will be for the future ISS) crew members and with Mission Control and workers on the ground.

What Is a Ham or Amateur Radio Operator?

More than 2.8 million people worldwide, including more than 670,000 Americans, are currently licensed Amateur Radio operators or "hams." Oddly enough, there is no universally accepted explanation for where the popular term "ham" originated. Various theories have been put forth, but all are generally discredited. The most likely explanation is that the term derives from the frontier-day custom of referring to unskilled or inept telegraph operators as "ham-fisted." Regardless, it is a term in which Amateur Radio operators take pride.

The term "amateur" refers to one who engages in a pursuit as a pastime rather than as a profession. Amateur Radio is the personal use of short wave radio equipment for direct worldwide communications on a one-to-one basis. Amateur Radio has been a source of communicating and technical skills, especially during an emergency. Hams never accept compensation for services they provide.

The First Space Flights for Ham Radio

On November 28, 1983, Space Shuttle mission STS-9 was launched carrying Mission Specialist Owen Garriott, Amateur Radio call sign W5LFL, and his ham radio into orbit for 10 days on the Space Shuttle Columbia. For seven of those days, hams around the world heard Dr. Garriott's voice calling Earth-bound ham radio stations. Lance Collister, call sign WA1JXN, of Frenchtown, Montana, became the first Amateur Radio operator to work an astronaut-ham orbiting the world, and by the end of the mission, over 300 radio calls were logged by Garriott. The calls ranged from classrooms of children to King Hussein of Jordan. Garriott was even patched in to the Capsule Communicator (CAPCOM) at Mission Control Center to demonstrate the utility of the ham system operating as a backup to some of the orbiter's communication systems. SAREX radios are operated on the conditions that they will not interfere with mission activities and that safety requirements will be met.

The second time a ham radio transmission came from space was on the Challenger STS-51 mission, and a new dimension was added to the already proven techniques used on STS-9. Working with a small group of hams, Mission Specialist Tony England, call sign WØORE, developed the idea of adding a re-

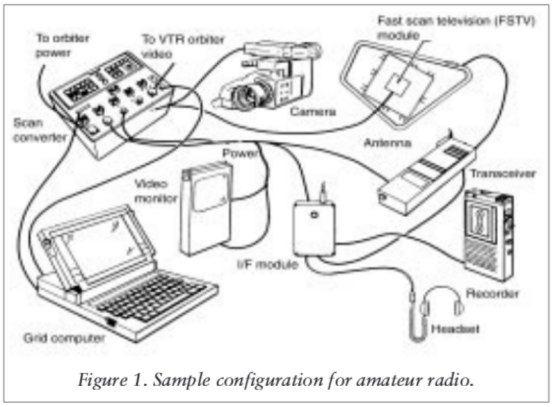


Figure 1. Sample configuration for amateur radio.

Equipment Configurations

peater with a 2-meter radio frequency input and a 10-meter radio frequency output that would also have the capability for slow-scan television (SSTV) uplink and downlink. This mission would determine if television images could be sent and monitored in space. In addition to the 130 voice contacts made—including one from a ham radio mounted in an automobile—there were 10 exchanges involving SSTV signals monitored by the Shuttle ham station. The first SSTV image monitored by Tony England was that of his wife, Kathi. This was the first television to be watched in space.

There are different configurations for Amateur Radio equipment on the Shuttle orbiter. One configuration consists of a hand-held transceiver, interface module, a payload general support computer (PGSC), window antenna, packet radio (digital) module, headset, and terminal node controller (TNC). The TNC interconnects with a radio transceiver so the data to and from the computer is transmitted to and received from the Amateur Radio stations on the ground. This configuration is capable of operating in either the voice or data mode in communications with Amateur stations within the line of sight (LOS) of the Space Shuttle orbiter or Space Station. This configuration can be operated in the attended mode for voice communications and in either the attended or automatic mode for data communications. A similar configuration will be used on the ISS along with other innovative ham radio set-ups.

Another configuration (see Figure 1) consists of a hand-held transceiver, an interface module, a headset, a slow-scan and fast-scan television converter, a television camera and monitor, a PGSC, and an antenna capable of being mounted in one of the orbiter's flight deck windows. This configuration communicates with Amateur Radio stations within LOS of the Shuttle orbiter in one of four modes: voice, Slow-Scan Television (SSTV), data, or Fast-Scan Television (FSTV).

Ground Equipment

An elaborate radio station setup in schools is not required to make a 2-meter radio frequency contact. Ham radio operators will be glad to help with radios and antennas. Contact ARRL (see page 5) for information on how to find a list of hams in your area.

QSL Cards

Specially designed QSL cards (post cards designed by hams to confirm two-way radio contact or reception of signal) are available to anyone who sends a reception report of Amateur Radio operation from the Shuttle orbiter or the future International Space Station. Non-amateurs can listen in on a ham receiver or monitor on scanners to qualify for the special QSL. Send all reception and confirmed contact reports to ARRL.

Licenses

Every Amateur Radio operator must be licensed by the Federal Communications Commission (FCC). In order to obtain a license, a ham must pass examinations in radio theory, rules and, for some licenses, international Morse Code proficiency.

There are Amateur Radio operators from ages 8 to 80, and they qualify for one of five grades of licenses, each at progressively higher levels of proficiency. The five grades are Novice, Technician, General, Advanced, and Amateur Extra. Higher classes of licenses have additional operating privileges. The minimum license required to operate on the frequencies to the Shuttle orbiter and on the future International Space Station is Technician.

Call Sign

The Amateur Radio operator's call letters are issued by the FCC at the time of obtaining a license. The first letter indicates nationality; in the United States the first letters are A, K, N, or W.

There are several means of communicating with Amateur Radio in addition to Morse Code (radiotelegraphy) and voice transmission (radiotelephony). These include radio teletype, computer-data exchange, and fast scan and slow scan amateur television.

References and Resources

AMSAT: The Radio Amateur Satellite Corporation was founded in 1969 to provide satellites that can be used for Amateur Radio communication throughout the world and to disseminate information derived from these communications. For more information, write to:

Radio Amateur Satellite Corporation
PO Box 27
Washington, DC 20044

ARRL: The American Radio Relay League was founded in 1914 as the ham radio operators' organization. ARRL publishes monthly licensing guides, teacher's materials, technical journals and an annual handbook and is the representative body with the Federal Communications Commission. For more information, write to:

American Radio Relay League
225 Main Street
Newington, CT 06111

SAREX on the World Wide Web

ARRL Web Site:
http://www.arrl.org/sarex/

AMSAT Web Site:
http://www.amsat.org

NASA's SAREX Web Site:
http://www.ccsds.org/sarex/

Goddard Space Flight Center Amateur Radio Club:
http://garc.gsfc.nasa.gov/www/

Johnson Space Center Amateur Radio Club:
http://www.phoenix.net/~mbordel/index.html

Activity: Waves, Waves, Everywhere

Objectives

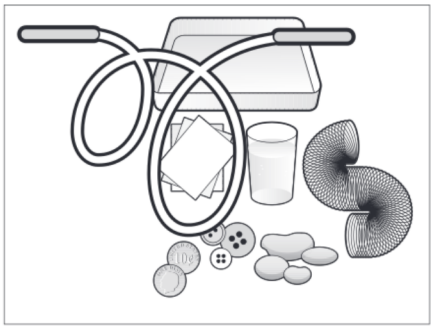
- Identify the components of a radio wave
- Identify the ranges of frequencies of the electromagnetic spectrum
- Observe water waves
- Create waves in different frequencies

Activity Overview

This activity will allow students to understand the relationship between water waves and air waves by learning about their parts. Students will also learn about frequencies of the electromagnetic spectrum. They will work individually and in teams. Younger students will observe and draw waves in the water and with a Slinky. Older students will be able to see the relationship of radio waves to other waves in the electromagnetic spectrum and will be able to identify these parts. They will work in pairs to observe and create a visual representation of waves in varying frequencies.

Materials

- Glass or metal pan
- Water
- White paper
- Eye dropper
- 1 Slinky per group of 4; or
- 1 short rope or jump rope
- Data Collection Sheet



Science Standards

- Science as Inquiry
- Physical Science
- Transfer of Energy
- Science and Technology
- Understanding About Science and Technology

Technology Standards

- Technological Knowledge
  – Technological Concepts and Principals

Mathematics Standards

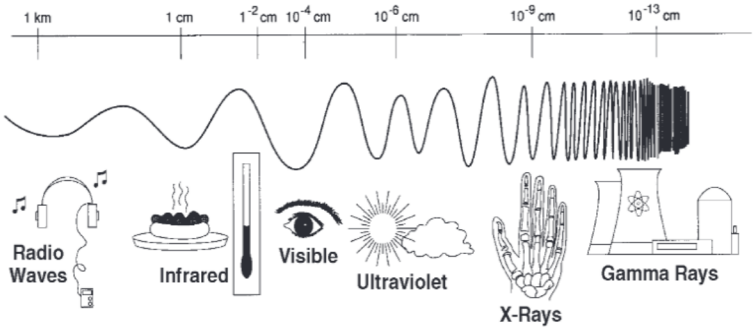
- Problem Solving
- Patterns
- Relationships

Timeframe: 30–45 minutes

Background Information

All around the world every minute of every day people are talking, and they are all talking at the same time. Think of places that you have been where everyone is talking at once—between classes at school, football games, shopping malls. Was it hard to hear just one particular conversation?

When you turn on a radio, you hear people talking or you hear music. As you change the tuner to successive stations, you find that there is some form of audio on all the stations. You may wonder how they can all talk at once, but you can only hear one station at a time. This is due, in part, to **electromagnetic waves**— waves that are partly electric and partly magnetic and carry energy emitted by vibrating electric charges in atoms. All waves are on an electromagnetic spectrum.



The **electromagnetic spectrum** is a continuous range of waves—radio waves, infrared, visible, ultraviolet, x-rays, and gamma rays. It is a means of classifying electromagnetic waves according to their frequency. Waves all move, or vibrate, at the same speed ("c" for constant), but differ in their frequency. The **frequency** is how often a vibration occurs. This unit of frequency is called a **hertz** (Hz). When Heinrich Hertz first demonstrated radio waves in 1886, he found that the source of all waves was something that vibrates. Radio and television stations often announce that they are operating on a frequency of "x-number" of Megahertz. This is the frequency range assigned to them by the International Telecommunication Union (ITU). This organization divides the entire range of communications frequencies among those who use them. This includes commercial radio, television, and Amateur Radio. Radio waves vibrate at the lowest frequency and have the longest wavelengths on the electromagnetic spectrum.

Visible light is just a small part of this vast spectrum. Light waves and radio waves are both electromagnetic waves that originate from the vibration of electrons. Sound waves are not electromagnetic waves, but a mechanical vibration of matter. So even though we hear a radio by means of sound waves, radio waves and sound waves are not the same.

A specific radio frequency is assigned to Amateur Radio operators when they are transmitting to space. All Amateur Radio operators, this includes those who operate for Space Amateur Radio Experiments (SAREX) missions, use a small portion of the frequency bands on the electromagnetic spectrum. Any amateur station that is located more than 50km above Earth's surface is defined by the Federal Communications Commission (FCC) as a space station. Amateur

satellites, the Space Shuttle orbiters, the Russian MIR Space Station, and the International Space Station all fall under this category.

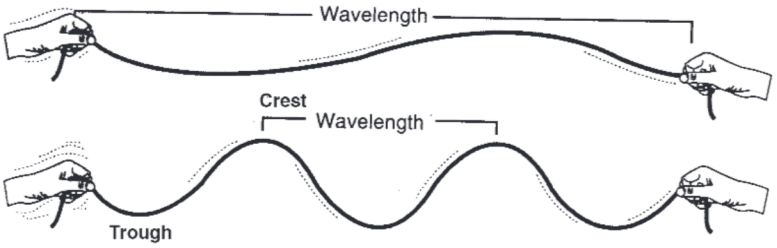
If you drop a pebble into a pond circular waves will emanate from the drop source. The human eye can follow these waves as they progress outward from the drop point. These waves like all other waves have **amplitude, wavelength,** and **frequency.** These three characteristics are present in all waves that make up the electromagnetic spectrum.

The **frequency** of a wave is measured in hertz, the wavelength in meters. Thus, the speed of a given wave is measured in meters per second. This relationship is the same for all kinds of waves, such as sound waves, light waves, or water waves.

A **wavelength** is the distance a wave travels through space in a single cycle. It can be measured from any point along the wave as long as it is consistently measured from the same point. The speed of the wave is equal to the frequency times the wave length. The **amplitude** of a wave is the maximum displacement on either side of the midpoint of a wave. The **midpoint** is the point at which the wave is at rest.

Let's Begin

1. Gather students around a pan of water on the floor. If the pan is glass, place a white piece of paper under the pan. Have students observe that the surface of the water is flat. Ask them to predict what will happen when a drop of water is dropped into the pan of water. Write predications on the Data Collection Sheet. Discuss predictions.
2. Have a student drop water from an eyedropper into the center of the pan. Ask for observations on what has happened. Guide students to observe the wave that has been created as it moves outward along the surface of the water in expanding circles. The image of the wave should be reflected on the paper under the glass pan.
3. Draw observations on the Data Collection Sheet. What shapes were the waves that were created? How did the waves move? Were the circles evenly spaced? Students should record observations on the Data Collection Sheet.



4. Show the picture of the wave. Identify the different parts of the wave—crest, trough, amplitude, midpoint, wavelength. Explain that the highest parts are **crests,** and that the lowest parts are **troughs.** The distance between the crests of two waves side by side is called **wavelength.** The height of the crests above the midpoint is called the **amplitude.** The troughs are usually the same distance below the midpoint as the crests are above. Students should record these vocabulary definitions on the Data Collection Sheet.
5. Drop water again. Observe waves again. Have students look for the crest, trough, amplitude, and wavelengths. Ask students to name the different parts of the waves they just observed. Do they see a difference in patterns of the waves?

Introduce the Slinky. (**HINT:** A short rope or jump rope may be substituted.) Ask for students observations of the properties. Explain that the Slinky represents waves and how they might look at different frequencies.

1. Ask two students to demonstrate how a wave is created. Stretch the Slinky to about 1 meter on the floor (not carpet) or table top. (Do not overstretch.) Ask one student to hold one end of the Slinky still. The second student will move the other end slowly back and forth. They should observe that a wave has been created.
2. Have students do the procedure in groups of four. Ask them to draw on the Data Collection Sheet the wave they see. Tell them to increase the rate at which they move the Slinky back and forth. Explain to

students that they are changing the frequency of the wave. Ask them to explain the relationship between the rate at which the Slinky is moved back and forth and the frequency. How is the wavelength changed? Guide them to understand that faster movement corresponds to higher frequency and shorter wavelengths.

3. Show the chart of the electromagnetic spectrum contained in the Background Information. (Teachers may wish to make a transparency of this chart. Students may also wish to refer to the Data Collection Sheet to view the chart.) Explain that each mark on the frequency scale represents a frequency ten times higher than the mark to its right. The small numbers after the 10s tell how many zeros are in the number. For example, 10^6 is 1 followed by 6 zeros (1,000,000). Discuss the different forms of waves contained in the spectrum and where they are placed. Have students label on the Data Collection Sheet the radio waves, microwaves, infrared, visible light, ultraviolet, x–rays, and Gamma rays. Ask them to move the Slinky again and tell which waves they are showing.

Extensions

1. Find out more about the Electromagnetic Spectrum. Write a report and present it to the class on three ways frequencies in the spectrum affect our daily lives.
2. Understanding the Electromagnetic Spectrum helps to understand radio waves in a more global way. Ask students to find examples in a magazine, newspaper, on television, or on the Internet of items contained in the spectrum frequencies. Bring pictures or write names of objects on paper and place on a large drawing of the Electromagnetic Spectrum on the board.

Data Collection Sheet

Name _____

Group Names _____

Date _____

What will happen when a pebble is dropped into the water? _____

_____

_____

Draw observations of water after pebble is dropped:

Electromagnetic Spectrum _____

_____

Frequency _____

_____

Hertz _____

_____

Wavelength _____

_____

Crest _____

_____

Trough _____

_____

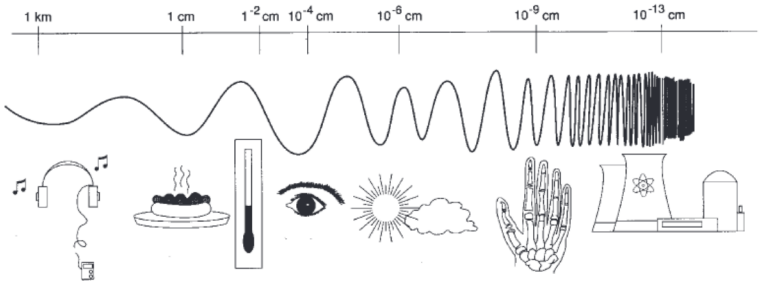
Amplitude _____

_____

Midpoint _____

_____

Vocabulary



Label the Parts of the Electromagnetic Spectrum

Observations of Slinky (written here or drawn below) _____

What did you learn? _____

Activity: Can I Hear You?

Objective

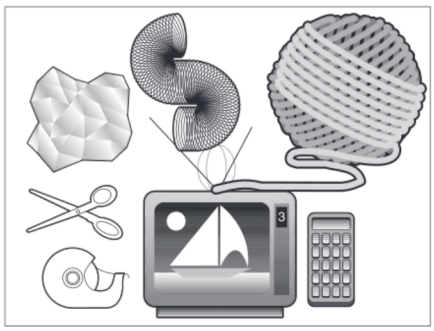
- Demonstrate radio waves cannot pass through certain metals

Activity Overview

Students will work as a class to discover that energy waves must be present in order for the remote control to change the channel on the television. They will make oral and written observations and predict what they think will happen when the remote control is pointed at the television. They will compare the results when the receiving eye on the television is uncovered and when it is covered with aluminum foil. Then the class will discuss what has happened, and be guided by the teacher to draw conclusions.

Materials

- Television
- Tape
- Scissors
- Remote control
- Aluminum foil
- 6' yarn (any color)
- 1 slinky per group of 4
- Data Collection Sheet



Science Standards

- Science as Inquiry
- Physical Science
- Transfer of Energy
- Science and Technology
- Science as Human Endeavor

Technology Standards

- Technological Knowledge
  - Technological Concepts and Principles
- Technological Processes
  - Utilizing and Managing Technological Systems
- Technological Contexts
  - Informational Technology

Timeframe 30–45 minutes

Background Information

The Space Amateur Radio Experiment (SAREX) has been included on many Shuttle flights and will be on the International Space Station. In order for SAREX to be operational, a signal must connect a radio on Earth to the Shuttle orbiter or International Space Station.The signal cannot be seen by the human eye, but must be present for an astronaut or a student to talk or be heard.This signal is called a radio wave. Radio waves are a form of energy. They go from the radio on Earth to a land-based antenna. The signal is then transmitted to an antenna located in the window of the orbiter, then to the SAREX system inside the orbiter. This process is reversed as the signal is sent back to Earth. Many school children over the years have been able to participate in or listen to conversations to and from space using this system.

This activity involves the entire class. A television has been used since it is an item readily accessible in most schools. Most television remote controls use infrared signals. In this activity, the signal will be blocked by aluminum foil, a very light, man-made metal.

Let's Begin

1. Share with students the Background Information. Draw attention to the television. Have students list observations of the television on the Data Collection Sheets. Discuss the observations and make a group list on the board.
2. Show the remote control and ask the students what function it has. Students list individual observations of the properties of the remote control on the Data Collection Sheets and then on the board.
3. Ask a student to turn on the television. List individual predictions on Data Collection Sheets and on the board as to what will happen when another student points the remote control at the television and pushes the channel button. Let a student demonstrate by changing channels.
4. Ask what the students think caused the remote control to turn on the television. Guide them to understand the television receiving eye received the signal that caused the channel to change. Ask two students to take the yarn and show the path the signals took. Have them hold the yarn in place. (Guide them to the receiving eye on the television, not the screen.) Ask the class for the definition of a receiving eye. Check the list of observations made on the Data Collection Sheets and the board. If the term receiving eye is not there, add it to the list.
5. Ask a student to take a piece of aluminum foil and tape it over the receiving eye on the television. Have students write predictions on the Data Collection Sheet as to what will happen when a student tries to change the channel again. Elicit responses. **NOTE:** Aluminum is a very light weight, non-magnetic metal.The signal sent out from the remote control device is reflected by this metal.
6. Have a student try to change channels. Discuss what has happened. Ask the two students with the yarn if they can show the path the signal took this time. Lead them to stretch the yarn from the remote to the receiving eye and back out again showing the signal did not get through but was reflected instead. Write on the Data Collection

Sheet their observations of what has happened. Ask for volunteers to read to the class. Discuss the observations. Repeat the activity as many times as necessary. Collect Data Collection Sheets for assessment.

Extensions

1. Have students choose other materials to try to block the signal from changing the channel. Wax paper, notebook paper, cardboard, wood, rubber, etc. Make observations and predict what will happen.
2. Have the students use remote-controlled cars or walkie-talkies to show the presence of radio waves. Experiment with the different variables such as the distance the waves travel. How far away can the car be controlled? How far away can you hear another person?
3. Have students try pointing the remote control at different angles from the television. Does the control need to be pointed at the television? What happens when it is pointed in another direction?

Data Collection Sheet

Name _____

Group Names _____

Date _____

List observations of television	List observations of remote control

Predictions

Predictions for aluminum foil	What have you learned?



Activity: "Hello Over There"

Objectives

- Demonstrate with light beams how Amateur Radio satellite and repeaters send and receive signals
- Problem solve how a beam of light can be directed around a barrier

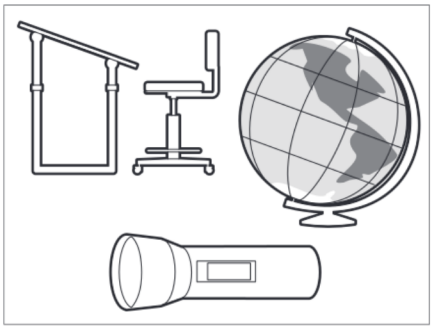
Activity Overview

This activity will allow students to simulate radio waves being transmitted and received using repeaters. Earth will be observed so students will understand why this method of communication is needed. In teams of four, students will problem solve to send a beam of light from one side of a barrier to the other. They will learn the path that light follows and how it reacts when a smooth, shiny surface (mirror) is placed in its path. Amateur Radio vocabulary will be introduced. Students will complete a Data Collection Sheet detailing methods used to solve a problem. Older students will predict where the light waves will be positioned on the other side of the barrier.

Materials

For each team of 4:

- 1 flashlight
- 1 mirror
- 1 chair or desk to act as barrier
- 1 piece of white paper
- Globe or map of Earth
- Data Collection Sheet



Science Standards

- Science as Inquiry
- Science and Technology
- Abilities of Technological Design

Technology Standards

- Technological Knowledge
  - Technological Concepts and Principles
- Technological Processes
  - Utilizing and Managing Technological Systems
- Technological Contexts
  - Informational Technology

Mathematics Standards

- Problem Solving
- Communication
- Geometric and Spatial Relations

Timeframe: 30–45 minutes

Background Information

When looking at a relief map of the Earth, one cannot help but notice that Earth is not a flat plain. There are many valleys and mountain ranges. When standing on an ocean shoreline, Earth appears flat. But we know that Earth is round. Pictures sent from satellites and orbiting spacecraft have allowed us to see our round Earth. Since radio waves travel in a straight line, how then can we send a signal to the other side of a barrier and beyond? Some radio signals, called **direct waves,** travel in a straight direction or line-of-sight. These signals cannot bend or "jump" over a barrier such as a hill or mountain range. They are also unable to curve around Earth. The signal from a radio on one side of the hill is transmitted to the other side by a repeater positioned on the top of the barrier. A **repeater** receives a signal on one frequency and simultaneously sends, or re-transmits (repeats) it on another frequency to a radio on the other side of the barrier thereby extending the range of the re-transmitted signals. The frequency it receives on is the **input frequency,** and the frequency it transmits on is the **output frequency.** Often located atop a tall building or high mountain, VHF and UHF repeaters greatly extend the operating range of Amateur Radio operators using mobile and hand-held transceivers. When a transmitter and receiver are combined into one box, it becomes a transceiver and can send and receive signals. If a repeater serves an area, it's not necessary for everyone to live on a hilltop. But you have to be able to hear the repeater's transmitter and reach the repeater's receiver with your transmitted signal.

Let's Begin

1. Share background information with students. Show globe or relief map of Earth. Have students write or draw their observations of Earth on the Data Sheet. Discuss these observations orally.
2. Gather students together around a barrier (chair, desk, etc.) Explain to students that the barrier represents a very tall hill or mountain range.
3. Show flashlight, mirror, and piece of paper. Discuss the properties of each, how they are used in our daily lives, and any prior knowledge students may have about light beams and how they travel. The flashlight beam represents radio waves, the mirror represents the repeater on top of a hill, and the piece of paper represents the radio on the other side.

HINT: Cover the flashlight with a piece of paper that has a small, vertical slit cut in the middle. This will create a narrower light beam.

Discuss vocabulary words and have students write definitions to those words on the Data Collection Sheet.

4. Tell students they will work in teams of four. The problem they must solve is **to devise a way to send a beam of light to the other side of the barrier going over the top of the barrier.** The light must travel from the flashlight held touching the floor on one side of the barrier to the piece of paper placed on the floor on the other side of the barrier. Remind them that they must go over the barrier. They will need to document the steps they take in the Data Collection Sheet. After a group discussion, make sure students understand the task. Give ample time for students to work in their groups to write the problem to be solved, discuss and predict what they think will

happen, solve the problem, and write down the information on the Data Collection Sheet. Have each group share their procedure with the class. Allow the class to ask questions and make suggestions.

5. As a follow up to the initial activity, each group can take what they have learned from watching the other groups and the suggestions they have been given and improve their procedure.

For Younger Students

For younger students, the teacher might show the globe or map and discuss them. Make a class list of the students' observations. Show them the materials. Let them shine the flashlight and observe how the light travels. Position one student on the floor holding the flashlight, another standing at the end of the barrier holding the mirror pointing toward the ground high above the student's head as if it were a repeater on a hill, and a third student sitting on the other side of the barrier holding the piece of white paper to simulate receiving the signal. Guide the students to discover that if they shine the light onto the mirror, it will reflect over the barrier and onto the other side.

Help the student holding the paper to position himself or herself to where the light will shine on the paper. Allow all students to take part while the group helps direct what is happening.

Extensions

1. Have students experiment with different surfaces other than a mirror, such as aluminum foil, smooth, wrinkled, pleated. What happens to the beam of light on each of these surfaces? Why does this occur?
2. Have students experiment with variables. Keep the position of the flashlight and the mirror constant. Change the direction of the mirror. Note the changes in angles in which the light strikes the mirror. Predict where the light will strike. Move the paper to that position. Turn on the light. Were students correct? Why?
3. Have older students predict where they think the light beam will fall and place a piece of paper on the floor where they think the beam of light will hit. What reasons can they give for their prediction?
4. Discuss the angle of incidence and the angle of reflection. Have students measure angles of the light as they approach the mirror and as they leave the mirror. Use a laser beam if possible for a finer line. Have students arrange mirrors on a table top in a circle, and send a beam of light from one mirror to another. Use as many as 10 mirrors. Students should problem solve to come to the conclusion that the entrance and exit angles are the same. (Reference: *Conceptual Physics*, Seventh Edition, Paul G. Hewitt, ISBN 0-673-52185-0)
5. Research in the library and on the Internet to find out more about radio waves and how they act and react in different situation.

Data Collection Sheet

Name _____

Group Names _____

Date _____

Observations of Earth	Problem to Solve

Repeater _____

_____

Input Frequency _____

_____

Output Frequency _____

_____

Vocabulary

Data Collection Sheet

What Materials Did You Use? _____

_____

What Did You Do? _____

_____

_____

What Did You Observe? _____

_____

_____

What Did You Learn? _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Activity: Say It With Space Talk

Objectives

- State oral directions clearly and correctly
- Construct a structure using oral directions

Activity Overview

Students will work in pairs to discover the importance of correct communication. They will construct a simulated microphone and learn how to use it correctly. They will work as a NASA astronaut and the Capsule Communicator (CAPCOM) to explain how to correctly build a structure with pattern blocks. The microphone will be used correctly each time they speak. The class will discuss and assess the importance of correct communication as it pertains to space travel.

Materials (For each pair of students)



- Pattern blocks
- 1 manila folder (or hard bound book)
- 2 popsicle sticks or tongue depressors, or two cardboard centers from paper towel rolls
- Aluminum foil pieces
- Books or short stories about space (1 for each group)
- Optional: 2.5 cm styrofoam ball for top of microphone
- Data Collection Sheet

Science Standards

- Science as Inquiry
- Science and Technology
- Science as a Human Endeavor

Technology Standards

- Technological Knowledge
  - Linkages
- Technological Processes
  - Utilizing and Managing Technological Systems
- Technological Contexts
  - Informational Technology

Mathematics Standards

- Problem Solving
- Communication
- Geometric and Spatial Sense
- Patterns and Relationships

Timeframe: 30–45 minutes

Background Information

Communication is an important, vital, and necessary part of all spaceflights. The members of each Shuttle and International Space Station crew must talk with each other and with workers on the ground to carry out the many functions needed to fly the spacecraft and rendezvous with other objects in space. Mission Control must keep in constant contact with other personnel at sites around the world to monitor the progress of the spacecraft as it orbits Earth. Teachers and students in schools communicate with each other to learn more about space travel and how it is changing our lives each and every day.

The astronauts use a radio on board the Shuttle on frequencies used by Amateur (or "ham") Radio operators to communicate directly with large groups of students. For all operations, Earth stations listen to the input or receiving frequency and transmit only when the Shuttle is in range of the ground station and the astronauts are using the radio. Students listen for any instructions from the astronauts as to the output or transmitting frequency before transmitting to avoid interfering with other radio users. They practice using a microphone correctly just as the astronauts must do during their training for the mission.

Let's Begin

1. When students, astronauts, and ham radio operators use the Amateur Radio to talk with people next door, all over the world, or orbiting in space, they use a microphone. Explain to students that they are going to make a "pretend" microphone that will be used when practicing how to talk correctly over the radio. Give each student one popsicle stick, tongue depressor, or cardboard center from a paper roll, and a large piece of aluminum foil. Demonstrate how to wrap the foil around the top of the stick in a ball so it looks like the top of a microphone. A 2.5 cm styrofoam ball may be placed on top of the stick and covered with one layer of foil instead.
2. Model for students how to hold the microphone in one hand, not too close to the mouth. Say the names of the nine planets to demonstrate how to speak slowly and distinctly. Be sure to tell the students each time they have finished speaking that they are to say "Over." This is the word used by Amateur Radio operators to signify they have finished their transmission and others may now talk. Allow time for students to make a microphone and to practice speaking with their teammate. Circulate among the students and make sure they are holding the microphone correctly and speaking correctly. Have one student say the nine planets, stopping wherever they wish and saying "Over." The teammate must begin speaking into the microphone saying the next planet, and when finished, saying, "over."

   Example: "Mercury, over." "Venus, Earth, Mars, over." "Jupiter, Saturn, over."

   After the initial practice time, tell students they are going to read to their teammates. Each student in the team will read a paragraph or page from a book or story while holding the microphone correctly. Each time they have finished reading, they must say "over" before the next person can begin. Teammates are not to begin until they hear the word "over."

   When the class has had sufficient practice time, have them put down the microphones and show them the pattern blocks. Ask students to tell you what they know about each shape. Have students draw each

shape or write the names of each block on the Data Collection Sheet as you display them to the class. (Square, triangle, two parallelograms, hexagon, trapezoid)

HINT: For older students, use one block of each shape. For younger students, pick only two or three.

Explain to students that when astronauts are in space, they talk to the ground through a Capsule Communicator (CAPCOM). This is another astronaut located in the Mission Control Center (MCC) at Johnson Space Center (JSC) in Houston. All information and directions are relayed to the astronauts on orbit through the CAPCOM.

3. Tell students that one member of each team will be taking the role of astronaut and the other member will be CAPCOM. Show students the blocks you are going to use and ask them to get those blocks from their pile.
4. Model the activity by taking the role of CAPCOM and having all students become astronauts. Build a structure behind a manila folder so students cannot see the structure. Make sure students understand spatial perspective and orientation of left and right.

After you have built a structure, use your microphone to give detailed instructions so the students will be able to replicate what you have built. Remember to say "over" after each set of instructions.

5. After the students have completed building, compare the structures. Discuss which words you used that were helpful to them in building. Have students make a list of these words on the Data Collection Sheet.
6. Students will now be given time to build with their partners. They will build many times, switching roles each time, and using the microphone each time. Circulate among the class to monitor and assist.
7. When building has been accomplished many times, have students write directions on the Data Collection Sheets. These sheets can be taken up for assessments. They can also be used as written instructions for other students to build structures.
8. Discuss the importance communication played in building the structure. How would this be important in spaceflight? How will this be important in building the International Space Station?

Extensions

1. Have students use two-way radios. Each student should be in a different room or location. Build the structures by communicating the directions correctly over the radio.
2. Have students write their own script for a play describing a problem on the Shuttle or International Space Station. The problem would necessitate the building or repairing of some piece of equipment used by astronauts during a mission. Students could perform the play. If video equipment is available, students could set up their own production as a news cast and show the production to other classes.
3. Have students use the microphones each time they talk for an entire day.

Data Collection Sheet

Name _____

Group Names _____

Date _____

Names/Shapes of Pattern Blocks

Directions for building my structure:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____

Communications are important in spaceflight because: _____

_____

_____

_____

What have you learned? _____

_____

_____

Appendix A

How Can I, a Teacher, Get Started in SAREX?

Schools wanting a scheduled SAREX radio contact with the astronauts are required to submit a proposal and a SAREX school application to ARRL, 225 Main St., Newington CT 06111.

While only a few schools get scheduled radio contacts per mission, all schools can participate by eavesdropping, or by trying to make a random contact with the astronauts. Teachers can use lessons in this SAREX Guide to accompany their SAREX radio activities. Imagine listening in on the astronauts from your classroom! If you are a school teacher, but are unfamiliar with ham radio, you can still take part in SAREX. Contact ARRL to get a list of your local Amateur Radio clubs to assist you.

How Do I Apply for a Scheduled School Radio Contact?

If your school is interested in SAREX, you must complete a SAREX school application and write an educational proposal. ARRL collects these for the SAREX Working Group who makes the final selection with the astronauts. All grade levels and type of schools (rural, suburban and particularly urban) are encouraged to apply. For a SAREX school application send a business-sized self-addressed stamped envelope to ARRL, or e-mail your request for an electronic version to: *sarex@arrl.org*

A proposal must accompany all completed applications. The SAREX Working Group and NASA want to know:

(1) How will you:

  (a) integrate this activity into the school curriculum, and

  (b) involve as many grade levels as you can, participating through essay contests, poster drawing, letter writing, etc.?

(2) Do you have an experienced group of hams to assist in setting up all necessary Amateur Radio equipment and antennas?

(3) How will you get as much media coverage as possible?

How Will I Know If My School Is Selected For a Contact?

Schools that have been selected for SAREX scheduled contacts are called by a SAREX coordinator.

NASA requires selections to be made about six months prior to launch. If a school is not chosen, its application is recycled for future missions. Note: Schools typically wait one year or longer.

Appendix B

Space Amateur Radio Experiment (SAREX) Application Form

This application is for: [ ] SAREX [ ] MirEX [ ] No Preference

School Information

1. School name: _____
2. Coordinating teacher: _____
3. School address: _____

   _____
4. School city: _____
5. School state: _____
6. School ZIP: _____
7. School country: _____
8. School phone number: _____
9. School FAX number: _____
10. Has the school previously been selected? (YES or NO): _____
11. If YES, which mission? STS: _____

Radio Contact Coordinator
(To be filled out by an Amateur Radio operator)

12. Name: _____
13. Call sign: _____
14. Address: _____
15. City: _____
16. State: _____
17. ZIP: _____
18. Country: _____
19. Work phone number: _____
20. Home phone number: _____
21. FAX number: _____

22. E-mail address: _____

Data About Site of Radio Contact

23. Site of radio contact: _____
24. Radio coordinator during contact: _____
25. Call sign: _____
26. Site phone number: _____
27. Site FAX number: _____
28. Latitude [Use decimal format] (South is negative): _____
29. Longitude [Use decimal format] (West is negative): _____
30. Elevation [Use meters above mean sea-level]: _____
31. Time zone: _____
32. Does your area go to daylight time? (YES or NO): _____
33. Language to be used during contact: _____
34. Are weekends, holidays or nights a problem for your contact? (YES/NO) _____

Assisting Local Amateur Radio Club
(To be filled out by the Amateur Radio club)

35. Name of amateur radio club: _____
36. Club contact person: _____
37. Contact person's call sign: _____
38. Is this person experienced with satellite operations? (YES or NO): ____

Space Amateur Radio Experiment (SAREX) Application Form (continued)

Station and Equipment Data
(To be used during SAREX Amateur Radio contact)

39. Transceiver to be used (Make/Model): _____

40. Does it have memories? (YES or NO): _____

41. Output power (Watts): _____

42. Frequency range (MHz): _____

43. Station equipped with an RX preamplifier? (YES or NO): _____

44. If YES, manufacturer and model of preamplifier: _____

_____

45. Station equipped with a TX amplifier? (YES or NO): _____

46. If YES, maximum output power of TX amplifier (Watts): _____

47. Is the radio capable of a non-standard split? (YES or NO): _____

48. Antenna Type (VERTICAL, SATELLITE (AZ/EL?), OTHER) [specify]:

_____

49. Antenna gain (dbd or dbi): _____

50. Number of elements: _____

51. Polarization (HORIZONTAL, CIRCULAR, or VERTICAL) _____

52. Antenna equipped with a rotator?
(NONE, AZIMUTH ONLY, or AZ/EL): _____

53. Satellite tracking program available? (YES or NO): _____

54. If YES, name of tracking program: _____

55. Do you have automatic antenna control? (YES or NO): _____

56. VHF packet capability? (YES or NO): _____

57. VHF SSTV capability? (YES or NO): _____

58. Please note any antenna obscuration data: _____

_____

_____

_____

NASA Resources for Educators

Central Operation of Resources for Educators

NASA's Central Operation of Resources for Educators (CORE) was established for the national and international distribution of NASA-produced educational materials in audiovisual format. Educators can obtain a catalog and an order form by one of the following methods:

- NASA CORE
  Lorain County Joint Vocational School
  15181 Route 58 South
  Oberlin, OH 44074
- Phone (440) 774-1051, Ext. 249 or 293
- Fax (440) 774-2144
- E-mail *nasaco@leeca.esu.k12.oh.us*
- Home Page: *http://spacelink.nasa.gov/CORE*

Educator Resource Center Network

To make additional information available to the education community, the NASA Education Division has created the NASA Educator Resource Center (ERC) network. ERCs contain a wealth of information for educators: publications, reference books, slide sets, audio cassettes, videotapes, telelecture programs, computer programs, lesson plans, and teacher guides with activities. Educators may preview, copy, or receive NASA materials at these sites. Because each NASA Field Center has its own areas of expertise, no two ERCs are exactly alike. Phone calls are welcome if you are unable to visit the ERC that serves your geographic area. A list of the centers and the regions they serve includes:

AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY
NASA Educator Resource Center
Mail Stop 253-2
NASA Ames Research Center
Moffett Field, CA 94035-1000
Phone: (650) 604-3574

CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT
NASA Educator Resource Laboratory
Mail Code 130.3
NASA Goddard Space Flight Center
Greenbelt, MD 20771-0001
Phone: (301) 286-8570

CO, KS, NE, NM, ND, OK, SD, TX
JSC Educator Resource Center
Space Center Houston
NASA Johnson Space Center
1601 NASA Road One
Houston, TX 77058-3696
Phone: (281) 483-8696

FL, GA, PR, VI
NASA Educator Resource Laboratory
Mail Code ERL
NASA Kennedy Space Center
Kennedy Space Center, FL 32899-0001
Phone: (407) 867-4090

KY, NC, SC, VA, WV
Virginia Air and Space Museum
NASA Educator Resource Center for
NASA Langley Research Center
600 Settler's Landing Road
Hampton, VA 23669-4033
Phone: (757) 727-0900 x 757

IL, IN, MI, MN, OH, WI
NASA Educator Resource Center
Mail Stop 8-1
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135-3191
Phone: (216) 433-2017

AL, AR, IA, LA, MO,TN
U.S. Space and Rocket Center
NASA Educator Resource Center for
NASA Marshall Space Flight Center
P.O. Box 070015
Huntsville, AL 35807-7015
Phone: (205) 544-5812

MS
NASA Educator Resource Center
Building 1200
NASA John C. Stennis Space Center
Stennis Space Center, MS 39529-6000
Phone: (228) 688-3338

NASA Educator Resource Center
JPL Educational Outreach
Mail Stop CS-530
NASA Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109-8099
Phone: (818) 354-6916

CA cities near the center
NASA Educator Resource Center for
NASA Dryden Flight Research Center
45108 N. 3rd Street East
Lancaster, CA 93535
Phone: (805) 948-7347

VA and MD's Eastern Shores
NASA Educator Resource Lab
Education Complex - Visitor Center
Building J-1
NASA Wallops Flight Facility
Wallops Island, VA 23337-5099
Phone: (757) 824-2297/2298

Regional Educator Resource Centers

Regional Educator Resource Centers (RERCs) offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as RERCs in many states. A complete list of RERCs is available through CORE, or electronically via NASA Spacelink at *http://spacelink.nasa.gov*

NASA On-line Resources for Educators

NASA On-line Resources for Educators provide current educational information and instructional resource materials to teachers, faculty, and students. A wide range of information is available, including science, mathematics, engineering, and technology education lesson plans, historical information related to the aeronautics and space program, current status reports on NASA projects, news releases, information on NASA educational programs, useful software, and graphics files. Educators and students can also use NASA resources as learning tools to explore the Internet, accessing information about educational grants, interacting with other schools which are already online, participating in on-line interactive projects, and communicating with NASA scientists, engineers, and other team members to experience the excitement of real NASA projects.

Access these resources through the NASA Education Home Page:
http://www.hq.nasa.gov/education

NASA Television

NASA Television (NTV) is the Agency's distribution system for live and taped programs. It offers the public a front-row seat for launches and missions, as well as informational and educational programming, historical documentaries, and updates on the latest developments in aeronautics and space science. NTV is transmitted on the GE-2 satellite, Transponder 9C at 85 degrees West longitude, vertical polarization, with a frequency of 3880 megahertz, and audio of 6.8 megahertz.

Apart from live mission coverage, regular NASA Television programming includes a Video File from noon to 1:00 pm, a NASA Gallery File from 1:00 to 2:00 pm, and an Education File from 2:00 to 3:00 pm (all times Eastern). This sequence is repeated at 3:00 pm, 6:00 pm, and 9:00 pm, Monday through Friday. The NTV Education File features programming for teachers and students on science, mathematics, and technology. NASA Television programming may be videotaped for later use.

For more information on NASA Television, contact:

NASA Headquarters, Code P-2, NASA TV, Washington, DC 20546-0001
Phone: (202) 358-3572

NTV Home Page: *http://www.hq.nasa.gov/ntv.html*

"How to Access NASA's Education Materials and Services" EP-1996-11-345-HQ

This brochure serves as a guide to accessing a variety of NASA materials and services for educators. Copies are available through the ERC network, or electronically via NASA Spacelink. NASA Spacelink can be accessed at the following address: *http://spacelink.nasa.gov*

Amateur Radio in Space
A Teacher's Guide with Activities in Science, Mathematics, and Technology
EDUCATOR REPLY CARD

To achieve America's goals in Educational Excellence, it is NASA's mission to develop supplementary instructional materials and curricula in science, mathematics, geography, and technology. NASA seeks to involve the educational community in the development and improvement of these materials. Your evaluation and suggestions are vital to continually improving NASA educational materials.

Please take a moment to respond to the statements and questions below. You can submit your response through the Internet or by mail. Send your reply to the following Internet address:

http://ednet.gsfc.nasa.gov/edcats/teacher_guide

You will then be asked to enter your data at the appropriate prompt.

Otherwise, please return the reply card by mail. Thank you.

1. With what grades did you use the educator guide?
   Number of Teachers/Faculty:
   _____ K-4 _____ 5-8 _____ 9-12 _____ Community College
   College/University - _____ Undergraduate _____ Graduate

   Number of Students:
   _____ K-4 _____ 5-8 _____ 9-12 _____ Community College
   College/University - _____ Undergraduate _____ Graduate

   Number of Others:
   _____ Administrators/Staff _____ Parents _____ Professional Groups
   _____ General Public _____ Civic Groups _____ Other

2. What is your home 5- or 9-digit zip code? __ __ __ __ __ — __ __ __ __

3. This is a valuable educator guide?
   ❑ Strongly Agree ❑ Agree ❑ Neutral ❑ Disagree ❑ Strongly Disagree

4. I expect to apply what I learned in this educator guide.
   ❑ Strongly Agree ❑ Agree ❑ Neutral ❑ Disagree ❑ Strongly Disagree

Fold along line and tape closed.

5. What kind of recommendation would you make to someone who asks about this educator guide?
   ❑ Excellent ❑ Good ❑ Average ❑ Poor ❑ Very Poor

6. How did you use this educator guide?
   ❑ Background Information
   ❑ Critical Thinking Tasks
   ❑ Demonstrate NASA Materials
   ❑ Demonstration
   ❑ Group Discussions
   ❑ Hands-On Activities
   ❑ Integration Into Existing Curricula
   ❑ Interdisciplinary Activity
   ❑ Lecture
   ❑ Science and Mathematics Standards Integration
   ❑ Team Activities
   ❑ Other: Please specify: _____

7. Where did you learn about this educator guide?
   ❑ NASA Educator Resource Center
   ❑ NASA Central Operation of Resources for Educators (CORE)
   ❑ Institution/School System
   ❑ Fellow Educator
   ❑ Workshop/Conference
   ❑ Other: Please specify: _____

8. What features of this educator guide did you find particularly helpful?
   _____
   _____

9. How can we make this educator guide more effective for you?
   _____
   _____

10. Additional comments:
    _____
    _____

Today's Date: _____

EG-1998-03-114-HQ

Please Place
Stamp Here
Post Office
Will Not Deliver
Without Proper
Postage

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
EDUCATION DIVISION
MAIL CODE FE
WASHINGTON DC 20546–0001

Fold along line and tape closed.