Elementary School Aerospace Activities

A Resource for Teachers

NASA

National
Aeronautics and
Space
Administration

Elementary School Aerospace Activities

A Resource for Teachers

A curriculum project prepared at The University of Nebraska—Lincoln

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Contents

Introduction

Elementary School Aerospace Activities provides for the elementary teacher a much needed manual for guiding his thinking and planning when introducing aerospace developments into his classroom programs. Since the publication in the early and middle 1960's of *Teaching to Meet the Challenges of the Space Age,* developed by the State University of New York's College at Plattsburgh; *Introducing Children to Space: The Lincoln Plan,* developed by the University of Nebraska and the Lincoln Public Schools; and *The Planetarium: An Elementary School Teachers Resource,* by the University of Bridgeport, NASA has published little to guide the elementary teacher.

These earlier volumes reached over 200,000 elementary school teachers. From recent expressions of interest, it is believed that teachers will also welcome this volume. For those who are not familiar with the earlier publications, we note that we speak of these teacher-oriented publications such as *Elementary School Aerospace Activities* as curriculum supplements. We use the term "curriculum supplement" advisedly, as such books are neither textbooks nor courses of study, but rather compilations of suggestions for teachers' classroom activities. The books are roughly organized into what might be termed resource units, each unit centering around one of the major phases of America's activity in aerospace. The teacher may draw a word or a phrase, a research topic for an interested boy or girl, a class activity, a unit, or a series of units. The text may also prove useful to supervisors, curriculum workers, and textbook writers.

This University of Nebraska project is the product of educators, each of whom is regarded as a specialist in the curriculum and each of whom has been associated with aerospace education as a leader for 10 to 15 years: Dr. Allman in Houston and Dr. Kopp, Dr. Williams, and Mrs. Rademacher in Nebraska. Classroom tryout was given the materials by 7 teachers of the Roberts Elementary School in Houston and 12 teachers of the Clare McPhee Laboratory School in Lincoln. NASA appreciates the dedication of the University of Nebraska's team that produced this volume and the services of the Houston and Lincoln teachers who field-tested its materials.

NASA's Technical Monitor for this project was Ms. Muriel M. Thorne, Educational Programs Officer. Coordinating the project was Dr. Frederick B. Tuttle, Director of Educational Programs, Office of Public Affairs, NASA, assisted by Mr. Myrl H. Ahrendt, Instructional Materials Officer, Educational Programs Division, until his retirement in June 1974, and Mr. Robert S. Tiemann, Educational Programs Officer.

National Aeronautics and Space Administration — April 1977
Washington, D.C.

Foreword

As far back as 1942, one of the leaders in aerospace education, William A. Wheatley, insisted that small children, as well as their older brothers and sisters, were entitled to identify with man's explorations in air. Dozens of universities and school systems as well as state and national educational organizations helped Mr. Wheatley achieve his dream of lifting children in their thoughts and habits from Earth into air. When Mr. Wheatley, at the age of 70, joined the staff of United Airlines, he established the Division of School and College Services. This Division established the first summer scholarships for teachers at the University of Nebraska and thus provided the manpower for preparing the first aviation leaflets called "Exploring Aviation."

Of course, the beginning of the aerospace age can be identified with the famous flight of the Wright brothers at Kitty Hawk on December 17, 1903. The National Air and Space Museum of the Smithsonian Institution features this famous airplane that first lifted man, under power, from his Earth environment into air. Without doubt, one of the most complete aerospace education laboratories in the world is the Air and Space Museum of the Smithsonian Institution, Washington, D.C. Fortunately, the aerospace laboratories of NASA are spread across the land. Children may hear most about the NASA Lyndon B. Johnson Space Center at Houston, Texas; the unmanned spacecraft center, the NASA Goddard Space Flight Center, Greenbelt, Maryland; or the launch center, the NASA John F. Kennedy Space Center in Florida. Children and teachers alike will want to learn about these centers and their companion NASA aerospace laboratories which hold the future of America's flights through air and space.

The Educational Programs Division of NASA is a great source of instructional materials for teaching children about air and space. Still important, but in scarce supply, is the publication entitled *Introducing Children to Space* that was prepared for this federal agency by University of Nebraska and Lincoln Public School teachers. This new book, *Elementary School Aerospace Activities,* is for teachers who will serve in classrooms during the late 1970's and 1980's. Its content suggests a variety of ways in which elementary school pupils may be exposed to the greatest adventure of our time, namely, exploring air and space.

It would appear that the whole world wants to be free to fly through air and space. This desire has determined the course of today's education and often today's industry. It is said that the aerospace industries are one of the nation's largest employers. Readers are invited to study this statement in relationship to the activities associated with the cities of Los Angeles, Seattle, St. Louis, and Wichita.

A number-one news item today is NASA's development of the Space Shuttle that can be used for hundreds of peaceful projects and, if necessary, help protect America in times of conflict. We urge children and teachers today to follow closely the development of this new spaceship and to go back and study the tremendous achievements of Americans in the past as they built their airplanes larger and larger, as they constructed an experimental airplane that broke the sound barrier, and as they carried forward the highly advanced space development programs known as Mercury, Gemini, Apollo, and Skylab. NASA has numerous films to supplement printed materials in telling the story of man's achievement of freedom from his planet Earth. Teachers need not be afraid of introducing children to the environments of air and space. All they need to do is to assume the role of explorer along with the children and make the great sky above, the schoolhouse of educational conquest.

Frank E. Sorenson
Professor of Education Emeritus
The University of Nebraska—Lincoln
Lincoln, Nebraska

Preface

Elementary School Aerospace Activities: A Resource for Teachers has been made possible as the result of the cooperation of the Educational Programs Division of NASA. Much of the development of this program has been centered in the Department of Elementary Education, The University of Nebraska—Lincoln and the Clare McPhee Laboratory School in Lincoln, Nebraska, which houses one of the nation's outstanding aerospace libraries for children. The materials for the publication have been field-tested not only in the Lincoln Public Schools, but also extensively in the Houston Public Schools, Houston, Texas.

The instructional plan of this handbook follows an outline which presents an approximate chronological development of the story of man and flight, with emphasis on flight into space. Included also are projections for future exploration of space and utilization of space flight capabilities. A complete section outline is placed at the beginning of each section. This is followed by a segmented presentation of the same outline along with activities suggested to correlate with the concept in that portion of the outline. Each activity is marked with suggestions for appropriate age-level use: *P*(5-7); *I*(8-9); and *U*(10-11). These designations are for the convenience of teachers regardless of grouping patterns being utilized in their schools. Suggestions for research topics are also listed. These are intended primarily for the intermediate and upper age levels. Activities are illustrated with diagrams to increase clarity of directions given, and selected pictures show children involved in some of the suggested activities. The metric system of measurement is used throughout; however, the U.S. Customary equivalent is included for convenience of those teachers not familiar with the metric system.

A bibliography of selected printed materials is included at the end of each section. These, too, have suggested age-level designations as a guideline for teachers, whatever the organizational pattern in their schools. "T" designates material primarily for teacher use. A complete list of these printed and audiovisual materials is placed at the end of the handbook. In an attempt to provide a listing of more recent instructional materials, no materials dated prior to 1967 were included unless they were especially useful for the development of a particular concept. In addition to this bibliography, there is a listing of sources which the teacher may contact for free and inexpensive materials as well as additional bibliographic materials. Addresses of publishers, producers, and distributors are included for the teacher's convenience. A glossary of those aerospace terms which cannot be found easily in an ordinary desk dictionary is also included at the end of the handbook.

The production of this publication has been achieved through the efforts of Dr. Audean Allman, Assistant Professor, Texas Southern University, Houston, Texas; Mrs. Jean Rademacher, Demonstration Teacher, The Clare McPhee School, Lincoln, Nebraska; and Dr. Mary Heard Williams, Associate Professor, Department of Elementary Education, The University of Nebraska, Lincoln, Nebraska. These three master teachers have blended hundreds of ideas into a tested and viable publication which can well help motivate some future astronaut to master uncharted areas of the universe. Special recognition should also be given to Mr. James C. Norman, architectural student at The University of Nebraska—Lincoln for the sketches in the publication. To all these persons, a special thanks for their cooperation.

O. W. Kopp
Publication Project Chairman
Chairman, Department of
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UNIT I

Earth Characteristics That Affect Flight

Outline

The characteristics of the Earth's atmosphere and its magnetosphere must be considered in planning for flight in the atmosphere or in space.

A. Knowledge about the characteristics of each layer of Earth's atmosphere has increased as a result of data collected by NASA's sounding rockets.

1. Weather phenomena that occur only in the troposphere may determine flight paths and timing.

2. Extremes in temperature at different levels of the atmosphere make it necessary to provide protection against both very cold and very hot temperatures.

3. Decreasing density of the air as altitude increases makes a pressurized cabin and a supply of oxygen necessary for survival at high altitudes.

4. The jet stream adds to the speed of aircraft flying with it.

5. When a manned flying craft rises to an altitude above the protective layer of ozone found in the upper stratosphere, its crew must be protected from solar radiation.

6. The ionosphere reflects radio waves back to Earth, making radio communication possible between planes in flight and between planes and ground stations.

7. Atmospheric gases and dust particles make it impossible for one to get a clear view of objects in the universe without rising above the atmosphere.

B. The magnetosphere was discovered as a result of data collected by satellites.

1. The magnetic lines of force around the Earth trap solar and cosmic particles, thus protecting life on Earth from excessive radiation.

2. The Van Allen belts make it necessary either to direct manned flights through areas of lesser radiation over the magnetic poles or to provide greater protection from radiation.

3. During periods of greater solar activity, the solar wind increases in intensity and causes magnetic storms in the Earth's magnetosphere resulting in disturbances in radio communication.

Outline

The characteristics of the Earth's atmosphere and its magnetosphere must be considered in planning for flight in the atmosphere or in space.

A. Atmosphere

Knowledge about the characteristics of each layer of Earth's atmosphere has increased as a result of data collected by NASA's sounding rockets.

1. Weather

Weather phenomena that occur only in the troposphere (0-8 or 16 kilometers; 0-5 or 10 miles altitude) may determine flight paths and timing.

Activities

**I-U.* Prepare a chart or bulletin board depicting various layers of the atmosphere. Include information about the altitudes to which various aircraft, balloons, satellites, etc., have gone.

I-U. Make a bar graph showing the approximate heights of the layers of the atmosphere.

I-U. Combine colored water and cooking oil in a tall cylindrical container. Observe that, when not stirred constantly, the two liquids separate into layers because of differences in density (weight per unit of volume).

I-U. Demonstrate that differences in density permit layering of substances. Place a drop of mercury in the bottom of a test tube. Add a saturated salt solution dyed red with food coloring. Using a medicine dropper, carefully float a saturated copper sulfate solution on the salt solution. Next add some water, then castor oil or olive oil, then light machine oil. Compare to layering of Earth's atmosphere.

Research

Criteria that are used to subdivide the Earth's atmosphere into layers

Characteristics of each layer of the atmosphere

How the characteristics of each layer of the atmosphere affect air and space travel

An atmosphere research facility, NASA Wallops Flight Center, Wallops Island, Virginia

I-U. Bring weather maps from the newspaper and follow daily changes in weather patterns.

I-U. Visit the local weather service station.

I-U. Using weather maps, attempt to forecast the weather.

I-U. Keep a line-graph record of high and low temperatures, daily precipitation, percent cloud cover, etc., for a period of time.

P-I-U. Make weather instruments and collect weather data daily.

I-U. Write a story about a real or imaginary experience in a hurricane, tornado, or thunderstorm.

I-U. Make a collection of sayings about the weather. Is there any basis of truth in them?

P-I-U. Using white chalk on dark blue paper, draw pictures of different types of clouds.

*Suggested age level: P(5-7), I(8-9), U(10-11).

P-I-U. Using cotton on a blue background, make a bulletin board display of different kinds of clouds, showing elevations at which they usually form.

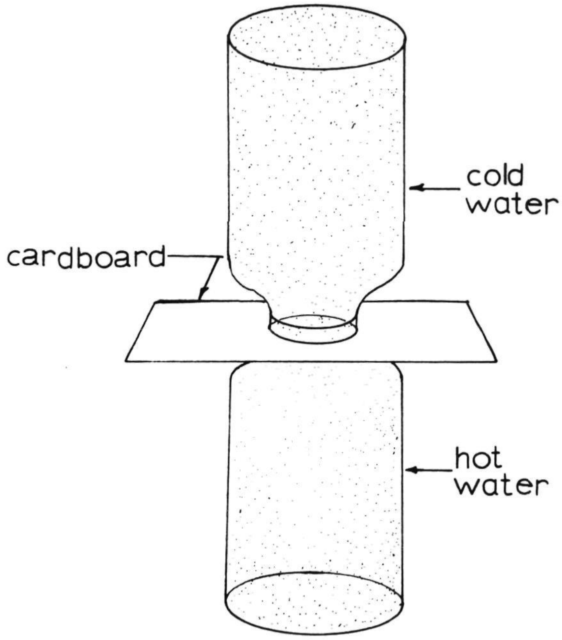
I-U. Place an open container of ammonia in one area of the classroom and observe how air movement and diffusion cause the odor to spread throughout the room.

P-I-U. Make pinwheels and use them to demonstrate air movement.

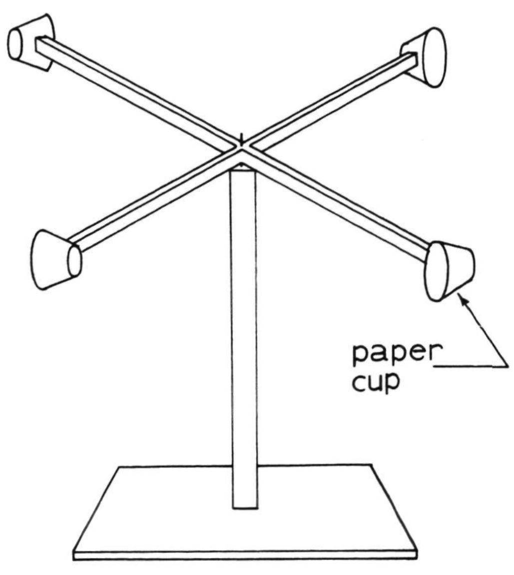
P-I-U. Burn a string in a dish and observe the direction the smoke travels when the dish is placed in different parts of the room.

P-I-U. Hold a smoking string (or cloth) over a source of heat, then over a cold surface. Observe the difference in the direction the smoke moves.

P-I-U. Fill one of two identical bottles with cold water and the other with hot water. Color the hot water with food coloring. Cover the container of cold water with a piece of cardboard. Holding the cardboard in place invert the container of cold water so that the top of the inverted cold water container rests on the top of the hot water container. Gently remove the cardboard and observe the rising hot water. Compare to convection currents of hot air rising in the atmosphere.



P-I-U. Make an anemometer. Fit two pieces of wood together to form an "X". Secure a paper cup to each end of each piece of wood. Mount to turn freely on a stand. Calibrate by counting the number of revolutions in a given time period.



I-U. Heat a lightly stoppered empty test tube until the expanding air forces the stopper out.

P-I-U. Put a balloon over the mouth of a bottle. Place bottle in a pan of water. Heat until the expanding air inflates the balloon.

P-I-U. Hold a metal tray of ice cubes over a container of boiling water. Observe the water droplets that form as the water vapor condenses on the bottom of the tray.

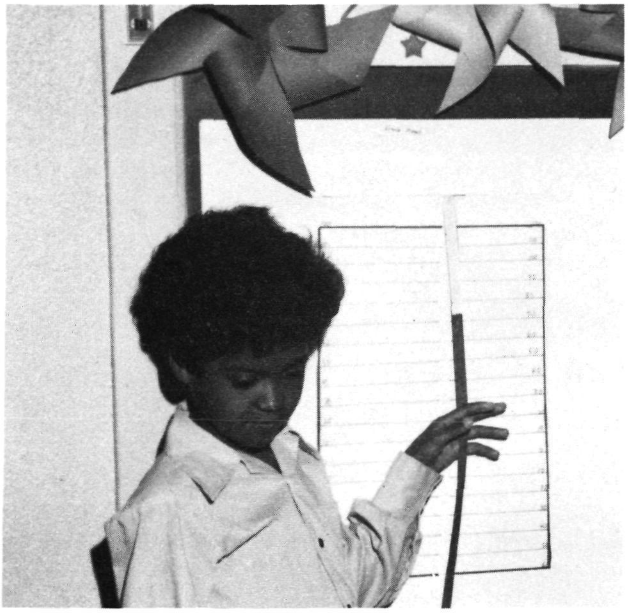
U. Find the dew point (the temperature at which water will condense from the air) by adding ice to a can half-filled with water. Stir constantly with a thermometer and observe the temperature at which moisture droplets begin to form on the outside of the can.

Research

What percent or fractional part of the time is there cloud cover in your local area?

2. Temperature

Extremes in temperature at different levels of the atmosphere make it necessary to provide protection against both very cold and very hot temperatures.



P-I. On a large piece of oak tag make lines and figures to simulate the scale on a thermometer. Cut a slit at the bottom and at the top of the scale (about -30°C and 45°C; about -20°F and 110°F). Sew a piece of red ribbon to a piece of white ribbon to make one long ribbon. Insert the ribbon in the slits on the oak tag "thermometer," red at the bottom, white at the top. Adjust the ribbon each day so that the red ribbon indicates the temperature.

P-I-U. Make a thermometer by placing colored water in a bottle fitted with a one-hole stopper which contains a length of glass tubing. Observe how changes in temperature cause water in the tube to rise and fall.

I-U. Place a sheet of asbestos next to a source of heat. Observe that the side next to the heat becomes quite hot, while the side away from the heat does not. Compare the protection offered by the asbestos' insulating qualities to the atmosphere's protection of the Earth from the Sun's heat.

U. If the outside temperature is 20°C at 2.5 kilometers (67°F at 8000 feet), what will it be at 8.5 kilometers (28,000 feet)? There is a drop of 6.6°C per kilometer (3 1/2°F per 1000 feet) approximately. Answer: -19.6°C; -3°F.

U. Compare Fahrenheit, Celsius, and Kelvin temperature scales. Convert temperatures from one temperature scale to another.

Research

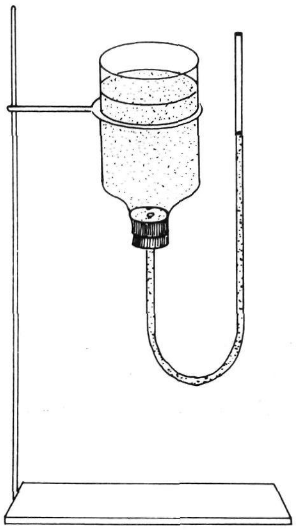
Origin of Celsius, Fahrenheit, and Kelvin scales

How much the temperature of the atmosphere varies from layer to layer

Cause of the variation in the temperature of the layers of the atmosphere

3. Density and pressure

Decreasing density of the air as altitude increases makes a pressurized cabin and a supply of oxygen necessary for survival at high altitudes.



P-I-U. Place the end of a medicine dropper in a pan of colored water. Squeeze the dropper and observe air leaving. Release and observe water replacing the lost air. Hold the dropper up in the air and observe that air pressure keeps the water in the tube.

P-I-U. Use a string to suspend a meter stick at its center. Adjust until the meter stick hangs level. Inflate two similar balloons to approximately the same size and attach to the ends of the meter stick, one at each end. Adjust until balloons hang at the same level. Allow air to escape from one balloon and observe that the balloon filled with air is now heavier than the empty balloon.

P-I-U. Weigh a football, basketball, or soccer ball before and after inflation. Observe the increase in weight when inflated. (An accurate scale is needed to measure the small change in weight.)

I-U. Determine the amount of pressure exerted by the total weight of a column of air resting upon a given surface at sea level. A column of air from sea level to the top of the atmosphere weighs approximately 1 kilogram per square centimeter (15 pounds per square inch) of surface it rests upon.

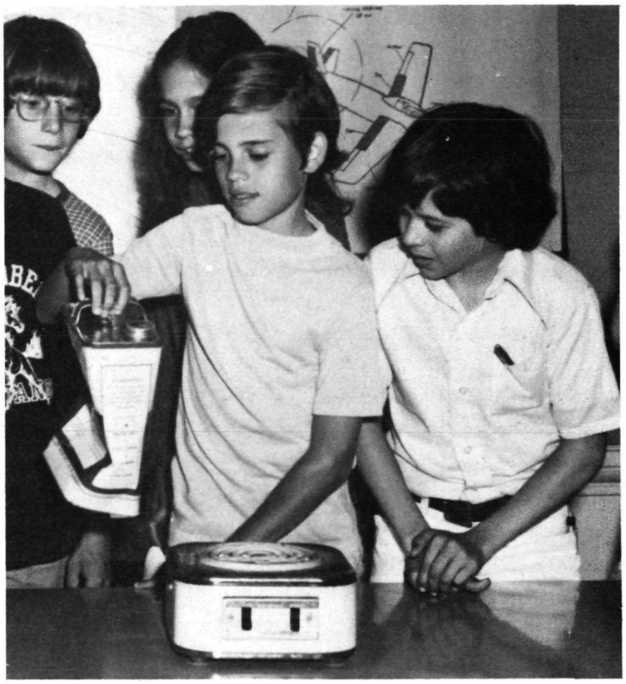
I-U. Calculate the amount of air pressure on someone's back. Measure from shoulder to shoulder and shoulder to hip. Determine the number of square centimeters (inches) of surface, and multiply by 1 kilogram (15 pounds) to determine the number of kilograms (pounds) of pressure.

I-U. Calculate the amount of air pressure on an aircraft wing at sea level and at various altitudes.

P-I-U. Place the end of a length of glass tubing into water. Cover the other end with your finger; raise the tube out of the water. Notice that air pressure keeps the water suspended in the tube.

P-I-U. Cover a glass tumbler full of water with a square of heavy paper. Turn it sidewise and upside down to show that air presses in all directions.

P-I-U. Try to drink water through a straw which is fitted tightly into a one-hole stopper which seals the water container airtight.



P-I-U. Pour water into a rectangular metal can to the depth of about 2 centimeters (1/2 inch). Heat the can until the water boils. Let steam escape for about 2 minutes. Remove from the heat source, stopper tightly, and wait for the can to cool. Observe that differences between inside air pressure and outside air pressure cause the can to collapse.

I-U. Air moves from a high pressure area to a low pressure area. Inflate a balloon fastened to one end of a piece of glass tubing. Place an empty balloon over the other end of the tubing. Observe that air pressure tends to equalize.

P-I-U. Prick an inflated balloon with a pin to illustrate that air will move from an area of greater pressure to an area of lesser pressure.

P-I-U. Discuss sensations felt as altitude changed when in the mountains or flying in a plane.

I-U. Pressure decreases as depth decreases. Punch three or four holes, one above the other, in the side of a large can. Fill with water and observe the differences in the distances the water spurts from the holes. Compare to decrease in air pressure as altitude increases (air depth decreases).

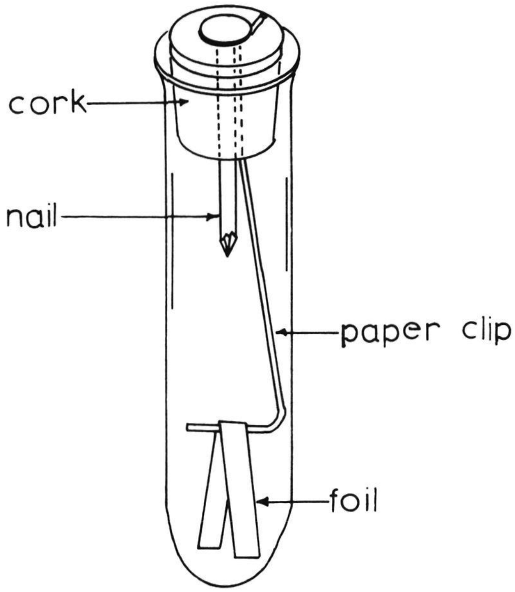
4. Jet Stream

The jet stream—a current of high-speed winds in the upper troposphere—adds to the speed of aircraft flying with it.

I-U. Discuss the advantages of flying with the jet stream on long-distance flights.

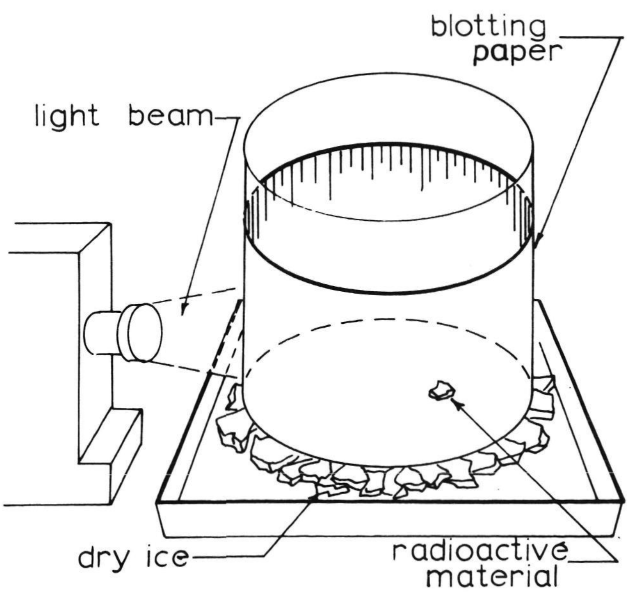
5. Radiation

When a manned flying craft rises to an altitude above the protective layer of ozone found in the upper stratosphere, its crew must be protected from solar radiation.



U. Construct an electroscope for use in detecting radiation. Push a nail and a straightened paper clip side-by-side through the center of a cork which fits the mouth of a test tube. Bend the end of the paper clip at a right angle and glue a 1.25 centimeter by 7.5 centimeter (1/2 inch by 3 inch) piece of metal foil from a gum wrapper on the bent part so that the foil will hang suspended from its center across the paper clip. Insert the cork and assembly into a test tube. Charge the electroscope by touching the top of the nail with a comb that has been rubbed briskly with a piece of wool. Observe that the foil leaves spread apart. Observe that, over a period of time, the leaves will fall together. This is caused, in part, by cosmic radiation. The speed of collapse is an indication of the quantity of cosmic radiation entering the test tube. (Radiation from a radium dial watch or clock will also cause the foil leaves to fall.)

U. Use a Geiger counter (from Civil Defense) to detect radiation from samples of radioactive materials.



U. Construct a "cloud chamber." Paint the bottom of a large plastic ice cream container with flat black paint. Fit a strip of blotter around the lower half of the inside of the container. Pour about 3 millimeters (1/8 inch) of methyl alcohol into the bottom of the container and saturate the blotter. Place a source of radiation (radium dial watch or clock numerals) in the bottom of the container which has been placed in dry ice (1/4-1/2 kilogram; 1/2-1 pound). Shine a strong beam of light (slide projector) across the container and look through the beam toward the black background. When the alcohol vapor has cooled to the point of super-saturation, cosmic rays passing through the vapor will produce visible trails. (See Hone *et al. Teaching Elementary Science,* pp. 352-353.)

U. Compare a neon or fluorescent light to the auroras.

Research

Cause of the auroral display of light

Airglow

Solar heating for homes

6. Ionosphere

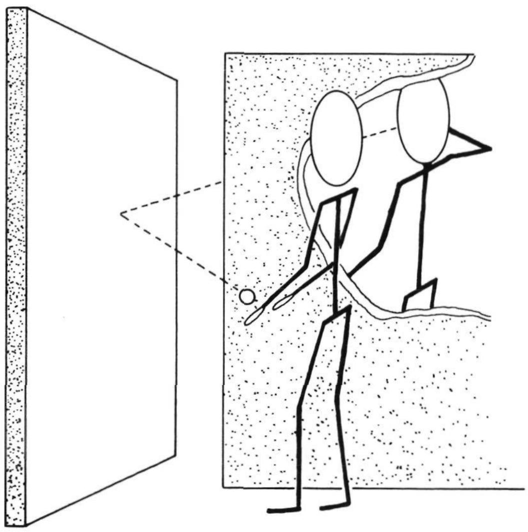
The ionosphere—a layer of electrically charged atoms and molecules in the thermosphere—reflects radio waves back to Earth, making radio communication possible between planes in flight and between planes and ground stations.

I-U. In a darkened room, shine a strong beam of light on a mirror or other reflective surface. Observe the reflected beam of light. Compare to reflection of radio waves off the ionosphere.

I-U. Anchor one end of a long piece of heavy cord or rope. Make waves along the length of the rope and observe that these waves are returned along the length of the rope.

I-U. Direct a beam of light from a projector through the teeth of a comb onto a mirror. Observe that because light rays travel in straight lines they will be reflected from the mirror at the same angle they strike the mirror. Compare to the reflection of radio waves off the ionosphere.

I-U. Pour 2.5-5 centimeters (1-2 inches) of water into a rectangular glass container and place it on an overhead projector. Using a pencil point, make waves in the water. Observe on the screen the reflection of the waves from the sides of the container or other barriers which may be placed in the water. (If an overhead projector is unavailable, support the container between two chairs and place a lighted lamp beneath it.)



I-U. Illustrate the way in which radio waves, reflected by the ionosphere, can be sent around the Earth in spite of barriers such as high mountains and the curve of the Earth's surface. Place a barrier between two students. Have one student bounce a ball against the wall or other similar surface at an angle that will cause the ball to go to the other student without hitting the barrier between them.

7. Atmospheric gases and dust

Atmospheric gases and dust particles make it impossible for one to get a clear view of objects in the universe without rising above the atmosphere. (It is the scarcity of particles in the space beyond the atmosphere that causes space to be dark.)

I-U. Observe dust particles in a beam of light in a darkened room. Increase the number of particles by adding chalk dust from an eraser. Observe the increased brightness as light is reflected from greater numbers of particles.

I-U. Paint the inside of a small box with flat black paint. Cut a slit in one end and a window in the top and cover both with clear plastic. Fill the box with smoke. Shine a light beam through the end slit. Through the window in the top, observe the smoke particles in the beam of light.

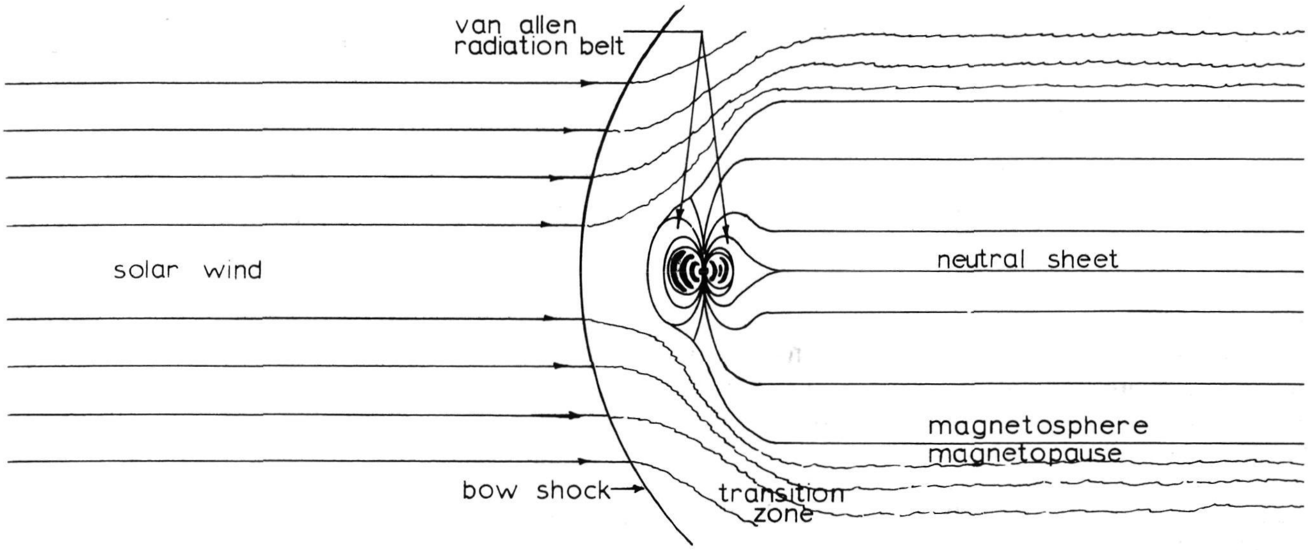
I-U. Put a few drops of milk into a container of water. Shine a strong light through the solution. Observe that the reflected light causes the solution to appear bluish in color. Compare to the sky color caused by reflection of light off dust particles in the atmosphere. Observe also that light that passes through the solution and is seen from the other side has a red-orange color. Compare to the color of the rising and setting Sun or Moon when observed at an angle through a greater thickness of atmosphere.

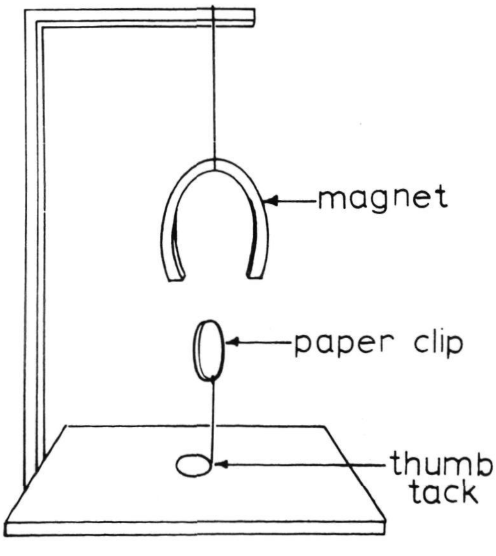
B. Magnetosphere

The magnetosphere—the magnetic field surrounding the Earth—was discovered as a result of data collected by satellites.

P-I-U. Place a variety of both metallic and nonmetallic objects in a box. Provide several kinds of magnets for pupils to use to investigate and determine the kinds of things that are and are not attracted by magnets.

P-I-U. Suspend a bar magnet by a thread so that it can swing freely and is not near any objects that might affect its freedom of movement. Leave it suspended for several hours and observe that the north pole points to the north, lining up with the magnetic field of the Earth. Repeat several times to confirm that it will always return to this north-south position.



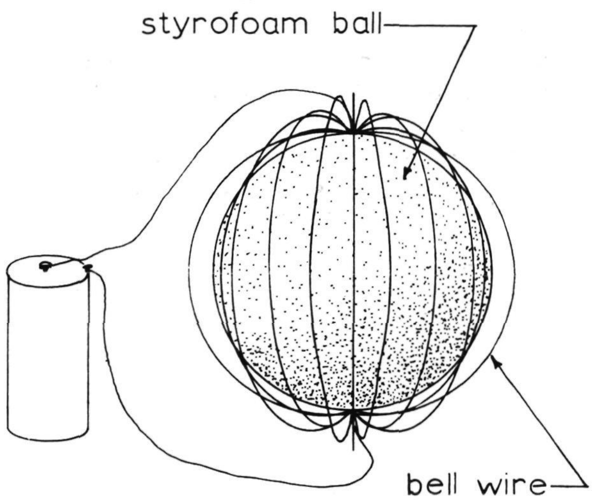


P-I-U. Using cotton string, suspend a magnet from a wooden stand. Tie the end of a length of cotton thread to a paper clip, loop the other end around a thumb tack and fasten the thumb tack to the base of the stand directly below the magnet. Careful adjustment of the distance between the magnet and the paper clip will make the paper clip seem to defy gravity and remain suspended below the magnet without touching it. (Magnetic force will travel through many kinds of materials. Insert sheets of paper, metal, pieces of cloth, etc., between the paper clip and the magnet.)

I-U. Cover a bar magnet with a sheet of clear plastic or light-colored cardboard. Sprinkle iron filings from a salt cellar, held 25-30 centimeters (10-12 inches) away, onto the covering material. Observe the pattern made by iron filings held in the lines of force between the poles of the magnet. Compare these lines of force to the lines of force in Earth's magnetosphere.

1. Magnetic lines of force

The magnetic lines of force around the Earth trap solar and cosmic particles, thus protecting life on Earth from excessive radiation.



U. Cover a strong bar magnet with a sheet of clear plastic or light-colored cardboard. Place a small button (Earth) directly above the center of the magnet. Sprinkle a few iron filings along the edge of one side of the magnet's covering. *Gently* blow filings toward the button. Observe that, depending on the force used in blowing, filings are trapped in the magnetic lines of force. Compare to trapping of cosmic radiation by Earth's magnetosphere.

U. Punch a hole through the center of a 2.5-5.0 centimeter (1-2 inch) styrofoam ball (Earth). Thread bell wire through the hole to form several loops around the ball to represent the magnetic lines of force around the Earth. Attach the free ends of the wire to one or more dry cells to form an electromagnet. While the wires are attached, sprinkle fine iron filings onto the wires around the ball and observe the way in which the filings are trapped by the wires instead of falling to the surface of the ball. Compare to the trapping of cosmic particles by the Earth's magnetic field.

Research

Use of barium particles to outline Earth's magnetic field

2. Radiation belts

The Van Allen belts—fast moving electrons and protons spiraling in Earth's magnetic field from 3800-16,000 kilometers (2,400-10,000 miles) altitude—make it necessary either to direct manned flights through areas of lesser radiation over the magnetic poles or to provide greater protection from radiation.

U. Prepare diagram of Earth's magnetic field and the Van Allen radiation belts.

Research

Discovery of the Van Allen belts

Cause of the Van Allen belts

Shielding from radiation

3. Solar wind

During periods of great solar activity, the solar wind increases in intensity and causes magnetic storms in the Earth's magnetosphere, resulting in disturbances in radio communication. (The solar wind is not a wind in the usual sense of the word, but a stream of an electrically conducting plasma emitted by the Sun.)

Caution: NEVER OBSERVE THE SUN DIRECTLY.

I-U. Fasten a piece of white paper to the inside of one end of a large carton. Punch a hole in the opposite end. Facing away from the Sun, hold the carton upside down overhead in a position that will let the Sun shine through the hole onto the sheet of paper at the opposite end. Observe this image of the Sun to see if dark spots (sunspots) can be detected.

I-U. Using binoculars or a simple telescope, focus the image of the Sun upon a sheet of white paper placed near the eyepiece. Examine the image for dark spots which are indications of solar storms which may appear on the Sun's surface.

U. Observe the way water flows around an object such as a stone. Compare this to the pattern of the solar wind as it flows around Earth.

U. Prepare diagrams of the solar wind and its effect on the Earth's magnetosphere.

Research

Cause of the heat of the Sun

Effect the solar wind has on the Earth

Selected bibliography

Branley. *A Book of Planet Earth for You* (I-U)
Cartwright. *Sunlight* (P-I)
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DePaola. *The Cloud Book* (P-I)
Fisher. *Wonderful World of Air* (U)
Freeman. *When Air Moves* (I-U)
Gallant. *Exploring the Weather* (U)
Hone *et al. Teaching Elementary Science* (U-T)
Hyde. *Exploring Earth and Space* (U)
Iger. *Weather on the Move* (U)
Kaufman. *Winds and Weather* (I-U)
Knight. *Let's Find Out About Weather* (P-I)
May. *Climate* (P-I)
Milgrom. *Understanding Weather* (I-U)
Rosenfeld. *Science Experiments with Air* (U)
Simon. *Weather and Climate* (I-U)
Sootin. *Long Search: Man Learns About Air* (U)

UNIT II

Flight in the Atmosphere

Outline

Before man could fly into space he had to discover the principles of flight in the atmosphere and learn how to apply these principles in designing aircraft.

A. Lighter-than-air craft were used for man's first voyages in the atmosphere.

B. The development of heavier-than-air craft had to wait until man could design a craft with sufficient power, lift, and stability to stay aloft.

1. Four forces act upon a plane flying in the atmosphere.

   a. Lift is produced by (a) the difference in the speed of air flowing over the wing surfaces and (b) the angle of attack.

   b. The weight of the airplane is produced by the attraction of gravity.

   c. Thrust may be produced by engine-driven propellers, jets, or rockets.

   d. Drag (resistance) may be reduced by streamlining the shape of the plane.

2. Many people have worked to increase the speed and efficiency of aircraft, to overcome sound and heat barriers, and to solve other problems related to flight in the atmosphere.

   a. When an airplane moves faster than the speed of sound, it must pass through the sound barrier.

   b. The heat barrier for an aircraft is the temperature at which the heat, caused by friction, weakens the structural parts of the plane.

   c. Data collected during the flights of the X-15 planes enabled man to explore the phenomenon of weightlessness, develop protective clothing for crews, demonstrate man's ability to control a vehicle in a high-speed, high-altitude environment, and design structures to withstand the high temperatures of reentry from space.

   d. Research to find ways to reduce drag at high speeds led to the development of the variable sweep wing, a wing whose angle to the body of the airplane can be changed in flight.

   e. Research to find ways to reduce length of runway needed for takeoff resulted in the development of planes that take off and land vertically or on short runways.

C. Through cooperation between NASA and other nations, progress is being made in aeronautical research.

Outline

Before man could fly into space he had to discover the principles of flight in the atmosphere and learn how to apply these principles in designing aircraft.

Activities

**I-U*. Make a time line of the development of aviation.*

I-U. Draw a mural depicting the history of flight.

P-I-U. Draw or paint pictures to illustrate historical events in aviation.

I-U. Prepare an "eyewitness" radio program or write imaginary "current events" to fit moments in aviation history.

I-U. Draw or paint pictures to illustrate a bulletin board or booklet to be titled "Famous Firsts in Aviation."

I-U. Write biographies of men and women famous in aviation's history.

I-U. Dramatize or write stories about events in the lives of men and women important in the history of flight.

P-I-U. Draw pictures or make models of historical aircraft.

I-U. Report and discuss current events concerning aerospace.

P-I-U. Trace airline routes on maps and globes. Trace and discuss the advantage of great circle routes.

P-I-U. Visit the local airport and write about the work that is done there and the services that are provided.

P-I-U. Draw pictures of various kinds of activities one might see at the airport, or build a model airport or heliport.

U. Determine a good location for a multi-city, shared airport facility.

P-I-U. Invite an airport worker to visit class and tell about his or her duties.

I-U. Write an imaginary autobiography of an airline employee.

Research

Women in aeronautics

National Advisory Committee for Aeronautics (NACA)

National Aeronautics and Space Administration (NASA)

Aircraft in war

NASA Langley Research Center, Hampton, Virginia

Early attempts at flight (See Pollinger. *Strange But They Flew.*)

Myths about flight

Types of aircraft, their uses, and the history of their development

*Suggested age level: P(5-7), I(8-9), U(10-11).

Development of airline transportation

Small civilian aircraft and the companies that manufacture them

Aerospace manufacturing and transportation industries

Aerospace careers

Civilian airport facilities and their problems

Federal Aviation Administration and its duties

Research in aviation

Effect of aviation progress on our lives

A. Lighter-than-air craft

Lighter-than-air craft were used for man's first voyages in the atmosphere.

I-U. Develop a time line showing important events in the history of ballooning.

P-I-U. Draw or paint pictures illustrating the history of ballooning.

I-U. Write an "eyewitness" report or dramatize an episode in the development of balloon travel.

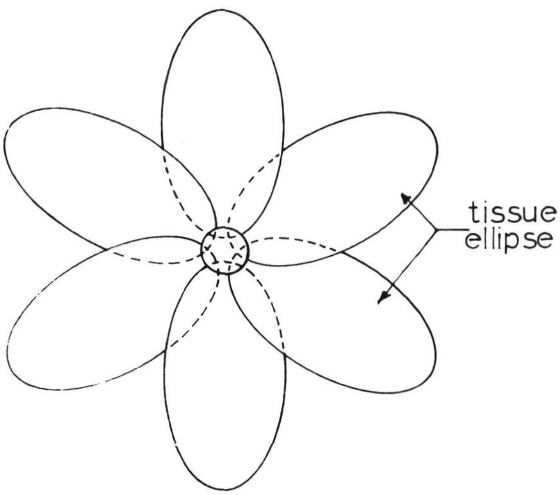
P-I-U. Watch the drifting of lighter-than-air materials: cotton, hair, dandelion seed, milkweed seed, etc.

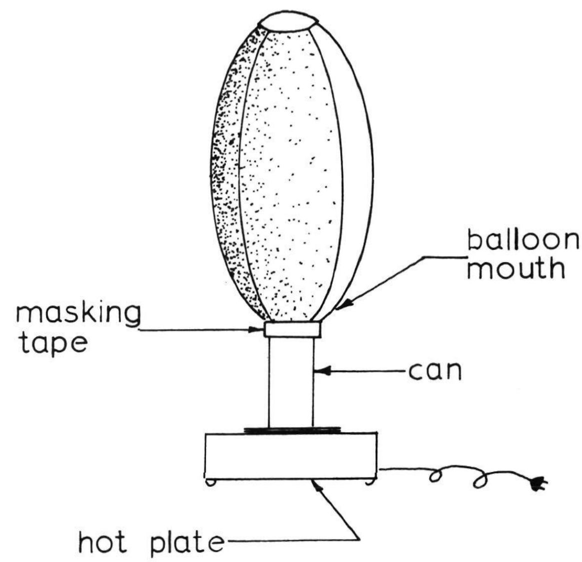
P-I-U. Sprinkle a small amount of talcum powder or cornstarch a few inches above a hot light bulb. Observe the currents caused by the rising heated air.

I-U. Float a cork in a container of water. Press the cork to the bottom of the container. Release it and watch it rise again. Compare the cork in water to a lighter-than-air craft rising in the air.

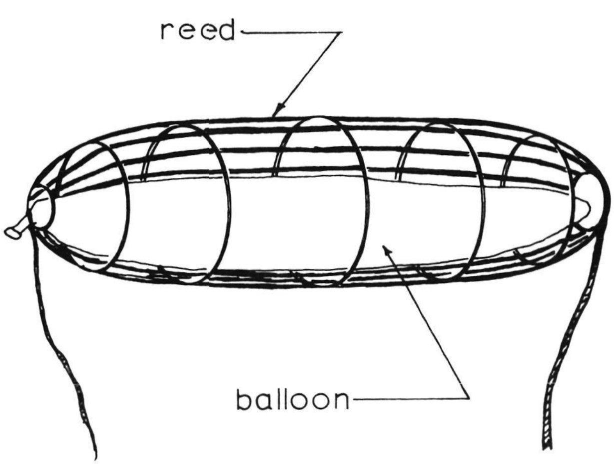
P-I-U. Make model balloons and use them as mobiles.

U. Make a hot-air balloon. Cut from tissue paper a circle and six elliptical sections whose relative dimensions are about 3-1. Paste the edges of the sections together, overlapping them at one end and fastening them to the circle. Reinforce the opening left at the other end with a 2.5 centimeter (1 inch) collar of masking tape. Fill balloon with hot air rising through a tin can (with its ends cut out) placed on a hot plate. Tether with light cotton string to control its flight.





U. Make a model dirigible by tying the ends of 4.5-5 millimeter (3/16 inch) reeds together at one end. Glue them to balsa wood hoops, evenly spaced, with larger hoops in the center graduating to smaller ones at the ends. Cover with tissue paper pasted in place. Insert empty balloon and fill balloon with helium. Tether with light cotton string at the front and rear.



P-I-U. Write stories or poems about ballooning.

Research

Use of balloons in war

History of ballooning

Use of balloons in collecting data for weather forecasting

Biographies of men and women famous in the history of ballooning

B. Heavier-than-air craft

The development of heavier-than-air craft had to wait until man could design a craft with sufficient power, lift, and stability to stay aloft.

I-U. Observe birds in flight (use binoculars if available).

P-I-U. Observe the wing and feather structure of birds.

I-U. Make and fly miniature kites in front of a fan.

P-I-U. Collect pictures of aircraft used for commercial and civilian purposes. Devise games that involve identifying the aircraft shown in the pictures.

P-I-U. Draw or paint a mural of different kinds of modern airplanes.

P-I-U. Make a picture book of airplanes that have different purposes.

P-I-U. Plan an imaginary airplane trip.

P-I-U. Write stories about airplanes or trips on airplanes.

P-I-U. Construct a table-model airport.

I-U. Construct dioramas of an airport.

P-I. Make pilot or crew hats and radio earphones.

P-I. From sturdy boxes, make an airplane large enough to get into.

I-U. Make mobiles of airplanes.

P-I-U. Have an exhibit of model planes.

I-U. Make oak tag silhouettes of airplane models. Fold so that ailerons, rudder, or elevator are movable. Suspend in an air stream and observe the effect when positions of the control surfaces are changed.

I-U. Make a model balsa wood plane with movable ailerons, rudder, and elevator. Suspend by a string through a screw eye at its point of balance. Place in a stream of air and observe the effect when positions of the control surfaces are changed.

I-U. Construct model gliders of balsa wood, paper, or tag board. Test for "fly-ability."

I-U. Make a model glider of balsa wood or tag board and test for aerodynamic stability. Attach model by a string to the end of a long stick. Twirl the model around the head. Make adjustments in the model until it will "fly" in the correct attitude.

I-U. Design an airplane. Prepare a model and test its aerodynamic stability. (See Barnaby. *How to Make and Fly Paper Airplanes.*)

I-U. Make a wind tunnel for testing model aircraft. To make the whirling air stream from an electric fan move in a straight line when testing models: (1) support a "honeycomb" separator from an egg crate in an upright position between the fan and the model or (2) fasten milk cartons together to form a honeycomb and place between the fan and the model. A smoldering punk, or dry ice in a pan of warm water, can supply the smoke or fog to show air currents. A piece of coat hanger wire bent and fastened to a board can be used to support the model in the air stream. The wind tunnel works best if it is set up in a cardboard carton with both ends removed and a plastic "window" in the side for viewing the model.

Research

Wind tunnels

Air passenger and freight service

Charles Lindbergh

Cardiac catheter—a sensor to measure blood flow rates—a spin-off from minute sensor used in wind tunnel model testing

Orville and Wilbur Wright

Airplanes of different types and uses

Amelia Earhart

1. Principles of flight

Four forces act upon a plane flying in the atmosphere.

a. Lift

Lift is produced by (a) the difference in the speed of air flowing over the wing surfaces (Bernoulli's principle) and (b) the angle of attack.

Bernoulli's principle: An increase in the speed of a gas produces a decrease in pressure. Therefore, when air moves faster across the upper surface of an object, the amount of downward pressure of the air on the upper surface is less than the amount of upward pressure of the air on the lower surface.

Angle of attack: The angle at which the wing meets the air stream.

I-U. Prepare a bulletin board showing how air flows over and around an airplane wing.

I-U. Hold a piece of paper just below the lower lip. Blow across the top and observe that the paper rises as the pressure on the top of the paper is reduced by the movement of the air.

I-U. Suspend a length of paper loosely between two piles of books. Blow across the top of the paper. Paper will rise.

I-U. Suspend two sheets of paper about 2.5 centimeters (1 inch) apart between two stacks of books. Blow between the sheets of paper. Papers will come together.

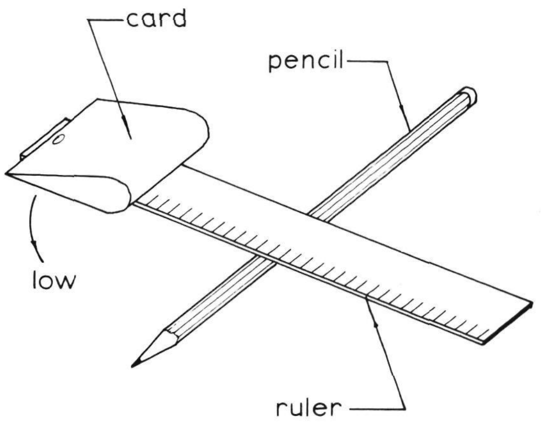
I-U. Use lightweight string or thread to suspend two table tennis balls about 2.5 centimeters (1 inch) apart. Using a straw, blow between the two balls. Balls will move together.

I-U. Make two lightweight paper tubes. Place them on a flat surface about 2.5 centimeters (1 inch) apart. Using a straw, blow between the paper rolls. Tubes will move together.

I-U. Suspend a table tennis ball in the stream of air formed by a vacuum cleaner or hair dryer with its hose attached to the blower end.

I-U. Place a table tennis ball in a glass funnel. Attempt to blow the ball out of the funnel.

I-U. Suspend two spoons, bowls back to back and slightly separated. Direct a flow of water from a faucet between them. Spoons will move together.



I-U. Tape or tack a card to a ruler so that it curves like an airplane wing. Balance ruler on a 6-sided pencil with the card end slightly lower. Using a straw, blow across the curved surface of the card. Card end will rise.

I-U. Pull a strip of paper through the air. Observe that the paper rises.

I-U. Push a sheet of paper forward through the air. Observe the paper rise as it pushes against the air.

Research

Jacob and Johann Bernoulli

b. Gravity

The weight of the airplane is produced by the attraction of gravity.

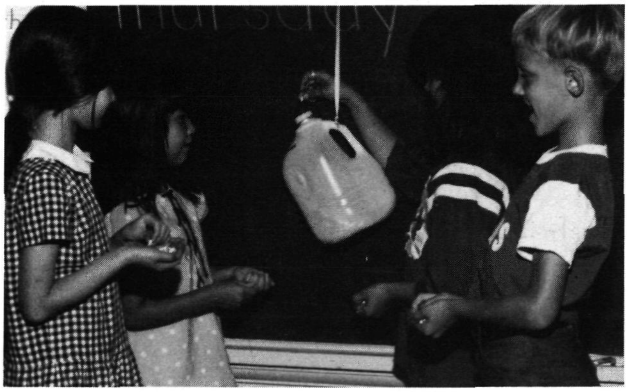
P-I. Have a child jump into the air. Discuss why he or she comes down again. Discuss what would happen without gravity.

P-I. Drop a pencil, a rock, and a ball. Discuss why they come down.

P-I. Jump rope. Discuss why the rope can be "turned."

I-U. Compare the speed of fall of two objects of identical size and shape, but different weights.

I-U. Observe the change in the speed of an object rolling down an inclined plane as the angle of inclination is increased or decreased.



I-U. Place marbles in a container suspended by a rubber band or from a spring. Add marbles and discuss how the increase in the length of the rubber band or spring indicates the increased pull of gravity.

I-U. Place a ruler at an angle across the corner of a table or desk with one end projecting about 2.5 centimeters (1 inch) beyond the edge. Place one coin on the projecting end and another coin on the other end of the ruler. Strike projecting end of the ruler with a sharp blow. The coin on the projecting end should fall straight to the floor at the same time that the coin on the other end of the ruler falls in an arc to the floor. Observe that both coins will hit the floor at the same time. (Practice in releasing the coins at the same time may be necessary.)

I-U. Place two marbles, one larger and heavier than the other, against a block of wood lying near the edge of a table. Strike the other side of the block gently but firmly with a hammer so that the marbles will start falling to the floor simultaneously. Observe that, even though of different size and weight, they hit the floor at the same time.

I-U. Fasten lead sinkers to a fish line at the following distances from the floor: 10, 40, 90, 160, 250, 360, 490, 640 centimeters (3, 12, 27, 48, 75, 108, 147, 192 inches)—as far as ceiling height permits. Hang the line from the ceiling and place a piece of metal directly under the line. Release the line and listen for the sinkers to hit the metal. Observe that they hit at regularly spaced intervals even though their distances from each other on the line vary.

U. Fasten lead sinkers at equal intervals along a fish line and follow directions as given above. Observe that the weights strike the metal at increasingly shorter intervals even though their distances from each other on the line are the same.

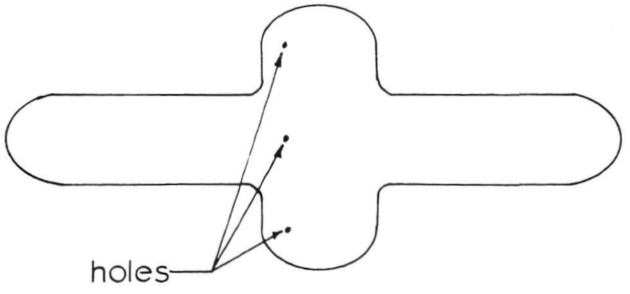
U. Calculate the weight of objects at different altitudes. (at 13,000 kilometers [8000 miles], weight is 1/4 weight at sea level; 20,000 kilometers [12,000 miles], weight is 1/9 weight at sea level; 25,000 kilometers [16,000 miles], weight is 1/16 weight at sea level)

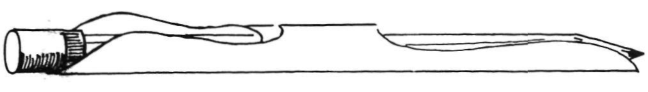
U. Acceleration or change of direction can increase the effect of the pull of gravity. Fasten heavy weights to the wings of a balsa glider. Move it as in level flight, then suddenly cause it to dive and then level off. The wings may snap off because of the increased stress. Test pilots test a plane's ability to withstand the extra g's of acceleration by using this kind of maneuver.

I-U. Discuss problems which may be encountered when using simple tools in a gravity-free environment.

c. Thrust

Thrust may be produced by engine-driven propellers, jets, or rockets.





I-U. Place a fan on a board lying on round pencils or dowels. Observe the movement of the board as the fan is turned on.

I-U. Place a fan in a small wagon. Observe that when the fan is turned on it will cause the wagon to move.

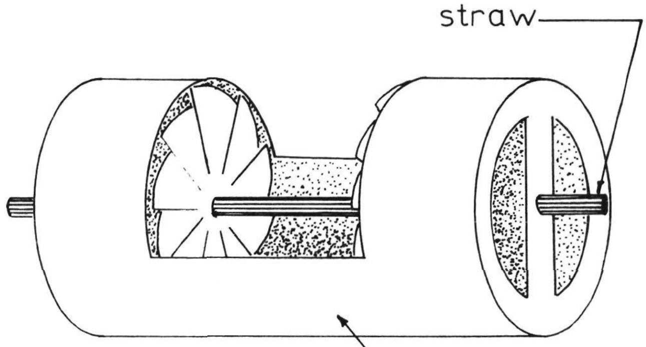
I-U. Fly a model airplane with a propeller powered by a rubber band.

I-U. Make a model propeller of lightweight cardboard. Roll cardboard around pencil to shape propeller. Remove and attach to pin stuck in eraser of pencil.

P-I-U. Tape an inflated balloon to a straw. Thread a long, lightweight wire through the straw and hold or fasten it at each end so that it will be taut. Release air from the balloon and observe its movement along the wire.

P-I-U. Fasten an inflated balloon to a small, lightweight toy so that when air is released, the toy will move forward.

P-I-U. Tape an inflated balloon to a model airplane. Release air and observe "flight."



P-I-U. Mount a model plane on a taut wire (use screw eyes in the top). Attach a carbon dioxide cylinder to the under part of the plane. Puncture the cylinder and observe the "flight" of the plane along the wire.

I-U. Wrap a test tube with screen wire for safety. Using two lightweight wires, suspend it horizontally above a source of heat. Place about 5 milliliters (1 teaspoonful) of water in the test tube and stopper it *loosely.* Heat. Observe the "reaction" movement of the test tube when the expanding water vapor forces the stopper out.

U. Make a model turbojet engine. Cut a section from the side of a small oatmeal box. Cut openings in the top and bottom of the box. Cut two 7.5 centimeter (three inch) circles of light cardboard and, using a pencil and ruler, divide each circle into eight equal pie-shaped pieces. Cut along the dividing lines from the outside of the circle part of the way in toward the center and bend the cut sections to form blades. Punch a hole in the center of each circle and push a straw through the two holes. Place the straw-and-circle device in the oatmeal box with the circles at either side of the opening cut in the side of the box and the straw protruding through the center of the top and bottom of the box. One circle represents the air compressor and the other the turbine of the model turboject engine. (See Pacilio. *Discovering Aerospace.*)

U. Make a model turboprop engine. See the directions above for the turbojet engine. After placing the straw-and-circle device in the oatmeal carton, make and add a propeller to one end of the straw on the outside of the box.

Additional activities related to jet propulsion may be found in Unit III A, Pages 28-29.

Research

Kinds of jet engines

Kinds of reciprocating engine designs

Carburation and ignition systems for reciprocating engines

Internal combustion engines

Types of propellers

d. Drag

Drag (resistance) may be reduced by streamlining the shape of the plane.

P-I-U. Run with a large square of lightweight cardboard held flat against the wind. Repeat with the edge against the wind. Observe the difference in the amount of resistance.

P-I-U. Open an umbrella. Hold it high above the head and pull it down quickly. Observe how air resists the movement of the umbrella.

P-I-U. Drag a clothespin through water, then attach a bucket (ketchup bottle cap) and notice the additional drag.

P-I-U. Drop, at the same time, two identical sheets of paper; one flat, one crumpled. Observe the effect of air resistance on the rate of fall.

P-I-U. Drop a sheet of aluminum foil and a marble at the same time. Crumple the foil into a ball, and again drop the foil and marble at the same time. Observe the effect of the air resistance on the rate of fall.

P-I-U. Make a parachute of a large handerchief. Tie an object to it. Drop an identical object at the same time the object fastened to the parachute is dropped. Observe how the air resistance slows down the fall of the object attached to the parachute.

P-I-U. Walk on surfaces of varying degrees of roughness (rough cement, wooden floor, highly polished surface, ice). Observe that walking is easier when there is something rough to push against. It becomes more difficult if there is too much resistance. Discuss walking on a wet, sandy beach.

P-I-U. Rub two pieces of metal together without any lubricant between them; repeat, using oil as a lubricant; repeat, using rollers or balls to reduce friction. Observe the differences in the amount of friction.

P-I-U. Blow through a straw against the flat side of a card held in front of a lighted candle. Observe the effect upon the flame. Fold a card into a teardrop shape. Blow against the rounded surface opposite the thin edge, with the thin edge toward the candle. Observe the effect of the flow of air around the streamlined shape.

Research

A.J. Garnerin—parachutes, 1797

Hang gliders

2. Problems of flight

Many people have worked to increase the speed and efficiency of aircraft, to overcome sound and heat barriers, and to solve other problems related to flight in the atmosphere.

Research

Titanium

Wind tunnels

Robert J. Collier Trophy

Charles E. Yeager

Supersonic flight

Computer techniques for testing aerodynamic stability of aircraft designs

NASA Hugh L. Dryden Flight Research Center, Edwards, California

NASA Ames Research Center, Moffett Field, California

NASA Langley Research Center, Hampton, Virginia

NASA Lewis Research Center, Cleveland, Ohio

a. Sound barrier

When an airplane moves faster than the speed of sound, it must pass through the sound barrier—a pile-up of sound waves moving ahead of the plane, because the plane is moving faster than the sound waves can move. (The speed of sound in air is approximately 330 meters per second at 0°C; 1090 feet per second at 32°F.)

I-U. Pour water into a large shallow glass container and place on an overhead projector. Drop a pebble in the water. Before the waves have subsided, draw the point of a pencil swiftly across the surface of the water. Observe the cone shape of the wave pattern as the waves are compressed. Compare to the cone shape of sound waves which cause the sonic boom.

Research

Problems caused by sonic booms

Bell XS-1 or X-1, early research plane

Supersonic transports (SST)

Lifting bodies

Hypersonic flight

Antisymmetrical wing

Supercritical wing

Use of low-velocity fan jets to aid in noise control

Study of owl flight to reduce aircraft noise

b. Heat barrier

The heat barrier for an aircraft is the temperature at which the heat, caused by friction, weakens the structural parts of the plane.

P-I-U. Place the palms of your hands together and rub them together rapidly. The friction produces heat.

P-I-U. Start a fire using a Boy Scout fire-by-friction drill set.

P-I-U. Pull a piece of rope through the hand quickly. Friction will cause an increase in temperature.

P-I-U. Bend a wire back and forth at one point. After several bends, feel the wire. It is heated due to friction of the molecules.

c. High-altitude flight

Data collected during the flights of the X-15 planes enabled man to explore the phenomenon of weightlessness, develop protective clothing for crews, demonstrate man's ability to control a vehicle in a high-speed, high-altitude environment, and design structures to withstand the high temperatures of reentry from space.

I-U. Calculate the amount of weight of an object at various g forces.

I-U. Place about 5 centimeters (2 inches) of water in a tall, narrow jar (olive bottle). Add a drop of olive oil. Then, slowly add rubbing alcohol. Observe the shape of the oil drop. Break the drop and observe the shape of the globules. Compare to the shape of liquids in a weightless condition.

I-U. Demonstrate weightlessness. Tie a toy figure to a string and hang the toy in an upright position within a lightweight picture frame or other lightweight rectangular frame. Drop the frame from a height and observe the figure while the frame is falling. Its position does not change within the frame; it is weightless with respect to its environment within the frame.

P-I. Try eating and drinking while standing on the head. Discuss effect of weightlessness on ability to eat and drink.

P-I-U. The feeling weightlessness may be experienced to a small degree on a playground swing. Notice the light feeling at the top of the swing's arc just before it begins its swing back toward Earth. Notice the feeling of heaviness as the swing passes close to Earth.

P-I-U. Discuss the feelings experienced in riding down in a fast elevator, jumping off a diving board, riding in a car or on a bike over a large bump in the street, or riding on a roller coaster. Compare to weightlessness.

Research

Scott Crossfield and the X-15

X-15 planes

X-24B planes

d. Drag reduction

Research to find ways to reduce drag at high speeds led to the development of the variable sweep wing, a wing whose angle to the body of the airplane can be changed in flight.

Research

Planes with variable sweep wings

Bell X-5 plane

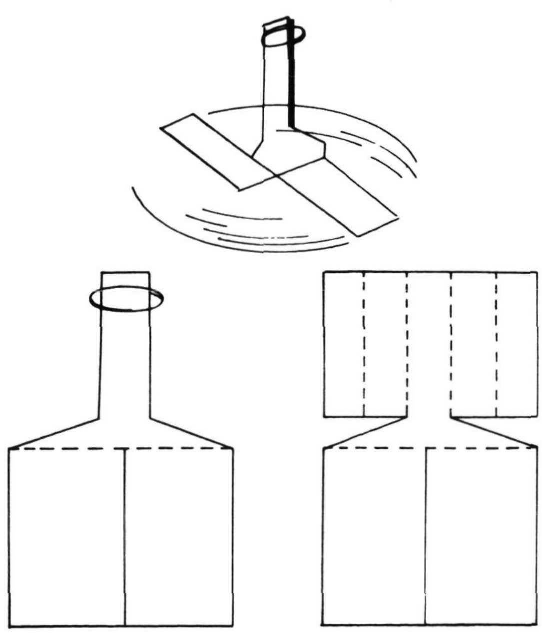
F-111 plane

Antisymmetrical wing

Supercritical wing

e. Runway length

Research to find ways to reduce length of runway needed for takeoff resulted in the development of planes that take off and land vertically or on short runways.



I-U. Make a model helicopter from a file card by cutting the card on the solid lines and folding it along the dotted lines shown in the diagram. Fasten the folded section with a paper clip and bend the blades in opposite directions. As this model falls it illustrates how the spin of the rotor blades of the helicopter can provide lift. (The amount of lift in this model is not sufficient to overcome gravity, but it does slow the fall of the card.)

P-I-U. Draw a mural showing the use of helicopters in intracity and intercity transportation of passengers and material.

P-I-U. Read or write stories about helicopters and their uses.

P-I-U. Draw or collect pictures of helicopters being used for rescue work, etc.

I-U. Attach an inflated balloon to each end of a 30 centimeter (one foot) long piece of light wood so that the openings of the balloons face in opposite directions. Suspend the stick by a thread fastened near the center so that the stick hangs level horizontally. Release air from the balloons and observe the rotor action powered by the balloon "jets."

Research

Tilt-wing planes (XC-142, Vertol 76)

Tilt-duct planes (Doak VZ-4, Bell X-22A)

Fan-in-wing craft (XV-5A)

Deflected-jet planes (Hawker P.1127)

Flexible wing craft (XV-8A)

NASA Ames Research Center, Moffett Field, California

Helicopters

Planes that take off and land vertically (VTOL)

Piloting a helicopter

Grooved runways

Development of the variable sweep wing

Development of short takeoff and landing craft (STOL)

C. International cooperation

Through cooperation between NASA and other nations, progress is being made in aeronautical research.

Research

U.S.A.-Canadian study of the "augmentor-wing"

U.S.A.-French testing of tilt rotors for V/STOL aircraft

U.S.A.-German study of the Dornier 31 (Do-31) aircraft, a jet V/STOL transport

U.S.A.-United Kingdom aeronautical research projects

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Branley. *Gravity is a Mystery* (P)
Coombs. *Skyhooks* (I-U)
Corbett. *What Makes a Plane Fly?* (I-U)
Delear. *The New World of Helicopters* (I-U)
Field. *Auguste Piccard* (U-T)
Fischer. *One Way is Down* (P-I)
Freeman. *Gravity and the Astronauts* (P)
Freeman. *When Air Moves* (I-U)
Hyde. *Flight Today and Tomorrow* (U)
Jacobs. *SST Plane of Tomorrow* (U)
May. *Women in Aeronautics* (U-T)
Pacilio. *Discovering Aerospace* (U-T)
Pollinger. *Strange But They Flew* (U)
Richards. *Giants in the Sky* (I-U)
Settle. *Story of Flight* (I-U)
Shapp and Shapp. *Let's Find Out About Airplanes* (P-I)
U.S. NASA. *Aeronautics* (U-T)
U.S. NASA. *NASA Aeronautics* (U-T)
U.S. NASA. *NASA Ames Research Center* (U-T)
U.S. NASA. *NASA Hugh L. Dryden Flight Research Center* (U-T)
U.S. NASA. *NASA Langley Research Center* (U-T)
U.S. NASA. *NASA Lewis Research Center* (U-T)
U.S. NASA. *Weightlessness* (U-T)
Victor. *Airplanes* (P-I)

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UNIT III

Rockets

Outline

Rocket engines, which carry with them all the necessary materials for propulsion, are used to launch flights into the upper atmosphere or into space.

A. Sir Isaac Newton's third law of motion is the basic principle involved in rocket propulsion.

B. Most rocket engines use either liquid or solid chemicals as fuel.

C. The direction a rocket moves may be controlled by movable fins (only in the atmosphere) or by a change in the direction of the flow of the rocket engine exhaust.

D. Launch vehicles with sufficient thrust had to be developed and tested before flight into space became feasible.

E. Launch vehicles are comprised of stages, with the initial stage being the most powerful so that it can overcome the pull of Earth's gravity. When the propellant in a stage has been consumed, the heavy structure is dropped away. The engines in the next stage can further increase velocity because there is much less weight for them to move.

F. The Space Shuttle is launched by reusable solid rocket boosters in combination with the Orbiter's own main rocket engine, which is fueled from a tank that drops away in orbit. The solid rocket boosters are jettisoned after burnout and fall back to Earth with parachutes; they are then retrieved and can be used again.

Outline

Rocket engines, which carry with them all the necessary materials for propulsion, are used to launch flights into the upper atmosphere or into space.

Activities

**I-U.* Make a time line of the development of rocket aircraft.

I-U. Compare and contrast rocket and jet engines.

P-I-U. Make a bulletin board showing stages in the development of rocket power.

P-I-U. Draw or collect pictures of different kinds of rockets.

I-U. Make model rockets.

Research

Sounding rockets

V-2 rockets

Robert Goddard

Joannes de Fontan and his rocket-driven boat (15th century, Italian)

William Congreve and the Congreve rocket (British, 1800's)

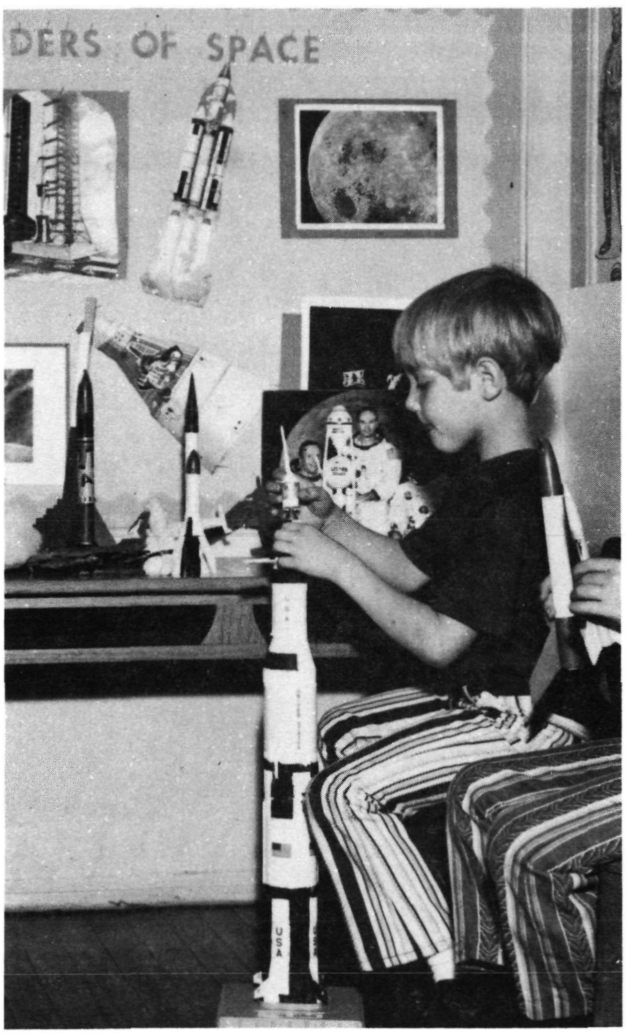
Manufacturing rockets

Scientists associated with modern rocketry

Kinds of rocket engines

History of the development of rocket power

Launching a rocket·



A. Newton's third law

Sir Isaac Newton's third law of motion is the basic principle involved in rocket propulsion. (For every action, there is an equal and opposite reaction.)

P-I-U. Inflate a balloon. Observe that air presses in all directions against the inside of the balloon. When balloon is released, air no longer presses against the balloon in the direction of the air flow, but continues to press in all other directions and the balloon goes in the direction opposite to the escaping air.

P-I-U. Stand in a small wagon and jump out, causing the wagon to move in the opposite direction.

*Suggested age level: P(5-7), I(8-9), U(10-11).

P-I-U. Wearing roller skates, throw a ball.

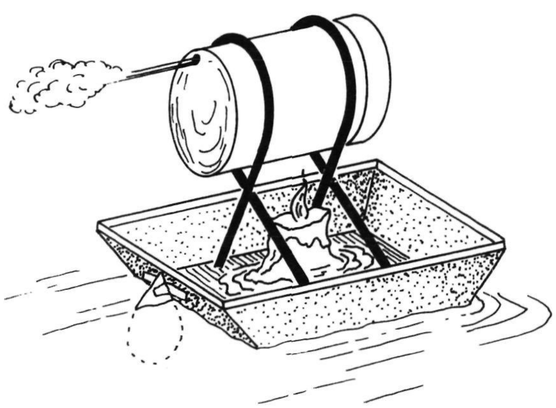
I-U. Place a fan on a board which is supported by several dowels which can act as rollers. Observe the movement of the board when the fan is turned on.

P-I-U. Inflate a balloon which has been taped to a soda straw. Place the straw on a length of taut wire fastened in a vertical position. Release air and observe reaction of balloon.

P-I-U. List examples of evidence of Newton's third law of motion in everyday life.

I-U. Wrap baking soda in a tissue or napkin. Insert in a bottle and add vinegar. Cork loosely and shake mixture. Lay bottle quickly on its side on several round pencils and observe the reaction as the cork is popped out.

I-U. The following activity is best conducted outdoors. Punch a hole in the cap of an unopened bottle of carbonated soft drink. Hold your finger tightly over the hole and shake the bottle vigorously. Lay the bottle on a smooth surface, and uncover the opening. Reaction to the escaping carbon dioxide forces the bottle to move.



I-U. Make a steam-reaction motor by punching a small nail hole near one edge of the bottom of a small can (35mm film can or shoe polish can). Fill the can about 1/4 full of water and support it on wire legs about 10 centimeters (4 inches) above the surface of a small "boat" (plastic soap dish) which is floating in a pan of water. Place a short candle under the center of the can. When the candle has heated the water enough for steam to escape, observe the movement of the boat.

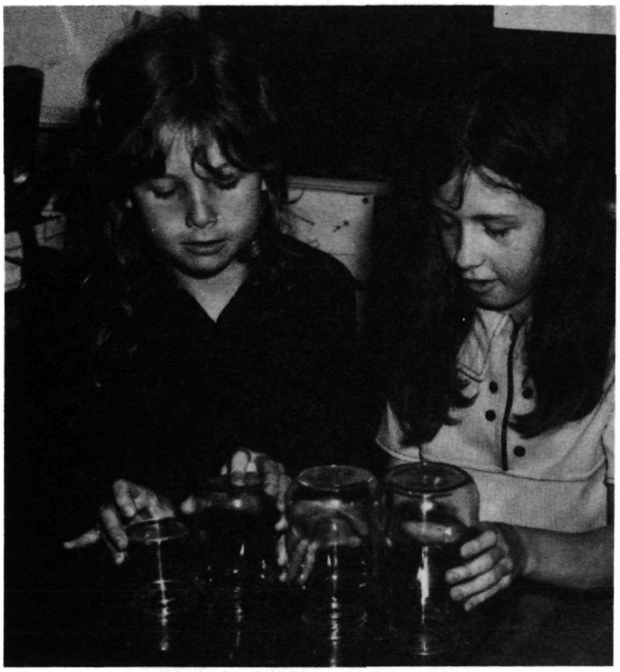
Additional activities related to Newton's third law may found in Unit II B, Pages 20-21.

Research

Sir Isaac Newton

B. Fuel

Most rocket engines use either liquid or solid chemicals as fuel.

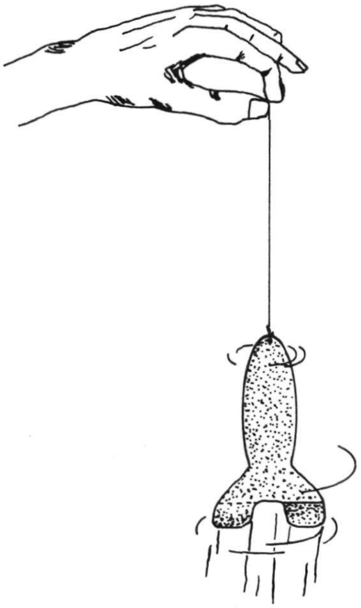


P-I-U. Demonstrate that air is needed for combustion by attempting to burn a lighted candle that has been covered with a jar.

I-U. Compare and contrast solid and liquid fueled rockets.

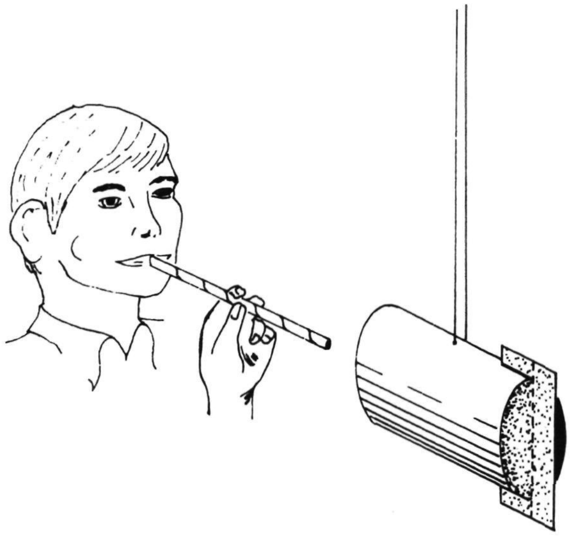
C. Guidance

The direction a rocket moves may be controlled by movable fins (only in the atmosphere) or by a change in the direction of the flow of the rocket engine exhaust.



I-U. Make a folded wax paper or foil boat. Power it with a balloon that has a short piece of straw taped in the opening. Inflate the balloon and, placing the boat in a pan of water, direct the flow of the air released from the balloon in first one direction and then another to illustrate the way in which a directed jet can be used to guide the trajectory of a rocket.

I-U. Illustrate the effect aerodynamic directional vanes have on the movement of a model rocket. Make the model from a file card and suspend it by a thread tied to its nose. Slowly pull the thread upward and observe the rocket's action. Change the position of the vanes and observe the effect.



I-U. Illustrate the effect of directional vanes placed in the path of the rocket's exhaust. Hang a paper tube horizontally by a thread. Place a vertical fin made of construction paper upright in a slot cut in the tube. Using a soda straw, blow through the end of the paper tube opposite the fin and observe the effect.

I-U. Spin a gyroscope and observe its resistance to change of direction.

Research

Gyroscopes

Guidance of rockets

Inertial guidance systems

D. Launch vehicles

Launch vehicles with sufficient thrust had to be developed and tested before flight into space became feasible.

P-I-U. Build a model of a launch vehicle. Use cardboard tubes, a cone-shaped paper cup for the nose, light cardboard for fins, and pieces of straw or plastic for the engines. To make a multistage rocket, use more tubes and simulate adapter rings.

P-I-U. Prepare a chart, bulletin board, or table top display showing the comparative sizes of launch vehicles.

P-I-U. Draw pictures or make models of the various launch vehicles.

P-I-U. Compare size of the Saturn V rocket to known height of buildings, etc.

P-I-U. Write stories describing the launching of a rocket.

P-I-U. Dramatize the launching of a rocket.

Research

History of the Saturn V rocket

Various kinds of launch vehicles and their uses

NASA George C. Marshall Space Flight Center, Alabama

E. Multistaging

Launch vehicles are comprised of stages, with the initial stage being the most powerful so that it can overcome the pull of Earth's gravity. When the propellant in a stage has been consumed, the heavy structure is dropped away. The engines in the next stage can further increase velocity because there is much less weight for them to move.

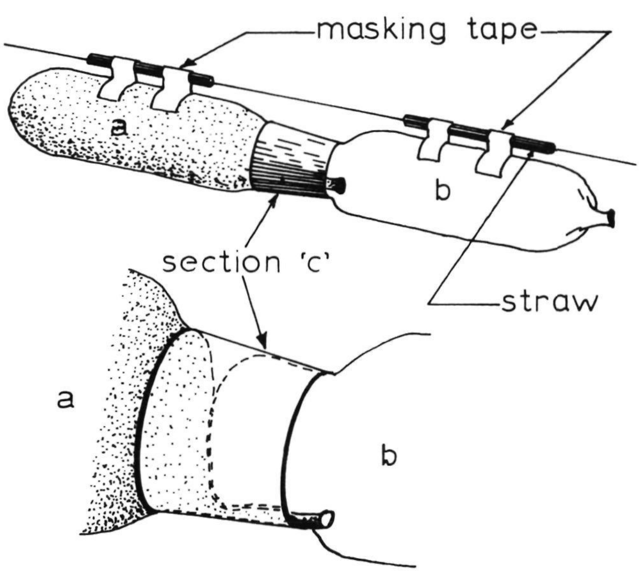
P-I-U. Draw a diagram of a three-stage launch vehicle.

P-I-U. Draw pictures or murals showing multistage vehicles at various stages.

P-I-U. Make a bulletin board showing stages of launch vehicles.

P-I-U. Place a toy motorcycle in a toy pickup truck which is on a toy semitrailer truck. Give the semitrailer truck a push. When it has stopped, unload the pickup truck and give it a push. When it has stopped, unload the motorcycle and give it a push. Compare the distance covered by this method to the distance each vehicle would travel alone. Relate to multistage launch vehicles.

P-I-U. Place three spring-wound toy cars or trucks on a starting line. Release simultaneously, and measure the distance each travels. Now place one on top of the other in a stack. Rewind the bottom vehicle (Car A) and allow it to travel as far as it will go while carrying the other two. Unload the two, leaving them stacked one upon the other, and place them beside Car A. Rewind the bottom vehicle of these two (Car B) and allow it to travel as far as it will go carrying the third car (Car C). Unload Car C, place it beside Car B. Rewind it and allow it to travel as far as it will go. The distance from the starting line will be the sum of the distances traveled by Cars A, B, and C.



I-U. Cut the bottom out of a paper or styrofoam cup. Extend the nozzle of one long balloon (Balloon *b*) through the bottomless cup and inflate the balloon. Holding the nozzle of Balloon *b* against the edge of the cup, place another long balloon (Balloon *a*) into the cup and inflate it. Balloon *a* should now press against the inside of the cup with sufficient force to keep Balloon *b* from deflating. Attach the assembly to two soda straws which have been strung on a light-weight wire. Holding the wire taut, release Balloon *a*. When it has deflated sufficiently, it will release Balloon *b*. Compare to multistaging of launch vehicles.

F. Space Shuttle launch

The Space Shuttle is launched by reusable solid rocket boosters in combination with the Orbiter's own main rocket engine, which is fueled from a tank that drops away in orbit. The solid rocket boosters are jettisoned after burnout and fall back to earth with parachutes; they are then retrieved and can be used again.

I-U. Make a model of the Space Shuttle. (See U.S. NASA *Space Shuttle*. EP-96 or SP-407.)

U. Discuss the advantages of having rockets be reusable.

U. Launch a model rocket. What has to be done to it to prepare it for another launch?

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Daugherty. *Robert Goddard* (U)
Goodrum. *Wernher Von Braun* (U-T)
Hendrickson. *Who Really Invented the Rocket?* (I-U-T)
Holder. *Saturn V* (U-T)
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Pacilio. *Discovering Aerospace* (U-T)
Stoiko. *Pioneers of Rocketry* (U-T)
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UNIT IV

Technological Advances

Outline

Technological advances had to be made in many areas before we could launch a vehicle into space beyond the Earth's atmosphere.

A. Management techniques, which make it possible to coordinate many subsystems within the total system for development and launching of spacecraft, have been developed.

B. Power supply of from 10-100 watts is needed to operate instruments aboard the spacecraft.

1. Chemical batteries are used to store or change chemical energy to electrical energy.

2. Solar cells convert sunlight into electrical energy.

3. Fuel cells generate electricity chemically through a reaction between a fuel (frequently hydrogen) and oxygen.

C. Tracking systems are used to locate and guide spacecraft.

1. The shape and location of an orbit depend upon the spacecraft's velocity and flight path.

2. Satellites can be controlled from Earth by radio signals.

3. On-board propulsion systems are used to generate additional thrust, to change orbital paths, and to change attitude (inclination) of the spacecraft.

D. Data from both manned and unmanned spacecraft are collected on Earth.

1. Numerous instruments have been developed to monitor environmental conditions, operating modes, and biological reactions of life aboard the spacecraft.

2. Recoverable spacecraft are returned to Earth by firing retrorockets to decrease velocity to less than orbital speed.

3. Passive unmanned satellites did not transmit radio signals, while active ones receive and transmit radio signals automatically or on command from Earth.

4. Information relayed from spacecraft is transmitted in computer codes and collected by computers which then translate the information into numerical data or pictures.

E. Spacecraft are designed to meet the purposes of the scientific investigation planned and to withstand the rigors of the space environment.

1. Spacecraft frequently are symmetrical around a central axis to resist launch acceleration stresses and to permit spin-stabilization.

2. The spacecraft, its biological specimens and its instrumentation, must be protected from extremes of temperature, the near vacuum of space, radiation, high-g forces, and micrometeorites.

Outline

Technological advances had to be made in many areas before we could launch a vehicle into space beyond the Earth's atmosphere.

Activities

**I-U.* Develop a time line of important events in the history of space flight up to the beginning of unmanned flight. Continue to add to the time line, bringing it up to date as other events are studied.

I-U. Draw or paint pictures to illustrate a booklet titled "Famous Firsts in Space."

I-U. Make a list of aerospace terms and find the source of the root words or the origin of the terms.

P-I-U. Develop a picture dictionary of aerospace terms.

P-I. Write and read chart stories about space programs.

P-I-U. Write a riddle about some object related to the exploration of space.

I-U. Play "Twenty Questions" using space-related terms and names.

P-I-U. Write a story using words from a list of space-related terms.

I-U. Interview someone in the neighborhood who is working on a space project.

U. Survey several blocks of the neighborhood to find and inteview people employed in space-related industries.

I-U. Invite as a speaker someone who is employed in a space-related industry.

U. Choose two teams and compete in finding careers or industries that have *not* been affected directly or indirectly by the space program. Be prepared to challenge the opposing team's list.

I-U. How can techniques developed for use in one area be applied to another? Conduct a class poll to find which children have parents in occupations which could be affected by the aerospace industry.

U. Discuss the question of spending money on more space research, on the "war on poverty," on energy, and on pollution control.

Research

Development of a silicone sealant for use on spacecraft

Electronic switch operated by eye movements

*Suggested age level: P(5-7), I(8-9), U(10-11).

Nondestructive testing techniques such as electronic radiography

Laminar flow clean-room techniques

Historical development of NASA

Problems involved in exploration of space

Progress in miniaturization of component parts

Development of computers

Development of fireproof materials

Advances in photography

Biomedical instrumentation

Advances in telecommunication

Mylar

Radar

Lasers

NASA John F. Kennedy Space Center, Florida

Pinpoint size ball bearings used in dental drills, originally developed for use in satellites

NASA Goddard Space Flight Center, Greenbelt, Maryland

Recent social and economic developments resulting from space program

Manufacturing in space

A. Management techniques

Management techniques, which make it possible to coordinate many subsystems within the total system for development and launching of spacecraft, have been developed.

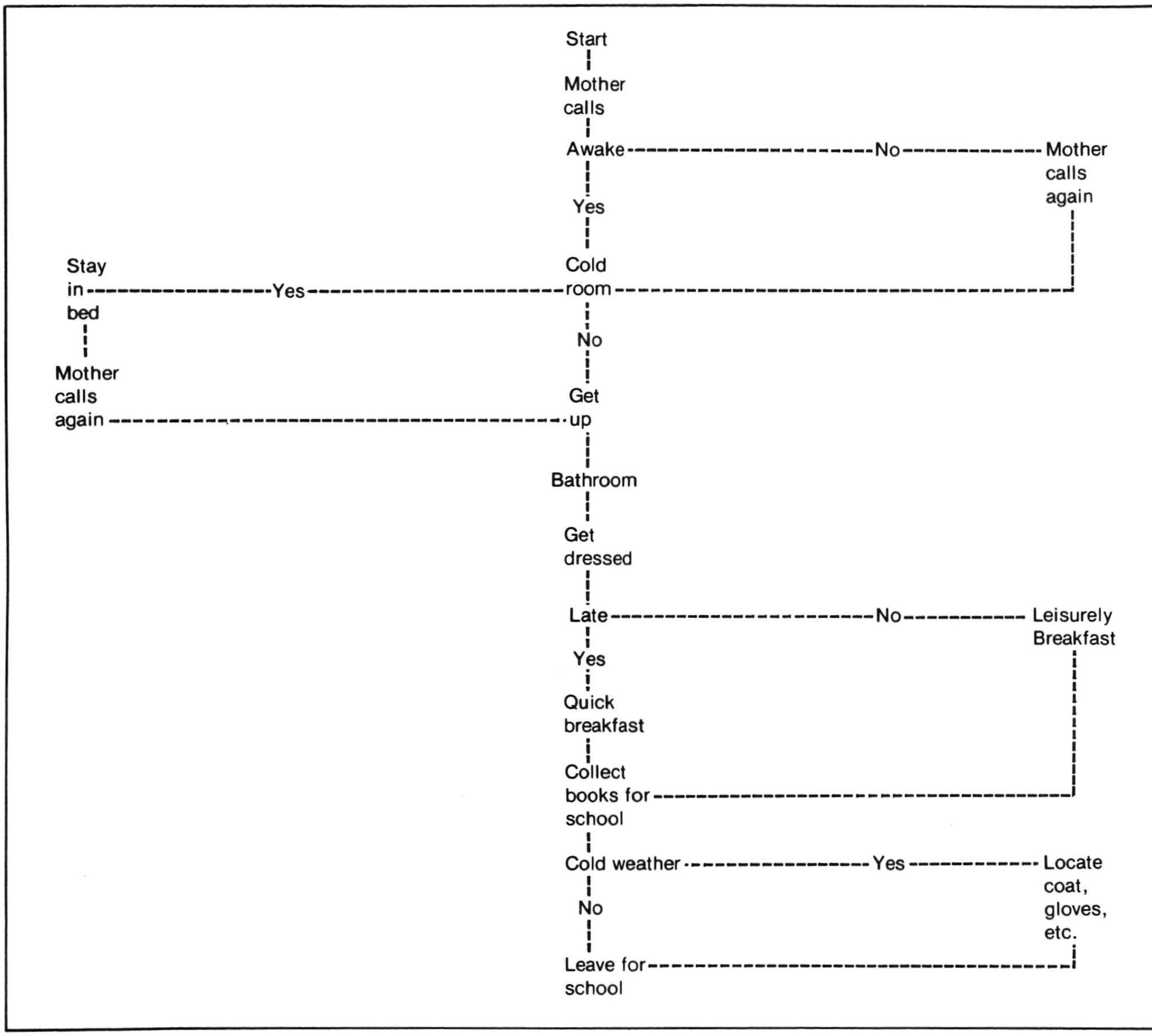
I-U. Develop a flow chart for accomplishing a task, indicating each step necessary to completion of the task.

U. Discuss the possibilities of using new management techniques to solve city problems or environmental problems.

Research

Spacecraft subsystems such as propulsion, navigation, biotechnical power

Example of flow chart for getting up and getting ready to leave for school . . .



B. Power

Power supply of from 10-100 watts is needed to operate instruments aboard the spacecraft.

I-U. Make a list of spacecraft instruments that need electrical power for operation. Which would need more (or less) power?

I-U. Make a circuit with one dry cell, a flashlight bulb, and a light socket. Add a second dry cell to the circuit in a way that will increase the brightness of the light. Try using one dry cell and several lights.

I-U. Write a story giving a selected instrument a personal dimension. Let the humanized instrument tell his tale of his importance in an imaginary space flight.

Research

Origin and meaning of the following terms: watts, kilowatts, volts, amperes, ohms

RTG (radioisotope thermoelectric generator)

1. Chemical batteries

Chemical batteries are used to store or change chemical energy to electrical energy.

I-U. Carefully examine an old dry cell that has been cut lengthwise down the center with a hacksaw. The dull metal can is made of zinc and is the negative terminal. The rod in the center is of carbon and is the positive terminal. The material between the zinc can and the carbon rod contains three chemicals: ammonium chloride (white), carbon particles and manganese dioxide (black). Compare dry cells to batteries used on the spacecraft.

I-U. Make a collection of old dry cells and batteries. Compare sizes and number of volts generated by each.

U. Make a circle graph showing the percentage of each chemical in the dry cell. Construct a dry cell changing the percentages of chemicals. What will the result be?

I-U. Make a coil of copper wire. Place a compass within the coil. Attach the free ends of the copper wire to different kinds of metal strips (a penny and a dime may be used). Place the strips of metal on opposite sides of a piece of sponge that is wet with acetic acid (vinegar). The movement of the compass needle is evidence of a flow of electricity through the coil of wire.

I-U. Attach a strip of zinc to a wire connected to one terminal of a galvanometer. Attach a strip of copper to a wire connected to the other terminal. Place the zinc and copper strips, not touching each other, in a glass jar containing an ammonium chloride solution. Observe the movement of the galvanometer needle as current is generated by the chemical action in the wet cell.

Research

Automobile batteries

Nickel-cadmium, silver-cadmium, mercuric oxide-zinc, and silver-zinc batteries

Voltaic cells

Alessandro Volta

2. Solar cells

Solar cells convert sunlight into electrical energy.

I-U. Draw a picture or make an aluminum foil model to represent a solar cell.

I-U. Find and display pictures of satellites that use solar cells for electrical power.

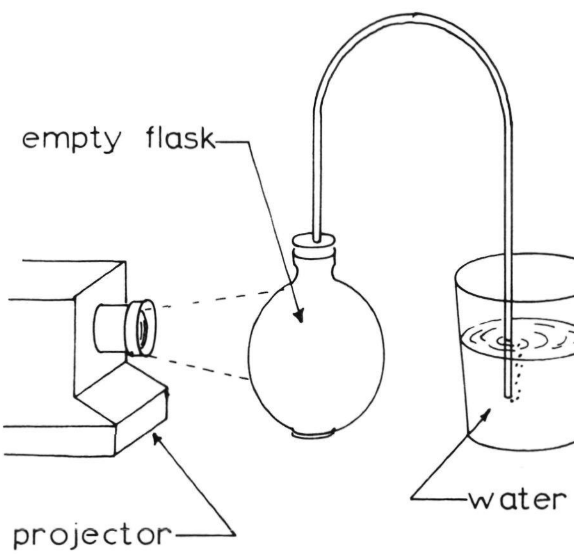
I-U. Obtain a solar cell from a hobby shop and, using a voltmeter, test its voltage in the dark, in the sunlight, and under artificial light. Connect the solar cell in a circuit with a flashlight bulb and observe the change in the bulb's brilliance as the intensity of the light striking the solar cell is varied.

P-I-U. Place a radiometer in the sunlight and observe the effect of the Sun's radiant energy. Do other sources of light have the same effect?

I-U. Demonstrate that light energy can be changed to heat energy. Fit a bottle with a one-hole stopper. Place one end of a U-shaped piece of glass tubing in the stopper, the other end in a glass of water. (Rubber tubing may be used in place of the U-shaped glass tubing if an air-tight seal is made.) Place a slide projector about 1.5 meters (5 feet) from the empty bottle, and shine the beam of light from the projector on to the bottle. As the air in the bottle is heated by the light, air bubbles will be seen coming from the end of the tubing which is under the water in the glass.

Research

Find evidence to show that light energy can be changed to heat energy



3. Fuel cells

Fuel cells generate electricity chemically through a reaction between a fuel (frequently hydrogen) and oxygen.

Research

Fuel cell research

Biochemical fuel cells

C. Navigation and guidance

Tracking systems are used to locate and guide spacecraft.

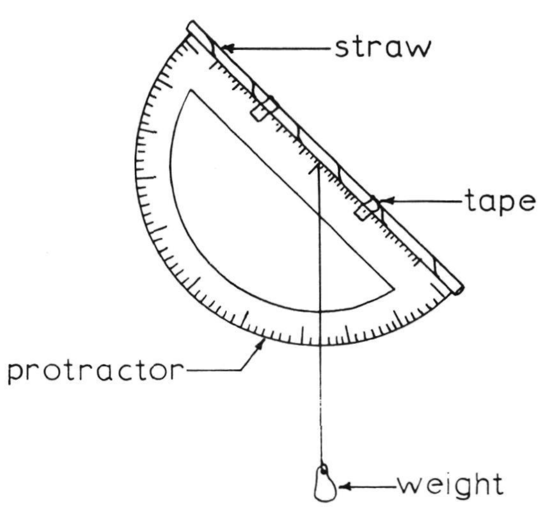
I-U. Locate tracking stations on a map or globe.

Approximate Coordinates of Selected NASA Tracking Stations

Fairbanks, Alaska	64°N; 147°W
Ascension Island	8°S; 14°W
Goldstone, California	35°N; 117°W
Guam	13°N; 144°E
Hawaii	21½°N; 159°W
Madrid, Spain	40°N; 3°W
Quito, Ecuador	0°; 78°W
Rosman, North Carolina	35°N; 82°W
Santiago, Chile	33°S; 70°W
Merritt Island, Florida	28°N; 81°W

I-U. Show why the path of a spacecraft's orbit is shown as a wavy line on a flat map.

I-U. Use map of tracking stations to find distances between monitoring stations.



1. Orbit

The shape and location of an orbit depends upon the spacecraft's velocity and flight path.

I-U. To demonstrate the way in which a tracking station (receiver) locates a satellite (transmitter), turn on a transistor radio and tune it to a station. Turn the radio, noticing the variations in the strength of the signal received. What is the relationship between the location of the radio station (transmitter) and the transistor radio (receiver)? If this experiment were conducted from another location, where would the radio point? If these lines of direction were plotted on a map, where would they intersect?

I-U. Curve a length of cardboard vertically into a semi-circle. Prop it so that it stays in that position. Place a small box on its side at a point equally distant from all points on the semi-circle. Starting from a distance behind the box, roll a marble or other round object against the cardboard with a force sufficient to cause it to be reflected back. Observe that it tends to roll toward the box at the center point. Compare to the way a dish antenna collects radio signals and focuses them at one point.

I-U. Demonstrate the problem of hitting a moving target from a moving target. Have one person running in a large circular path to represent Earth's orbit, and someone else running in a circular path around the first person to represent the Moon's orbit around Earth. Have the runners attempt to play catch without stopping their forward motion.

I-U. Make a simple sextant. Fasten a soda straw along the straight edge of a protractor. Suspend a weight on a string from the center of the straight edge. Sight through the straw toward the North Star. Read the degree marking on the protractor at the point where the string hangs across it. This is the approximate altitude of the North Star and is approximately the latitude of the sighting location.

Research

How tracking stations function

Guidance systems used for long-range flight, for short-range flight

Sextants

P-I-U. Demonstrate inertia by pushing a small model car. Observe that force is needed to start it moving and that it will keep moving until something stops it such as air, friction against the wheels, or other objects.

P-I-U. Attach a rubber band to the front of a toy truck. Pull on the rubber band to move the truck at a constant speed. Observe that more pull is needed at first to overcome inertia than is needed once the truck has started moving.

P-I-U. Cut away one end of a shoe box. Place a small rubber ball inside the box. Slide the box quickly along the table, open end forward. The ball will remain at the closed end of the box until the box stops.

P-I-U. Stack four or five checkers in a single stack. From 5-8 centimeters (2-3 inches) away, flick another checker at the bottom of the stack. The bottom checker will fly away; the stack will remain.

P-I-U. Place a coin on a small square of heavy cardboard placed on a drinking glass. Flick the cardboard from under the coin. Coin will fall into the glass.

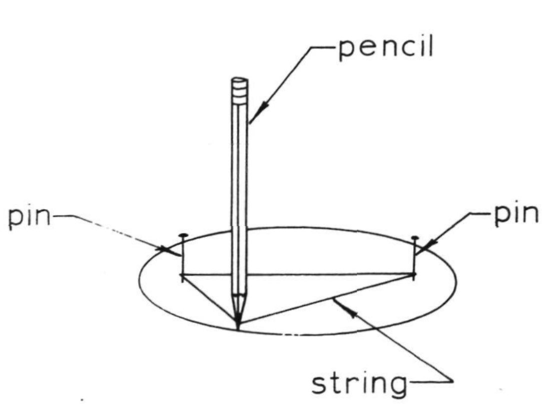
P-I-U. Seat or stand a doll at the back end of a shoe box which has been attached to a roller skate. Then give the skate a push so that it will roll across the floor and hit a brick or other heavy object. Repeat the experiment with the doll sitting with its back against the front end of the box. Observe the difference in what happens to the doll in the second collision as compared to the first. In the first collision, the doll lunges forward due to inertia of motion. In the second collision, the doll is restrained by the wall of the shoe box, and there is very little movement.

P-I-U. Demonstrate centrifugal effect by placing a small object on a phonograph turntable and watching it spin away.

I-U. Tie a ball on the end of a string, and twirl it around your head. Change the length of the string and notice the difference in the amount of speed needed to keep the ball in orbit. While twirling the ball, release the string and observe the direction the ball travels.

I-U. Swing a bucket of water overhead. Notice that the water stays in the bucket because of the centrifugal effect.

I-U. Draw an ellipse to represent an orbit. To do this, place two pins about 7.5 centimeters (3 inches) apart in a piece of cardboard. Make a loop of a piece of string that is over 15 centimeters (6 inches) long. Place loop around pins. With a pencil upright inside the loop, pull the loop taut and draw a line.



Activities related to gravity may be found in Unit II B, Pages 19-20.

2. Control

Satellites can be controlled from Earth by radio signals.

I-U. Invite a ham radio operator to tell the class about monitoring satellites.

I-U. Invite the owner of a radio-controlled toy car or plane to demonstrate the ways the vehicle can be controlled by radio signals.

I-U. Activities related to wave reflection may be found in Unit I A, Page 9.

Research

Fountain pen-size ultrasonic alarm

3. Guidance

On-board propulsion systems are used to generate additional thrust, to change orbital paths, and to change attitude (inclination) of the spacecraft.

P-I-U. Observe the movement of the arms of a rotating water sprinkler as it reacts to the jets of water.

I-U. Using a nail, punch two holes near the bottom, in opposite sides of a can, twisting the nail to one side (same direction for both holes). Suspend the can so that it can turn freely. Pour water into the can and observe movement.

I-U. Punch two holes near the top in diagonally opposite sides of a rectangular can that has a friction lid or stopper (not a screw-top lid). Insert and seal into place in the holes either metal or glass tubing bent at a 90° angle. The tube openings should both point either clockwise or counterclockwise in the same rotational direction. Add a small amount of water and suspend so that the can will turn freely. Heat until steam escapes from the "jet" tubes and causes the Hero engine to rotate.

Additional activities related to Newton's third law of motion (action and reaction) may be found in Unit II B, Pages 20-21 and Unit III A, Pages 28-29.

D. Data collection

Data from both manned and unmanned spacecraft are collected on Earth.

P-I-U. Pour water into a large shallow glass container and place on an overhead projector. Drop a pebble in the water. Watch the waves spread out around the spot where the pebble was dropped. Compare this to the way radio waves travel through the Earth's atmosphere.

P-I-U. Drop a large rock in a small pond or slowly moving stream. Watch the waves spread out around the spot where the rock fell. Observe how long they stay visible, the size of the waves, and how they decrease with distance. Compare to radio waves traveling through Earth's atmosphere.

P-I-U. Attach a small radio to the end of a meter stick. Tune in a local station, normal volume. Hold the meter stick by the other end, and extend it at arm's length. Slowly turn in place so that the radio moves through a complete circle. Observe the change in volume as the radio moves. What causes this change?

P-I-U. Illustrate the reflection of radio waves. Place a piece of paper on a table top. Position a filmstrip projector so that its beam shines through the teeth of the comb and falls beyond the comb, onto the paper. Place a mirror on the paper behind the comb so that the beam is reflected. Observe that the angle of reflection changes as the mirror is moved.

Research

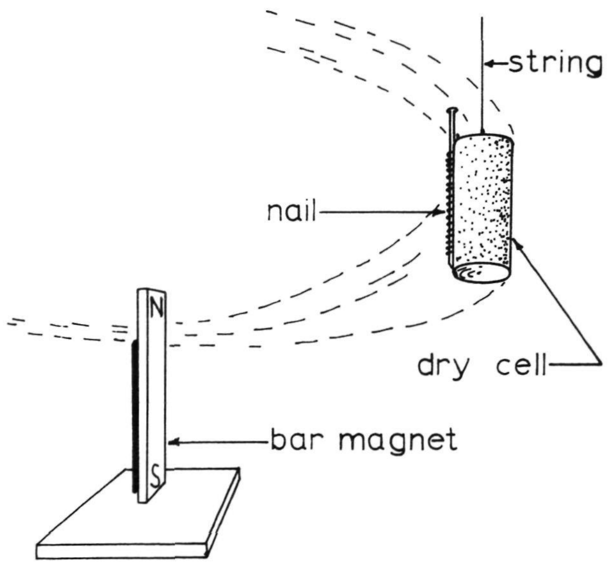
Telemetry

1. Instruments

Numerous instruments have been developed to monitor environmental conditions, operating modes, and biological reactions of life aboard the spacecraft.

P-I-U. Demonstrate the way in which satellites utilize the Earth's magnetic field to keep them Earth oriented. Make an electromagnet by wrapping several turns of wire around a large nail. Tie the electromagnet to the side of a dry cell leaving a length of string. Do not connect the wires to the dry cell. Support a strong bar magnet in an upright position (to represent Earth's magnetic field).

Holding the electromagnet and dry cell unit by the string so that it will swing freely, pass the unit (satellite) around the bar magnet. Observe that the bar magnet has little effect upon the unit. (The satellite is space oriented.) Now connect the electromagnet wires to the dry cell. Again pass the unit around the bar magnet and observe that the unit tends to turn to keep the same end toward the bar magnet. (The satellite is now Earth oriented.)



Research

Application of space technology to everyday life

Possible chemical control of cancer

Electron microscopes

Transducer for fitting artificial limbs

EKG transmitting system using spray-on electrodes

Heart monitor used to measure electrical signals from heart wall

Sensor for monitoring the breathing of comatose patients

Sensor developed for use in wind tunnel research that can be used to measure blood pressure within arteries or veins

Thermocouples

Scintillation (radiation) counters

2. Recoverable spacecraft

Recoverable spacecraft are returned to Earth by firing retrorockets to decrease velocity to less than orbital speed.

Activities related to Newton's third law (action and reaction) may be found in Unit II B, Pages 20-21, Unit III A, Pages 28-29, and Unit IV C, Page 44.

Research

Sonar "Pinger" used to locate objects in the ocean

Biosatellite recovery

3. Passive unmanned spacecraft

Passive unmanned satellites did not transmit radio signals, while active ones receive and transmit radio signals automatically or on command from Earth.

P-I-U. Discuss the differences between active repeater satellites such as the present Intelsat or former Telstar, and former passive satellites such as Echo.

P-I-U. Compare the differences in speed and force of a ball rebounding from a surface to a ball being thrown back by another person. In what way is this comparable to the differences in transmission between an active and a passive satellite?

Research

Radar

Sonar

Earth equipment for receiving signals from satellites

4. Computers

Information relayed from spacecraft is transmitted in computer codes and collected by computers, which then translate the information into numerical data or pictures.

I-U. Make up a space code. Transmit and receive messages in code, and decode them.

I-U. Make up and solve mathematical problems using base 2 and base 8.

I-U. Compare paint-by-number hobby painting to the translation of computer code into pictures.

I-U. Demonstrate the way in which a binary computer operates. Prepare six 30 x 45 centimeter (12 x 18 inch) cardboard sheets with a large 0 on one side and the numeral 1 on the other side. Have students hold these cardboard sheets or stand the sheets upright in the classroom chalk rail. Above each cardboard sheet (from left to right) indicate the place value of the position as 2^0 (units), 2^1 (twos), 2^2 (2 x 2), etc. By turning the cards to show either the 0 or the 1, practice representing base ten numbers in base two. Develop a code which uses numerals to represent letters of the alphabet, or words, and practice sending messages with the "computer."

U. Write a computer program to solve a simple mathematical problem. See example below.

Problem: How far does light travel in one year if it travels 186,000 miles per second?

Mathematical solution: 186,000 x 60 x 60 x 24 x 365 = 5,865,696,000,000

Computer program to solve problem:

```
XMILES = 186E3 * (60. ** 2) * 24. * 365.
PRINT 1, XMILES
1 FORMAT (1H, 7HMILES =, E14.8)
STOP
END
```

Explanation of code:

186E3—186 multiplied by 10 three times

*—code for multiply

** 2—multiply 2 times

PRINT 1, XMILES—print the answer as directed in the FORMAT line

1H—double space before printing answer

7HMILES—print "miles" in seven spaces

E14.8—print answer using 8 decimal places plus a numeral which indicates how many times to multiply the answer by 10.

Computer answer as printed by computer would be: .586569600E 13

Answer multipled by 10, 13 times is: 5,865,696,000,000

Research

Development of computer techniques and programing

Use of computers in everyday life

Number bases and why they are related to computer codes

Computer use to take attendance in a Sacramento, California, high school

Computer-enhanced X-rays

Use of computers to check assembly line operations

Use of computers by the U.S. Postal Service in small sack and parcel sorting

E. Spacecraft design

Spacecraft are designed to meet the purposes of the scientific investigation planned and to withstand the rigors of the environment.

P-I-U. Design a spacecraft or satellite and explain reasons for design details.

Research

Scientists associated with the development of spacecraft

1. Symmetry

Spacecraft frequently are symmetrical around a central axis to resist launch acceleration stresses and to permit spin-stabilization.

P-I-U. Draw or paint pictures of satellites of different shapes.

I-U. Make models of satellites. (See Ross. *Model Satellites and Spacecraft.*)

P-I-U. Make mobiles of satellites.

P-I-U. Observe that the spin of a toy gyroscope gives it stability.

P-I-U. Add pieces of clay to one side of a child's toy top and observe how this lack of symmetry affects the spin.

I-U. Find the center of gravity of an irregularly shaped flat object. Suspend the object and a weighted string so that they swing freely from the same point. Mark the vertical line the string describes on the object. Suspend the object from at least 2 other points on its periphery and again mark the vertical lines. The point where the lines cross is the center of gravity.

2. Protection of payload

The spacecraft, its biological specimens and its instrumentation, must be protected from extremes of temperature, the near vacuum of space, radiation, high-g forces, and micrometeorites.

P-I-U. Demonstrate the heat of radiation by focusing sunlight through a magnifying glass on a piece of paper. USE CAUTION: The paper may burst into flame.

P-I-U. Demonstrate differences in the absorption and radiation of heat. Paint half of a large can, both inside and outside, with black paint. Polish the other half with steel wool until it is bright and shiny. Place the can over a light bulb (like a lamp shade) so that the shiny and the black surfaces are equal distances from the bulb. Turn on the bulb and feel the difference in the amount of heat radiated through the can. USE CAUTION: The can may become hot enough to cause a burn. Determine the differences by measuring the temperatures with a thermometer.

P-I-U. Paint one of two identical cans with flat black paint. Polish the outside of the other with steel wool. Place equal amounts of water at the same temperature in the cans. Place cans in sunlight. Over a period of time record the changes in temperature. In which can does the water heat up faster?

P-I-U. Place thermometers under various types of insulating materials such as asbestos, several layers of aluminum foil, rubber, heat-resistant materials, etc. Subject the surfaces of the insulating materials to many kinds of heat including infrared rays, Bunsen burner flame, floodlight heat, sunlight, electric hot plate. Compare the results. Which insulation provided the best protection? Record data in a table to compare the results.

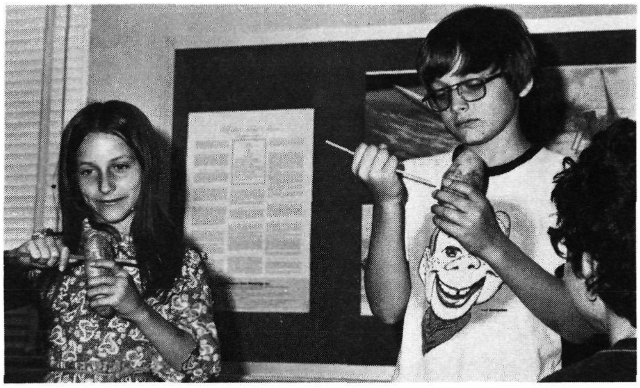
P-I-U. Place equal amounts of ice in a brown paper bag and a metallic ice cream bag. Seal the tops. In which bag does the ice melt first?

P-I-U. Demonstrate insulation properties of various materials. Fill two small jars with water of the same temperature. Put one into a larger container. Place both in sunlight. Over a period of time record the changes in temperature of the water. Repeat, filling air space between large container and water container with various materials, such as sawdust, soil, etc.

I-U. Demonstrate that the circulation of liquids can reduce heat. Pour some water into a paper cup and hold the cup over a flame. Observe the effect of the flame on the cup as the water boils. Continue boiling until the water evaporates. Observe the effect of the flame on the dry cup. USE CAUTION: When dry, the cup will burn.

P-I-U. Discuss the g-force experienced on a carnival ride or in a car that accelerates or stops suddenly. Compare reentry to slamming on the brakes of a speeding car.

Activities related to inertia may be found in Unit IV C, Pages 42-43.



I-U. Watch the night sky during a meteor shower. Dates of some of the annual meteor showers are given below.

Quadrantids	Jan. 1-3
Lyrids	April 21
Eta Aquarids	May 4-6
Delta Aquarids	July 28
Perseids	Aug. 12
Orionids	Oct. 20-23
Taurids	Nov. 3-10
Leonids	Nov. 17
Geminids	Dec. 12-13

P-I-U. Demonstrate the penetrating power of an object of small mass but high velocity, such as a micrometeroid. Hold a raw white potato in one hand. (USE CAUTION: Hand should not be behind potato.) With a quick, sharp motion, stab the potato with a soda straw. The straw should pierce the potato. Try a slower motion and compare the result. (The straw will not pierce the potato.)

P-I-U. Demonstrate the effectiveness of a meteoroid bumper or shield for spacecraft. Suspend a sheet of plastic or foil about 2.5 centimeters (1 inch) above a sand or mud surface. Drop stones of varying sizes from varying heights and observe the ability of the shield to absorb some of the energy of the projectile. Repeat without the shield in place, and compare the differences in penetration.

Research

Spacecraft insulation materials

Orionid meteors

Corning ware

Miss Baker, a monkey, launched into space in early experiments

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Dalton. *All About Energy* (P-I-U)
Gurney. *The Launching of Sputnik* (U)
Knight. *Eavesdropping on Space* (U-T)
May. *Astronautics* (P-I)
Moore. *Cosmic Debris* (I-U-T)
Parker. *Satellites and Space Travel* (U-T)
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U.S. NASA. *Medical Benefits from Space Research* (T)
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UNIT V

Unmanned Earth Satellites

Outline

Unmanned Earth satellites can be categorized according to their purpose.

A. Weather satellites are used to collect data for more accurate and longer range weather forecasts.

B. Communication satellites have made it possible to relay radio, television, and teletype messages around the Earth.

C. Earth observation satellites are used to collect information about the Earth.

1. Geodetic satellites are used to collect data to describe the shape of the Earth, to determine the structure of its gravitational field, and to prepare more accurate terrestrial maps.

2. Earth resources satellites are used to collect data on the oceans and their behavior; to aid in surveying the Earth's crust, the uses to which it is being put and the way it is being polluted; and to locate and assess its resources.

D. Applications Technology Satellites (ATS) are multipurpose satellites designed to test new equipment in the space environment.

E. Biosatellites are launched to test the effect of weightlessness, cosmic and solar radiation, acceleration, and other space phenomena on biological specimens.

F. Physics and astronomy satellites are used to collect data about the Sun, the Earth—its upper atmosphere, ionosphere, and magnetosphere—interstellar space, and the galaxies and their components.

G. The United States cooperates with other nations in the building, planning, including experiments, and launching of unmanned satellites.

Outline

Unmanned Earth satellites can be categorized according to their purposes.

Activities

***I-U.* List and discuss the kinds of information that can be collected efficiently by satellites above the Earth's atmosphere.

P-I-U. Draw or paint pictures of real and imaginary satellites.

P-I-U. Write stories, individually or collectively, about satellites and the work they do.

U. Make paper models of satellites to use as mobiles. (See Ross. *Model Satellites and Spacecraft.*)

P-I. Make a pictionary illustrating aerospace terms. Draw pictures or collect them from old magazines.

P-I-U. Dramatize the launching of a satellite.

P-I-U. Make a collection and display pictures of different kinds of satellites.

U. Panel discussion or debate: Various aspects of government and private enterprise control and operation of satellites.

U. Discuss advantages and disadvantages of medium-altitude and high-altitude Earth-orbiting satellites, as well as satellites of which the altitude can be changed.

Research

Navigation systems using satellites.

Kinds of launch vehicles and satellites

Origins of the names of the satellites

Atmosphere Explorers (Explorers 54 and 55)

A. Weather satellites

Weather satellites are used to collect data for more accurate and longer range weather forecasts.

P-I-U. Discuss reasons for the need for improved weather forecasting.

I-U. Make a time line showing changes in methods of forecasting weather.

I-U. Discuss how weather forecasting, using data from satellites, has benefited agriculture, transportation, and other industries.

U. Discuss or debate the topic: Weather should be controlled by man.

P-I-U. Build models of weather satellites.

P-I-U. Collect and display pictures of clouds taken by satellites. Try to identify weather patterns from the cloud formations.

Research

History of weather reporting

Use of weather satellite information in hurricane warning systems

*Suggested age level: P(5-7), I(8-9), U(10-11).

Farmer's Almanac and weather forecasting

National Oceanic and Atmospheric Administration (NOAA)

Old sayings related to weather

Use of infrared spectrometers in collecting weather data

Automatic Picture Transmission (APT)

International cooperation in the use of weather satellite data

TIROS satellites

Cameras

Nimbus satellites

NOAA satellites

B. Communication satellites

Communication satellites have made it possible to relay radio, television, and teletype messages around the Earth.

I-U. Make a time line showing important changes in ways of communicating.

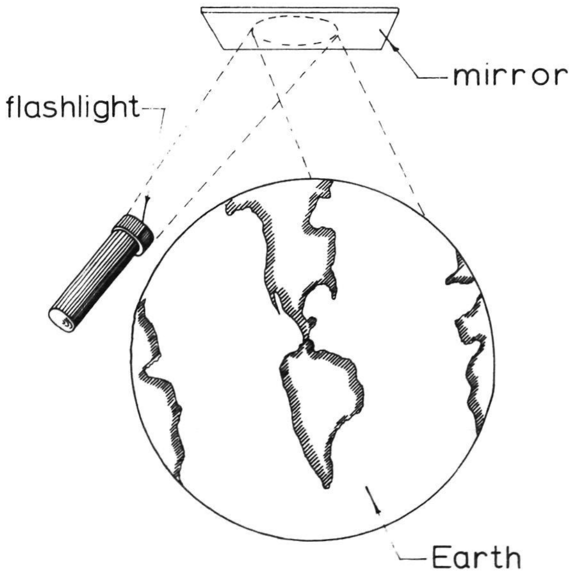
I-U. Compare and contrast worldwide communication by satellite to communication by cable.

P-I-U. Make models of communication satellites.

P-I-U. Draw or paint pictures of the different kinds of communication satellites.

I-U. Use models or a mobile to illustrate the way 3 synchronous-orbit satellites provide a worldwide communication network. Discuss the value of such a network to military surveillance, news dissemination, entertainment, etc.

I-U. Illustrate the way in which synchronous-orbit communication satellites work. Use a flashlight beam to represent a broadcast signal. Tape or hold the flashlight on a globe. Direct the beam to a small hand mirror (representing a satellite) held above the globe. Reflect the beam to a point as far as possible away from the origin of the beam.



Research

NASA's role in developing communications satellites

Laser

Communications Satellite Corporation (Comsat)

Syncom

Intelsat

Telstar

Transoceanic communication systems

Satellites and world education

Satellites and television

How the Sun affects communications

How a television picture is transmitted and received

C. Earth observation satellites

Earth observation satellites are used to collect information above the Earth.

P-I-U. List items of information that people need to know about the Earth. Discuss the best ways of obtaining each item of information.

1. Geodetic satellites

Geodetic satellites are used to collect data to describe the shape of the Earth, to determine the structure of its gravitational field, and to prepare more accurate terrestrial maps.

P-I-U. Hold a small ball close and observe its roundness. Observe a large ball from a similar distance. The large ball does not appear to be as round. Compare to our inability to realize the curve of the Earth's surface because of our closeness.

P-I-U. Compare the appearance of a model car or ship as it is moved closer to the eyes, along a flat surface and a curved surface held near eye level. Compare to the way a distant object appears to rise above the Earth's horizon.

I-U. Make a 3-dimensional clay model of your state. Use a scale that will result in a model small enough to photograph from a height of about ten inches. Compare to satellite photography of the Earth's surface.

I-U. Pretend you live on the Moon. Plan a way to map the surface of the Earth without traveling to Earth.

I-U. Using an aerial photograph for reference, draw a map of a specific area.

I-U. Make a collection of news stories about geodetic satellites.

Activities related to the Earth's magnetosphere may be found in Unit I B, Pages 10-12, on the ionosphere in Unit I A 6, Page 9.

Research

Early methods used in mapping

Cooperation with foreign countries in Earth resources surveys

Map projections

LAGEOS (Laser-reflecting Geodetic Satellite)

GEOS-3 (Geodetic satellite)

2. Earth resources satellites

Earth resources satellites are used to collect data on the oceans and their behavior; to aid in surveying the Earth's crust, the uses to which it is being put and the way it is being polluted; and to locate and assess its resources.

P-I. Fill a wide-mouthed glass jar with cold water. Fill an identical jar with hot water to which a bit of food coloring has been added. Cover the cold-water jar with a piece of cardboard and turn it upside down over the other jar, being sure the mouths line up evenly. Carefully pull the cardboard out. Observe the way the cold water sinks and the colored hot water rises into the top jar in currents. Relate to ocean currents and the way that heat-detecting infrared film can reveal currents.

I-U. Obtain copies of multispectral photography of both land and oceans and observe the differences that are seen in different land and different sea pictures. (Source: EROS Data Center)

I-U. Different details can be seen at different distances. While kneeling down, take a photograph of a patch of grass or pebbles in the school yard. Stand up and take a photo of the same area. If possible, use a step ladder to take another photo. Go to a high floor or the roof of the school and take a fourth photo. Study the four photos. How are they the same, how are they different in the detail and total area that can be seen? Relate to aerial and satellite photography.

U. Take color photographs of the same scene through different color filters. (Colored cellophane may be used instead of filters.) Relate to multispectral photography of Earth's surface.

U. Take photographs of familiar scenes using black and white infrared film available through regular camera shops; be sure to load film in the dark. Compare the photos with standard photos of the same scenes.

U. Demonstrate resolution. Paint two black dots, each about 1 centimeter (1/2 inch) in diameter and the same distance apart, on a white card. Place the card upright on the far side of the room. Have several students in turn walk toward the card and say when the two dots can be distinguished separately. Measure the distance from the card to the student. Relate the results to resolution of a camera aboard an aircraft or satellite.

U. Prepare dot cards like that described above but use red paint on one and blue on another. Repeat the resolution activity. How do the resolution distances for red and blue compare to each other, to black? Relate to multispectral photography.

I-U. Invite a speaker from the Agricultural Stabilization and Conservation Service, or some other agency or industry that uses LANDSAT imagery, to describe ways in which the imagery is used.

I-U. Place a radiometer in a sunny window. Observe the effects of differences in the amount of cloud cover on the operation of the radiometer.

Research

LANDSAT satellites (formerly ERTS, Earth Resources Technology Satellites)

SEASAT (Sea Satellite)

Find out how multispectral photography is used to detect plant disease, thermal pollution, forest fires, water pollution, development of urban areas, etc.

Polarized light

Spectroheliometer and spectroheliograph

Find out how satellites are being used to help the fishing industry

D. Applications technology satellites

Applications Technology Satellites are multipurpose satellites designed to test new equipment in the space environment.

Research

Find out what equipment was tested on each of the ATS satellites

The first color photos of Earth from space, taken by ATS-3

ATS-6 communication program in Appalachia, the Rocky Mountain area, Alaska, and in India

Purposes of ATS-1-5

E. Biosatellites

Biosatellites are launched to test the effect of weightlessness, cosmic and solar radiation, acceleration, and other space phenomena on biological specimens.

P-I-U. Discuss: "Life Without Gravity."

I-U. Discuss effects of radiation on Earth if there were no protective shielding by the atmosphere and magnetosphere.

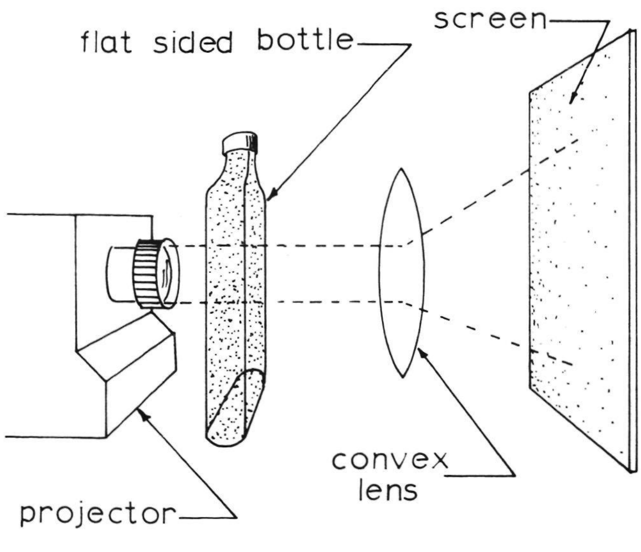
Additional activities related to radiation may be found in Unit I A, Page 8.

Research

NASA Ames Research Center, Moffett Field, California

F. Physics and astronomy satellites

Physics and astronomy satellites are used to collect data about the Sun, the Earth—its upper atmosphere, ionosphere, and magnetosphere—interstellar space, and the galaxies and their components.



I-U. Illustrate how the temperature of the Earth's atmosphere interferes with clear viewing of the universe. Hold a test tube one-half filled with very hot water in front of a bright light. While looking through the test tube, add cold water. Note the turbulence lines called a schlieren pattern.

I-U. On a cold day observe the air turbulence above a hot radiator.

I-U. Fill a flat-sided clear glass bottle half full of hot water. Shine the light from a projector through the bottle onto a screen through a large convex lens held between the bottle and screen. Add cold water. Observe the schlieren pattern.

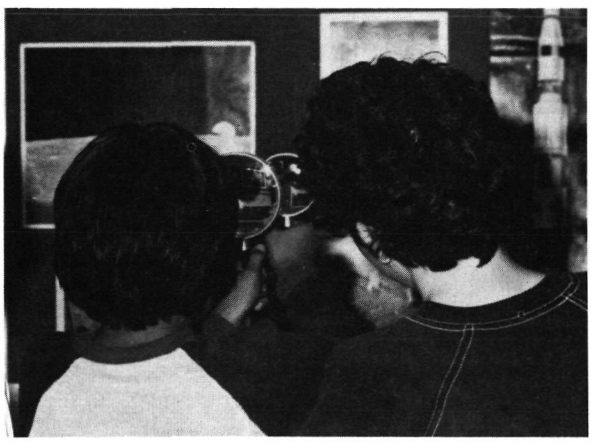
Other activities related to atmospheric interference may be found in Unit I A, Page 3.

I-U. Collect news items about the orbiting observatories.

I-U. Discuss solar data that have been collected by satellites.

P-I-U. Visit an observatory or planetarium.

P-I-U. Demonstrate the reflection of light by the planets. Use a polished metal ball to represent the planet and a light bulb to represent the Sun.



P-I-U. Compare visibility of a flashlight beam in a darkened room to its visibility in bright sunlight to illustrate why stars are seen only at night.

P-I-U. Use a prism to demonstrate that sunlight is made of all the colors of the spectrum.

I-U. To illustrate that differences in degree of heat and kind of material can cause differences in color, observe hot toaster coils, light bulb filaments when lit, wood flames, gas flames, etc. Relate to differences in colors of stars.

P-I-U. Demonstrate use of parallax to determine distances in space. Hold a finger about 15 centimeters (6 inches) in front of the nose. Close one eye and observe what is seen at a distance in line with the finger. Observe again with the other eye closed. Notice that different objects are now in line with the finger.

P-I-U. Demonstrate the principle of the refracting telescope by using two magnifying glasses of different magnification. Look through both lens at some object. Adjust distances until the object is seen clearly.

I-U. Build a simple refracting telescope. Obtain two mailing tubes; one slightly smaller in diameter than the other so that the smaller will slide back and forth easily within the larger. Anchor a short focal length convex lens in one end of the smaller tube. Anchor a convex lens with a longer focal length in the end of the larger mailing tube. Place the smaller tube inside the larger and focus on an object by sliding the smaller tube back and forth.

P-I-U. Make a spectroscope by covering one end of a mailing tube with aluminum foil. With a razor make a slit 2.5 centimeters (1 inch) long in the foil. Cover the other end with a square of diffraction grating framed with black friction tape. Make sure the lines of the diffraction grating are parallel to the slit in the aluminum foil. With the diffraction grating next to the eye, look at a light source through the slit in the foil. The spectrum will appear a little to one side.

Research

Percival Lowell

OSO (Orbiting Solar Observatory)

Galileo Galilei

OAO (Orbiting Astronomical Observatory)

Nicolaus Copernicus

Ptolemy (Claudius Ptolemaeus)

Tycho Brahe

Johannes Kepler

Galaxies and components

Black holes

Quasars

Helios

High-Energy Astronomy Observatory (HEAO)

Space Telescope (ST)

G. International cooperation

The United States cooperates with other nations in the building, planning, including experiments, and launching of unmanned satellites.

I-U. Make models of satellites launched by the United States in cooperation with other countries.

U. Discuss

a. Should activities in space be controlled by the United Nations?

b. The kinds of things the United States space program can do for other countries.

c. The kinds of things other countries can do for the United States space program.

d. Are international services necessary?

U. Discuss: Should the United States share with other nations all of the information it gathers about Earth and space?

U. Compare space developments in the USA and USSR.

Research

Space exploration projects of countries other than the USA

History of USA-USSR cooperation in space research

Involvement of foreign scientists in cooperative space projects

ATS-6 communications program with India

European Space Agency (formerly ESRO—European Space Research Organization)

CTS (Communications Technology Satellite)—with Canada

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U.S. NASA. *Why Survey from Space?* (I-U-T)
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U.S. NOAA. *Space, Environmental Vantage Point* (I-U-T)

UNIT VI

Unmanned Exploration of the Solar System

Outline

Unmanned lunar, solar, and interplanetary satellites and probes were sent to the Moon and into interplanetary space to gather additional information about the solar system and its members.

A. Information about the Moon was limited and largely hypothetical until data collected by unmanned space probes and satellites were analyzed.

1. The Moon's origin and some of its characteristics had been hypothesized by scientists prior to space flight.

    a. The Moon's gravity is approximately 1/6 of Earth's gravity.

    b. There is no atmosphere, therefore no weather, as we know it, on the Moon.

    c. On the surface of the Moon there are mountains, craters of varying sizes, and dry plains, called maria or seas.

    d. The Moon revolves around the Earth in a slightly elliptical orbit once every 27 1/3 days.

2. Lunar probes were used to collect lunar data before men were sent to the Moon.

    a. The series of nine Ranger probes was designed to take close-up photographs of the Moon before crashing into the surface.

    b. A series of seven Surveyors was designed to soft-land on the Moon for the purpose of taking pictures and analyzing the composition of the Moon's surface.

    c. A series of five Lunar Orbiters was placed in low orbit around the Moon to take sharp close-up photographs of extensive areas, to provide information about the Moon's size, shape, and gravitational field, and to determine radiation levels and micrometeorite frequency.

B. Information about the Sun was limited and largely hypothetical until data collected by unmanned space probes and satellites were analyzed.

C. Information about the planets and interplanetary space was limited and largely hypothetical until deep space probes and satellites were used to collect data.

1. Information collected by space probes and satellites is increasing our knowledge about the planet Venus.

2. Information collected by space probes, satellites, and landing craft is increasing our knowledge about the planet Mars.

a. A series of four Mariner space probes were launched to fly by Mars or to orbit that planet while taking photographs of the surface and relaying scientific measurements of the Martian atmosphere and gravitational field back to Earth.

b. Two Viking spacecraft were sent to land on the surface of Mars to carry out investigations into the possibility that life has existed or does exist there.

3. Information collected by space probes is increasing our knowledge about the planet Jupiter.

4. Information collected by space probes and satellites is increasing our knowledge about the Asteroid Belt.

5. Information collected by space probes and satellites is increasing our knowledge about the planet Mercury.

6. Information collected by space probes and satellites is increasing our knowledge about Saturn and the other distant planets.

D. International cooperation is providing for exchanges of information, personnel, and technology as we strive to learn more about the solar system and its members.

Outline

Unmanned lunar, solar, and interplanetary satellites and probes were sent to the Moon and into interplanetary space to gather additional information about the solar system and its members.

Activities

**I-U.* Write travel folders and draw or paint posters urging travel to other planets.

I-U. Collect or draw cartoons about space and space travel.

I-U. Make a dictionary of space terms using illustrations where possible. This may be done as a class project for later use by the entire class.

P-I-U. Make crossword puzzles using space-related terms.

I-U. Make a scrapbook of artists' representations of celestial bodies.

I-U. Make a chart. In one column show the space-related words that have their origin in mythology. In the other column include pictures and information that explain the relationship.

I-U. Write an "eyewitness" account of the appearance of Halley's comet.

I-U. Chart the milestones in space exploration from 1957 until the present time.

U. Discuss: Should the United States citizenry be given access to all space information which is obtained?

I-U. Select two teams and play a quiz game using information about the solar system. After determining the two teams, children on each team should name a captain and three or four representatives to answer questions posed by the opposite team. The rest of the team act as advisors using notes, books, and any other information they have gathered. Questions answered rate a predetermined number of points while unanswered ones rate no gain in points. Each team asks questions of the opposing team.

I-U. Create a story about a visit by a person from another planet. Write it as a feature story for the newspaper.

Research

How a planet differs from a star

NASA Goddard Space Flight Center, Greenbelt, Maryland

NASA George C. Marshall Space Flight Center, Alabama

Why a comet's tail always points away from the Sun

Albedo

Cause of a lunar eclipse

Cause of a solar eclipse

Meteor samples

*Suggested age level: P(5-7), I(8-9), U(10-11).

A. The Moon

Information about the Moon was limited and largely hypothetical until data collected by unmanned space probes were analyzed.

P-I-U. Observe the Moon over a period of several days when the Moon is visible in the day time. Keep a record of its shape, its position in the sky, and the time of the observation.

P-I-U. List and discuss the needs of life on Earth. Can the Moon support life?

I-U. Find old (prior to 1950) science fiction stories and old science books about the Moon. How exact were the authors?

I-U. Introduce science fiction as a literature form.

I-U. Write riddles or jingles using information about space or the Moon.

P-I-U. Write stories and poems about the Moon.

Research

Mythology, legend, and folklore related to the Moon

Tides

Literature and music about the Moon

Lunar phases

1. Prior to space probes

The Moon's origin and some of its characteristics had been hypothesized by scientists prior to space flight.

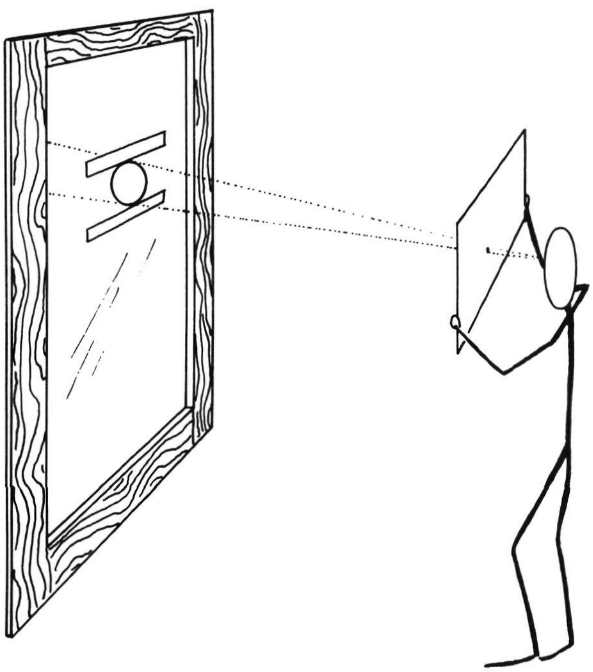
P-I-U. Visit a local observatory to view the Moon.

U. Investigate these three theories and hypothesize regarding their validity today:

(a) Darwin's theory that the Moon and Earth were at one time a single body.

(b) The Moon was once a planet and was pulled into Earth orbit by Earth's gravity.

(c) The Moon and Earth were formed as a double planet system.



U. Using the following method, calculate the size of the Moon. Place two strips of masking tape parallel and 3 centimeters (1 1/4 inches) apart on a windowpane. Make a pinhole in a card. Look at the Moon through the pinhole and through the windowpane between the two strips of tape. Move forward or backward until the image of the Moon fits exactly between the strips of tape. Set up the following ratio:

$$\frac{\text{Distance from pinhole to windowpane}}{\text{Distance from pinhole to Moon (385,000 kilometers; 239,000 miles)}} = \frac{\text{Diameter of Moon's image between tapes (3 centimeters: 1/14 inches)}}{\text{Diameter of Moon (X)}}$$

Substitute the measured distance (in centimeters or inches) from the pinhole to the windowpane and solve the equation to find the diameter of the Moon (in kilometers or miles). For example, if the measured distance is 350 centimeters (136 inches), the ratio would be

$$\frac{\text{350 cm (136 in)}}{\text{385,000 km (239,000 mi)}} = \frac{\text{3 cm (1 1/4 in)}}{X}$$

a. Gravity

The Moon's gravity is approximately 1/6 of Earth's gravity.

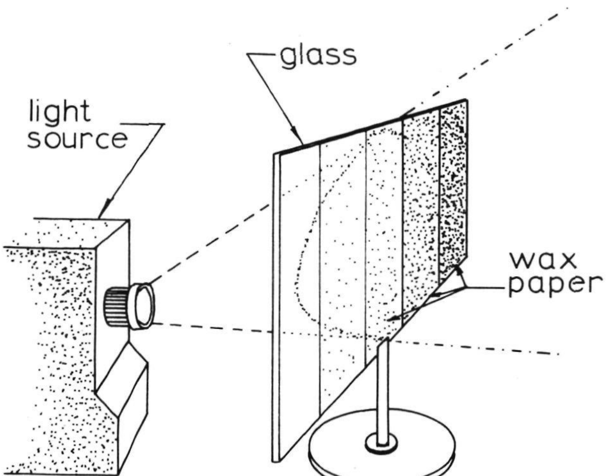
P-I-U. Fill one pail with 2.7 kilograms (6 pounds) of sand to represent 2.7 kilograms (6 pounds) on Earth. Fill another pail with .45 kilogram (1 pound) of sand to represent 2.7 kilograms (6 pounds) on the Moon. Compare the weights.

I-U. Calculate weight of various objects on the Moon, given their weight on Earth.

b. Atmosphere

There is no atmosphere, therefore no weather, as we know it, on the Moon.

I-U. Suspend a small bell inside a bottle containing a small amount of water. Fit the bottle with a one-hole stopper containing a glass tube and short piece of rubber tubing that can be clamped closed. Boil the water in the bottle long enough to force all air out. Close clamp. Listen for sound of bell in partial vacuum formed when bottle is cooled. Compare to absence of sound on the Moon.



U. Demonstrate the lack of atmosphere on the Moon by illustrating how varying densities of atmosphere would affect the visibility of the Moon's surface. Using a piece of glass about 30 centimeters x 45 centimeters (12 inches x 18 inches), tape layers of wax paper to it, with each successive layer 5 centimeters (2 inches) shorter than the previous layer, starting with a piece of wax paper 30 centimeters x 40 centimeters (12 inches x 16 inches). When completed there will be a 5 centimeter (2 inch) strip of clear glass and each consecutively adjoining strip will have one layer of wax paper more than the previous strip. Place an object to represent the Moon in the beam of a flashlight or projector and observe the object through the various densities of wax paper, which represent varying atmospheric densities.

Research

How the lack of lunar atmosphere affects:

shadows

photography

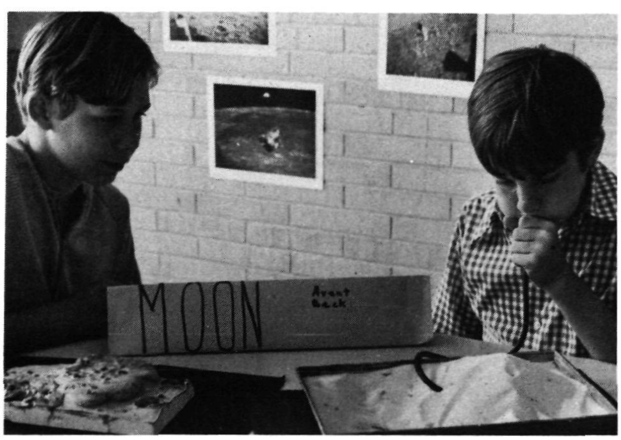
spacecraft temperatures

characteristics of the lunar surface

colors as they are seen on the Moon

c. Surface

On the surface of the Moon there are mountains, craters of varying sizes, and dry plains, called maria or seas.



I-U. Demonstrate the way in which lunar craters may have been formed by volcanic action. Punch a hole in the end of a cardboard box and push a section of plastic hose through the hole into the center. Fill the box with loose sandy soil about 7.5 centimeters (3 inches) deep. Blow very hard on the end of the hose and a crater will form.

P-I-U. Drop stones of varying sizes from varying heights onto a soft mud surface. Observe the depth and size of the "craters" formed. Toss stones of varying sizes so they will strike the surface from an angle. How do these craters differ from the craters formed by simply dropping the stones? What happens if dust, sand, or other material is used instead of mud?

U. Discuss theories of lunar crater formation.

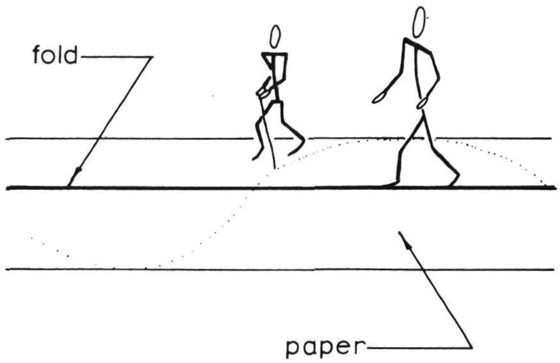
P-I-U. Make a "moonscape" by placing small objects, strings, etc., on a flat piece of cardboard. Cover with aluminum foil. Press foil down firmly around all objects and over the sides of the cardboard. Paint with black tempera paint to which a small amount of polyvinyl glue has been added.

I-U. Make a 3-dimensional map of the Moon's surface.

P-I-U. Draw or paint moonscapes.

d. Revolution

The Moon revolves around the Earth in a slightly elliptical orbit once every 27 1/3 days.



I-U. Show the approximate relationship between the Earth's motion and that of the Moon. Fold a long sheet of heavy wrapping paper lengthwise down the middle. Unfold it and place it flat on the floor, so that the fold mark shows. Have one child, representing the Earth, walk slowly down the fold line. Have another child, representing the Moon, orbit the Earth, marking his or her path on the paper with a felt-tipped pen.

Research

How calendar makers arrive at the date for Easter Sunday

How the Moon has been used to measure time

Time on the Moon

Moon phases

Tides

Lunar and solar eclipses

2. Lunar probes

Unmanned space probes were used to collect lunar data before men were sent to the moon.

I-U. List and discuss facts about the Moon that have been discovered by space probes.

I-U. Collect news items about the Moon.

a. Rangers

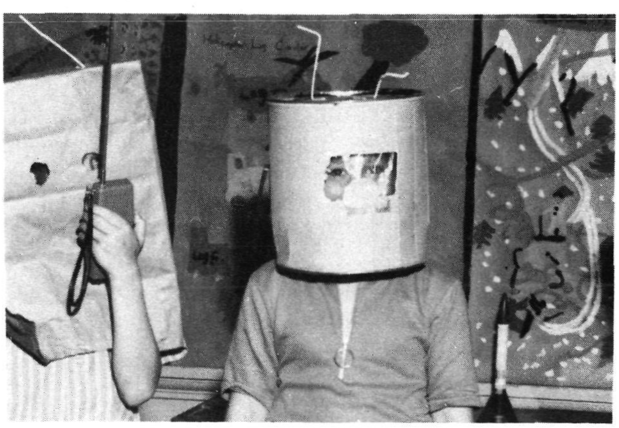
The series of nine Ranger probes was designed to take close-up photographs of the Moon before crashing into its surface.

I-U. Study pictures taken by one of the Ranger probes. Find examples of several types of craters: primary, secondary, ghost, overlapping.

I-U. Compare photographs taken by Ranger probes to those taken by Lunar Orbiters.

b. Surveyors

A series of seven Surveyors was designed to soft-land on the Moon for the purpose of taking pictures and analyzing the composition of the Moon's surface.



I-U. List information that would have been helpful to have before man landed on the Moon. (Examples are surface hardness, physical and chemical features, seismic activity of the Moon, micrometeorite activity near the surface of the Moon, surface bearing strength, temperatures.) Discuss how this information could be obtained by the Surveyor.

I-U. Demonstrate the way in which a lunar surface probe might operate. Place a glass or plastic tube about 30 centimeters (1 foot) long and about 2.5 centimeters (1 inch) in diameter upright on the surface to be tested. Drop a marble or steel ball through the tube onto the surface and measure the height of the bounce. The ratio between the rebound distance and the height of the drop can be used as an index of surface hardness. Test several different kinds of surfaces and compare.

P-I-U. Compare force needed to push a soda straw through cotton, marshmallows, rice, coarse gravel, dirt, small rocks, white potato, etc. Repeat using a plastic strip, a wooden strip, and a metal bar instead of the soda straw. Compare to methods used by instruments on Surveyor to test Moon's surface composition.

I-U. Demonstrate the way in which a "strain gauge" might be used to test surface hardness. Use an inverted postal weight scale to push a piece of copper tubing or pipe into different kinds of soils. Record the weight registered on the scale as the amount of force needed to penetrate the soil. Test several kinds of soil and compare.

I-U. Pretend to be some object on the Surveyor, and write a diary of day-by-day experiences.

c. Lunar Orbiters

A series of five Lunar Orbiters was placed in low orbit around the Moon to take sharp close-up photographs of extensive areas, to provide information about the Moon's size, shape, and gravitational field, and to determine radiation levels and micrometeorite frequency.

I-U. Find copies of lunar photographs taken by satellites. Discuss and interpret details of the Moon's surface.

I-U. Measure shadow lengths at different times of the day. What is the ratio of the height of an object to its shadow? How does the time of day affect the shadow length?

I-U. Make a large model of the Moon's surface. Place the model in the sunlight and take several pictures from above at different heights. Photographs should be taken at different times of the day to show that shadow angles and lengths vary with the angle of the sunlight. Study the photographs and compare to the model.

Research

Ranger

Surveyor

Lunar Orbiter

B. The Sun

Information about the Sun was limited and largely hypothetical until data collected by unmanned space probes and satellites were analyzed.

I-U. Discuss solar data that have been collected by satellites and probes.

P-I-U. Use commercially smoked glass or exposed X-ray film to observe the Sun. CAUTION: NEVER OBSERVE THE SUN DIRECTLY.

I-U. Discuss reasons for studying the Sun.

Research

Helios project with Germany

The Sun as a source of power

OSO (Orbiting Solar Observatory)

Solar wind

Solar storms and sunspots

Sun's magnetic field

Sun's corona

Solar prominences

Nuclear reactions

C. The planets and interplanetary space

Information about the planets and interplanetary space was limited and largely hypothetical until deep space probes were used to collect data.

I-U. Make a chart or bulletin board showing relative distances between planets in the solar system.

I-U. Make a chart or graph showing differences in sizes of the planets of the solar system.

U. Find and discuss theories about the formation of the solar system.

I-U. Place a meter stick on edge at one end of a table. Fasten a file card with two holes in it at the other end of the table. Place small objects at 10, 15, 20, and 25 centimeters (4, 6, 8, and 10 inches) from the card. View objects through one hole in the card and record the reading seen on the meter stick behind the objects. Look through the other hole and record the meter stick readings. Relate to use of parallax to measure distances in space.

P-I-U. Paint pictures that reflect the characteristics, real or imagined, of specific planets. Descriptive music might be used to motivate the activity.

I-U. Draw imaginary maps of the surfaces of planets.

Activities related to orbits may be found in Unit IV C, Pages 42-43.

Research

Interplanetary Explorers

Johannes Kepler

Nicolaus Copernicus

Galileo Galilei

Ptolemy (Claudius Ptolemaeus)

Moons of the planets

Saturn's rings

Jupiter's red spot

1. Venus

Information collected by space probes and satellites is increasing our knowledge about the planet Venus.

I-U. Observe Venus and Jupiter in the early morning and evening. Check star charts to locate these planets which will appear much brighter than the stars.

I-U. Gather news items about the latest data collected about Venus.

P-I-U. Draw or paint an imaginary picture of the surface of Venus beneath its cloud cover.

Research

Compare and contrast Venus and Earth

Sources of planetary heat

Why Venus appears brighter than other planets

Mariner spacecraft

Mariners 2, 5, and 10

Venera spacecraft (USSR)

Pioneer-Venus

2. Mars

Information collected by space probes, satellites, and landing craft is increasing our knowledge about the planet Mars.

P-I. Discover what was known about Mars before the space program began. Why is it called "the red planet"?

a. Mariner probes

A series of four Mariner space probes were launched to fly by Mars or to orbit that planet while taking photographs of the surface and relaying scientific measurements of the Martian atmosphere and gravitational field back to Earth.

I-U. Compare Giovanni Schiaparelli's map of Mars (1877) to pictures of Mars' surface taken by Mariner spacecraft.

I-U. List and discuss problems to be solved before a human can land safely on Mars.

I-U. What new information have we gained about the surface of Mars from the long Mariner 9 flight?

P-I-U. Visit a planetarium or an observatory.

I-U. Compare and contrast:

Earth and Mars

Earth's Moon and Mars' moons

b. Viking spacecraft

Two Viking spacecraft were sent to land on the surface of Mars and to carry out investigations into the possibility that life has existed or does exist there.

I-U. Investigate the "canals" that astronomers used to regard as evidence that Mars was inhabited. What information from the Mariner photographs is used to dispute the existence of those "canals"?

P-I. Take a nature walk. Discover what kind of organisms live under what kind of conditions—wet, dry; protected, open to sun and wind; etc.

I-U. Prepare travel folders inviting and encouraging "Earthlings" to visit Mars.

I-U. Place a number of small objects on a plate. Cover the plate with a thick layer of talcum powder. Place the plate inside a home-made wind tunnel and turn on the wind source. How does the shape of the object determine the pattern the powder makes? What does this show about the Martian surface?

U. Discuss how we know an object is animate or inanimate. How can we design instruments to analyze the object?

U. Investigate bacteria that live in hostile conditions such as in hot springs or in the arctic wastes. Relate what you learn to the life detection experiments of the Viking Landers.

Research

Landmarks on Mars revealed by Mariner spacecraft

Deimos and Phobos, Martian moons

Asaph Hall

Viking spacecraft

The data used in determining landing sites for Viking spacecraft

Jet Propulsion Laboratory, Pasadena, California

NASA Langley Research Center, Hampton, Virginia

Mariner 9 flight

3. Jupiter

Information collected by space probes and satellites is increasing our knowledge about the planet Jupiter.

Research

Pioneers 10 and 11

Jupiter's red spot

Jupiter's moons

Voyager spacecraft

4. Asteroid Belt

Information collected by space probes and satellites is increasing our knowledge about the Asteroid Belt.

Research

Pioneers 10 and 11

Hypotheses about the origin of the Asteroid Belt

Ceres, Hermes, Icarus—large asteroids

5. Mercury

Information collected by space probes and satellites is increasing our knowledge about the planet Mercury.

Research

Mariner spacecraft

Venus-Mercury flyby

Gravity-assist trajectories

6. Saturn and Beyond

Information collected by space probes and satellites is increasing our knowledge about Saturn and the other distant planets.

P-I-U. Demonstrate differences in the amount of reflection by various surfaces. Compare reflection from ice to reflection from ice crystals in Saturn's rings.

I-U. Discover when the Voyager will reach Jupiter and Saturn. If the journey is extended to Uranus, how long will the mission take?

I-U. Plan a step-by-step program for investigating an outer planet in an orderly approach such as was used for sending men to the Moon.

Research

Pioneer spacecraft

Titan (one of Saturn's moons)

Saturn's rings

Voyager spacecraft

Uranus

The discovery of Neptune and Pluto

D. International cooperation

International cooperation is providing for exchange of information, personnel, and technology as we strive to learn more about the solar system and its members.

U. Discuss values that can result from exchange of information and technology.

I-U. Locate on a map or globe the foreign countries that cooperate with the United States in space research.

U. Find out how personnel from foreign countries work with personnel from the United States in space research.

Research

Helios 1 and 2 (West Germany)

ISEE—International Sun-Earth Explorer (European Space Agency and US)

IUE—International Ultraviolet Explorer (European Space Agency, United Kingdom, and US)

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Asimov. *How Did We Find Out About Comets* (U-T)
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Branley. *A Book of Moon Rockets for You* (P)
Branley. *A Book of Planets for You* (P-I)
Branley. *A Book of Venus for You* (I-U)
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Branley. *Pieces of Another World: The Story of Moon Rocks* (U-T)
Gamow and Stubbs. *The Moon* (U-T)
Garelick. *Look at the Moon* (P)
Hendrickson. *Manned Spacecraft to Mars and Venus: How They Work* (U)
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Knight. *Thirty-two Moons* (U-T)
Kondo. *The Moon* (U-T)
Ley. *Gas Giants* (U-T)
Ley. *Inside the Orbit of the Earth* (U-T)
Nourse. *The Asteroids* (I-U)
Nourse. *The Giant Planets* (I-U)
Stampler. *Project Viking* (U-T)
U.S. NASA. *The Now Frontier* (U-T)
U.S. NASA. *Our Prodigal Sun* (U-T)

U.S. NASA. *Mars and Earth* (U-T)
U.S. NASA. *Mars as a Member of the Solar System* (U-T)
U.S. NASA. *Mars as a Planet* (U-T)
U.S. NASA. *Pioneer Mission to Jupiter* (U-T)
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U.S. NASA. *Two Over Mars* (T)
U.S. NASA. *Viking Mission to Mars* (U-T)
U.S. NASA. *The Viking Mission* (U-T)
U.S. NASA. *What's New on the Moon* (I-U-T)
Weaver. "Journey to Mars" (U-T)
Weaver. "Voyage to the Planets" (U-T)
Zim. *The Sun* (I-U)

UNIT VII

Life-support Systems

Outline

When astronauts venture into the hostile environment of space they must take everything they need to keep them alive and comfortable, and to return them safely to Earth.

A. The spacecraft, a life-support system, was developed to provide the conditions necessary to support life in a hostile environment, and to maintain communication with Earth.

1. The atmosphere must be controlled so that it provides an adequate breathing mixture under sufficient pressure.
2. The water supply must be managed to provide adequate amounts for drinking, personal hygiene, and humidity and temperature control.
3. The food the astronauts take with them must provide adequate nourishment, be appetizing, be very lightweight and convenient to use, require very little space, and need no refrigeration.
4. Heat control is necessary to maintain a comfortable temperature for the astronauts and to maintain an acceptable range of temperature for instruments.
5. Waste collection equipment and facilities are designed to overcome the no-gravity problem and to provide a means of storing wastes for later scientific analysis.
6. Methods were devised and facilities provided for exercising, brushing teeth, shaving, washing, and accomplishing other personal hygiene tasks.
7. Panels of instruments measure and control physical factors of the many subsystems such as pressure, electric power, temperature, etc., and warn of any malfunction.
8. Communications between spacecraft and ground control are necessary for collection of information from the astronauts as well as from instruments on board.

B. The space suit, another life-support system, was developed to provide an artificial atmosphere, adequate mobility for extravehicular activity, and protection against temperature extremes, solar radiation, and micrometeorites.

C. Spacecraft reentering Earth's atmosphere must have some degree of maneuverability and must be designed to reduce heat generated by the friction of reentry.

Outline

When astronauts venture into the hostile environment of space they must take everything they need to keep them alive and comfortable, and to return them safely to Earth.

Activities

**P-I-U.* Discuss: What are our basic needs?

U. Collect information about the physiological effects of space flight.

I-U. Compare and contrast problems encountered in exploration of the Antarctic to those encountered in exploration of space.

I-U. Compare Columbus' voyages to the Americas with the astronauts' flights to the Moon.

I-U. Compare and contrast exploration of Earth's seas and exploration of space.

Research

Shock absorbers used in highway guard rails—a spin-off from shock absorbers used under astronaut couches

Body sensors

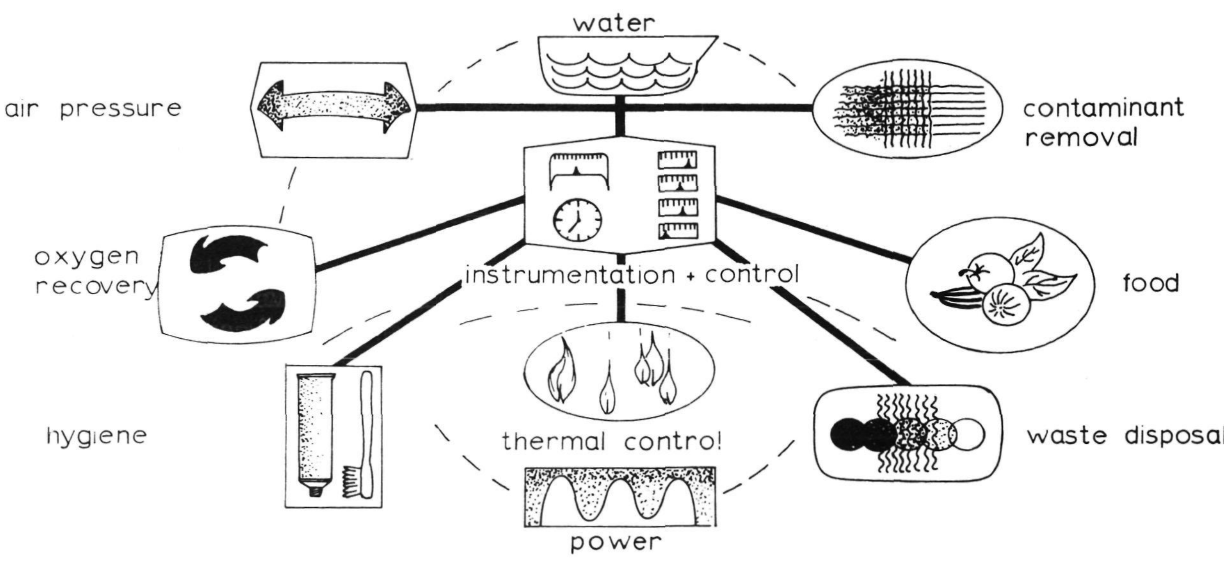
Electronic switch that can be operated by eye movements

Circadian rhythms

A. Spacecraft

The spacecraft, a life-support system, was developed to provide the conditions necessary to support life in a hostile environment, and to maintain communication with Earth.

I-U. Make a bulletin board showing the interdependence of the life-support systems.



1. Atmosphere

The atmosphere must be controlled so that it provides an adequate breathing mixture under sufficient pressure.

I-U. Hold a paper sack tightly over nose and mouth, inhaling and exhaling into the sack. Observe how quickly the amount of oxygen necessary for comfortable breathing is used up.

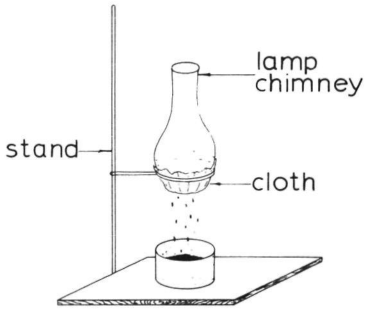
*Suggested age level: P(5-7), I(8-9), U(10-11).

U. Illustrate how differences in pressure affect the absorption and retention of gases. Uncap a warm bottle of soda pop, and observe the results. Carbon dioxide, which was forced into the pop under pressure before the bottle was capped, bubbles up and continues to do so until the pressure inside and outside of the bottle is equalized. Compare this to nitrogen absorption by body tissues.

2. Water supply

The water supply must be managed to provide adequate amounts for drinking, personal hygiene, and humidity and temperature control.

P-I-U. Using two containers with covers, fasten a piece of freshly peeled apple to the inside of each lid. Pour 100 milliliters (1/2 cup) of water into one jar; do not put any water in the other. Fasten the lids on the containers and place them in the sunlight. (The apple in the container without any water will dehydrate rapidly.) Relate to the necessity for adequate humidity levels to prevent dehydration.



I-U. Demonstrate filtration of water. Place about 5 centimeters (2 inches) of fine sand in a lamp chimney that has a cloth fastened across its large end. Pour dirty water in on top of the sand. Collect water as it drips through. Notice that much of the dirt has been removed.

Research

Water purification systems

Drinking water from sea water

Water hyacinths

3. Food

The food the astronauts take with them must provide adequate nourishment, be appetizing, be very lightweight and convenient to use, require very little space, and need no refrigeration.

I-U. Discuss problems which explorers and travelers through the ages have found in carrying the food and supplies they need.

I-U. Discuss the reasons for establishing strict weight, volume, packaging, and nutritional requirements for space food.

I-U. Prepare sample menus for a week's flight in space. Consider weight, nutrition, flavor, and appearance.

U. One kilogram equals 2 1/5 (2.2) pounds. Change 15 kilograms to pounds.

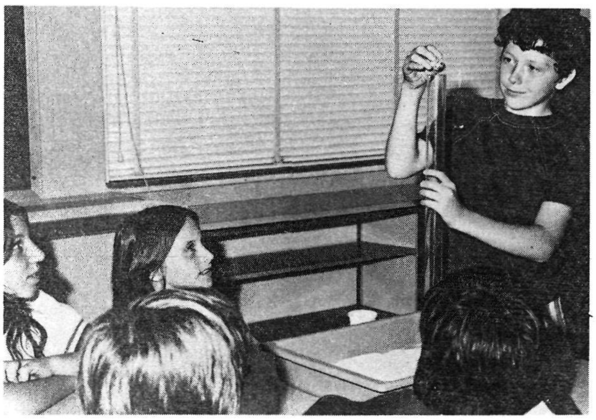
I-U. As a class project, make a time line showing the development of food processing techniques from the prehistoric caveman era to the present space age.

P-I-U. Compare the flavor and appearance of foods preserved in different ways. How does weight compare? Relate to methods of food preservation for space flight.

P-I-U. Bring to class some of the fruit from commercial cereals containing freeze-dried fruit. Place the fruit in a small bowl with a small amount of water for a few minutes. Measure the water before and after the fruit is placed in the bowl. Weigh the fruit before and after rehydration. Observe what happens to the fruit and to the water. Is the fruit still as hard as when it was first placed into the bowl of water?

P-I-U. To simulate the way early astronauts ate space foods, puree some food in a blender and seal the pureed food in small plastic bags. Eat the food as astronauts did. Clip a small hole in one corner of the bag and squeeze the food into the mouth.

P-I-U. Make instant pudding in a plastic bag and eat from a hole cut in one corner of the bag.



4. Temperature

Heat control is necessary to maintain a comfortable temperature for the astronauts and to maintain an acceptable range of temperature for instruments.

P-I-U. Demonstrate the astronaut's need for a temperature control system. Tie a small thermometer on a string and hang it around the neck. Record the thermometer reading. Put on a heavy raincoat and button it up to the neck. Put on long boots. Sit quietly in a chair for two minutes. Record the thermometer reading again. Discuss the reasons for the temperature reading being higher.

P-I-U. To show that color may be used to control temperature, take three tin cans of the same size, remove the lids and paper wrappers. Paint one can black, paint another white, and leave the third can uncoated. Fill the cans with tap water and place them in the Sun or under a heat lamp. After 10, 15, and 20 minutes, measure and record the temperature of each can of water. After completing this activity place the cans where no air currents will strike them, and fill each with hot water (not boiling). Again record the temperatures after 10, 15, and 20 minutes have passed. (The black can will absorb heat more rapidly and lose heat more slowly.)

P-I-U. Demonstrate the differences in heat absorption of different colors and different materials. Select pieces of cloth or paper of the same type, but different colors, and pieces of the same color, but different types. Place 4 or more thermometers in the direct sunlight. Cover each with a piece of the selected material. After a specified period of time, read the thermometers and note the differences in the amount of heat absorbed.

Additional activities related to heat may be found in Unit IV E, Pages 48-49.

5. Waste

Waste collection equipment and facilites are designed to overcome the no-gravity problem, and to provide a means of storing wastes for later scientific analysis.

P-I-U. Prepare three or more bacteria cultures. Keep them in a warm, dark place for three or four days. Keeping one culture as a control, introduce various kinds of germicides or disinfectants into the others to determine their effectiveness against germs.

I-U. Discuss the implications of discarding waste materials in space.

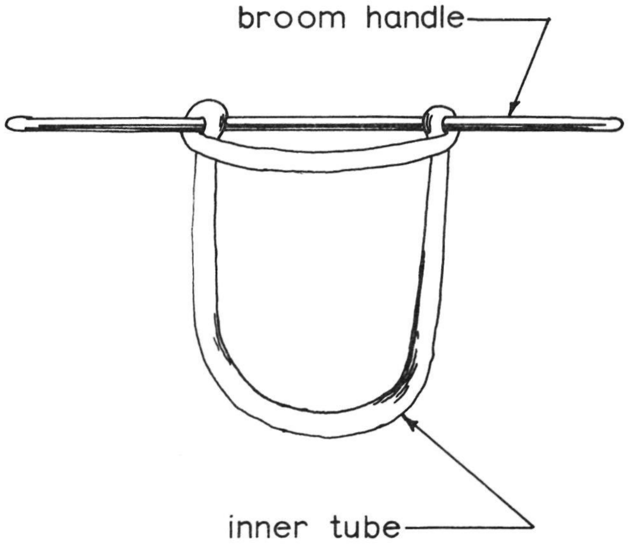
Research

Sewage disposal systems

Recycling waste

6. Personal hygiene

Methods were devised and facilities provided for exercising, brushing teeth, shaving, washing, and accomplishing other personal hygiene tasks.



P-I-U. Make a "bungee cord" (an in-flight exerciser). Loop-hitch a bicycle inner tube around the middle of a section of broom handle. Tighten securely. Leave the other end of the loop open.

Count the number of pulse beats for a period of 10 seconds. Place one foot in open end of the loop or "foot strap" holding the handle with both hands. Pull the bungee against the foot; release. Continue this operation at the rate of one pull per second for 30 seconds. Change to the other foot and repeat the operation. At the end of the second exercise, count the number of pulse beats for 10 seconds. Observe changes in pulse rate and muscular sensations.

P-I-U. Do isometric exercises such as the following:

a. Grasp right hand with left hand, palms facing, and pull in opposite directions for 5 seconds, 10 seconds, 20 seconds.

b. Clasp hands around knee. Pull leg toward chest 12 times. Try first one leg then the other.

7. Instrumentation

Panels of instruments measure and control physical factors of the many subsystems such as pressure, electric power, temperature, etc., and warn of any malfunction.

I-U. Visit a hospital or other large building where functions of air conditioning systems, electrical systems, water or steam systems, etc., are indicated on control panels.

Activities related to:

a. electric power may be found in Unit IV B, Pages 39-41.

b. temperature may be found in Unit I A, Page 5, Unit II B, Page 23, and Unit IV E, Pages 48-49.

c. pressure may be found in Unit I A, Pages 6-7.

8. Communications

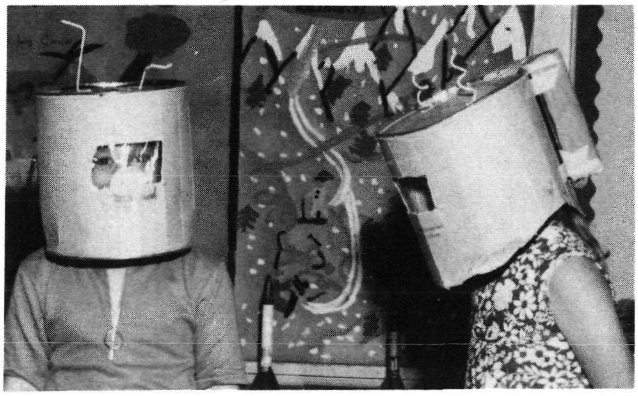
Communications between spacecraft and ground control are necessary for collection of information from the astronauts as well as from instruments on board.

I-U. Write and dramatize a series of communication sequences between astronauts and ground control.

U. Read a transcript of an in-flight conversation between members of a space crew and ground control.

B. Space suit

The space suit, another life-support system, was developed to provide an artificial atmosphere, adequate mobility for extravehicular activity, and protection against temperature extremes, solar radiation, and micrometeorites.



P-I. Simulate the bulkiness of the space suit. Put on several layers of clothing (pants, jackets, gloves) and observe how difficult it is to move.

P-I-U. Demonstrate the need for flexible joints in a space suit. Inflate long balloons to simulate the pressurized space suit. Attempt to bend a balloon and observe what happens to it as it is bent.

P-I. Make a space helmet. Using a large ice cream container, a small oblong box, string, cellophane or plastic, pipe cleaners, and brass fasteners, construct a space helmet.

P-I-U. Fill two identical screw-top jars with water of the same temperature. Record the temperature of the water. Seal both jars. Wrap one in several layers of paper, cloth, etc. Leave the other unwrapped. After about one hour measure and record the temperature in each jar. Relate this to the value of insulation in a space suit.

P-I-U. Demonstrate that evaporation causes a decrease in temperature. Dampen the back of the hand with a few drops of alcohol or water. Observe the cooling sensation. Fan the dampened area and observe that fanning increases the speed of evaporation and decreases the temperature.

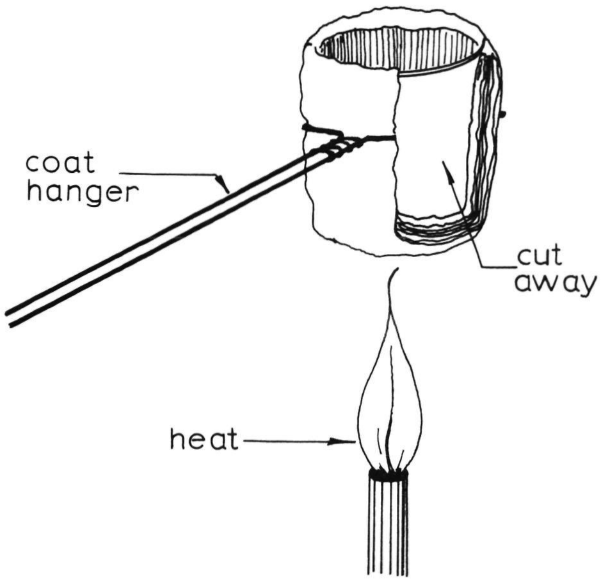
P-I. Demonstrate that the circulation of dry air within a space suit can be cooling. Place the blower end of an electric hair dryer hose inside the clothing and turn the dryer on while the heat setting is turned off. The drying air causes evaporation and a cooling effect.

Research

Lightweight plastic blanket for the outdoorsman—spin-off from new fabrics and weaving techniques tested for space suit materials

C. Reentry into Earth's atmosphere

Spacecraft reentering Earth's atmosphere must have some degree of maneuverability and must be designed to reduce heat generated by the friction of reentry.



U. Mark a point on a piece of paper or a map to represent a landing place. Draw a path to the point 7° wide to represent the reentry corridor.

I-U. Demonstrate how layers of materials can be used to insulate the astronauts against the heat of reentry. Crumple a paper towel around the outside of a paper cup (175-250 milliliters; 6-8 ounces). Add two layers of aiuminum foil and another loosely crumpled towel. Add a final covering of aluminum foil and tape it securely to the top edge of the cup. Make a holder of coat hanger wire. Place 60 milliliters (2 ounces) of water in the cup. Record the temperature of the water and then place the covered cup in the flame of a burner for one minute.

Record the water temperature again. If the cup is properly insulated, the temperature of the water will not rise more than 1.2°C (2°F).

I-U. Demonstrate ablative cooling. Freeze a thermometer in an ice cube. Holding the ice cube by the thermometer, place the ice cube in a candle flame. (Tilt thermometer so water will run down thermometer and not drip into the flame.) Observe changes in temperature as ice is melted. Compare melting ice to energy-absorbing ablative materials.

I-U. Demonstrate regenerative cooling. Fold the corners of a file card so that it will hold a small amount of water. Hold card with water in it over a source of heat. Observe that water conducts heat away so that paper does not burn until water has evaporated.

Activities related to:

a. inertia may be found in Unit IV C, Pages 42-43;

b. parachutes may be found in Unit II B, Pages 21-22;

c. rocket guidance may be found in Unit III C, Pages 30-31.

d. insulation may be found in Unit IV E, Page 49.

Research

Use of parachutes for reentry

NASA Ames Research Center, Moffett Field, California

Selected bibliography

Cobb. *Supersuits* (I-U)
Gagarin and Lebedev. *Survival in Space* (U-T)
U.S. NASA. *Food for Space* (U-T)
U.S. NASA. *Living in Space* (U-T)
U.S. NASA. *Medical Benefits from Space Research* (U-T)
U.S. NASA. *Space Suit* (U-T)
U.S. NASA. *Waste Management* (U-T)

UNIT VIII

Astronauts

Outline

Carefully selected and well-trained astronauts operate American spacecraft; these are called pilot astronauts and mission specialist astronauts.

A. Astronauts are selected for their engineering and flying ability, or for their scientific background and training.

B. Minimum physical standards for astronauts have been set.

C. The astronaut training program is divided into two major parts.

1. Crew members are trained to operate the spacecraft, both in normal pursuit of the flight's objectives, and in emergency and contingency situations.

2. Crew members are trained to become competent observers to accomplish the scientific objectives of the flights.

Outline

Carefully selected and well-trained astronauts operate American spacecraft; these are called pilot astronauts and mission specialist astronauts.

Activities

**I-U.* Compare and contrast problems of pilot astronauts to those of Western pioneers.

U. Discuss reasons why one is willing to face dangers of the unknown.

P-I-U. Draw or paint pictures of astronauts preparing for flight.

I-U. Write an imaginary conversation among an interviewer, a pilot astronaut, a mission specialist astronaut, and a payload specialist.

U. Discuss possible reasons for astronauts leaving the space program.

U. Discuss why payload specialists aboard Space Shuttle will not have to be fully trained pilot astronauts.

Research

Biographies of the astronauts

A. Selection

Astronauts are selected for their engineering and flying ability, or for their scientific background and training.

I-U. Discuss the personal qualities an astronaut should possess.

Research

Qualifications for pilot and mission specialist astronauts

B. Physical requirements

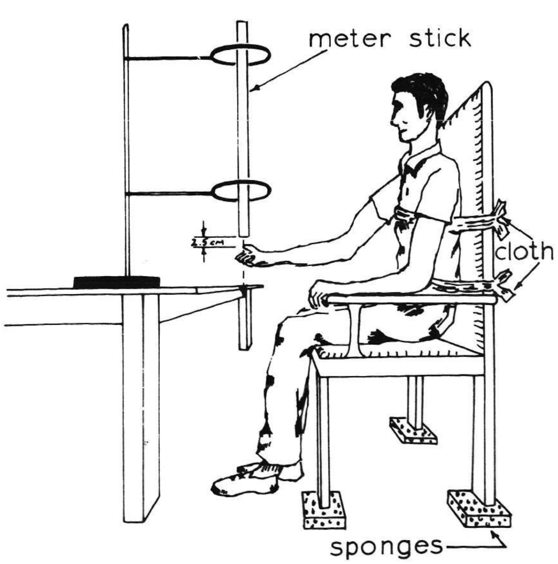
Minimum physical standards for astronauts have been set.

I-U. Find out about the qualifications for the first group of astronauts.

P-I-U. Check health of class to see if they would be "eligible" to be astronauts. Measure height and weight; count pulse rate before and after exercise, etc.

I-U. Demonstrate the effect vibration has on one's reaction time. Place a sponge or an automobile valve spring under each leg of an armchair. Seat a volunteer in the chair with feet off the floor. Use cloth strips to tie the body in place.

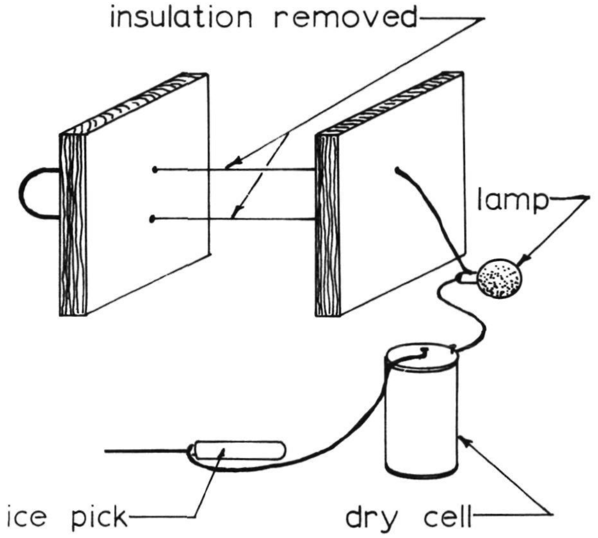
Align 2 ring clamps on a ringstand so that a meter stick will fall freely through them. The volunteer's hand is placed under the bottom ring and rested on the table corner, with the index finger and thumb separated about 2.5 centimeters (1 inch) and aligned so that the meter stick will fall freely between them. A student holds the meter stick in position. When the meter stick is released, the volunteer pinches the stick as quickly as possible after it starts to fall.



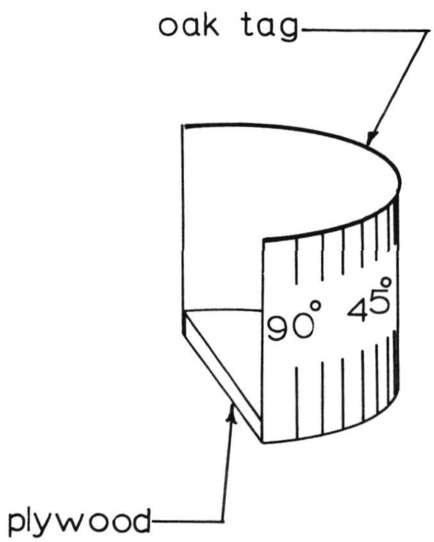
*Suggested age level: P(5-7), I(8-9), U(10-11).

Establish an average for normal vibration. Then have another student keep the chair vibrating at a constant rate and repeat the experiment to observe the effect of vibration on reaction time.

Blindfold the student and signal the release of the meter stick with a clicker to assess reaction to sound. Compare this reaction time to that of reaction to sight.

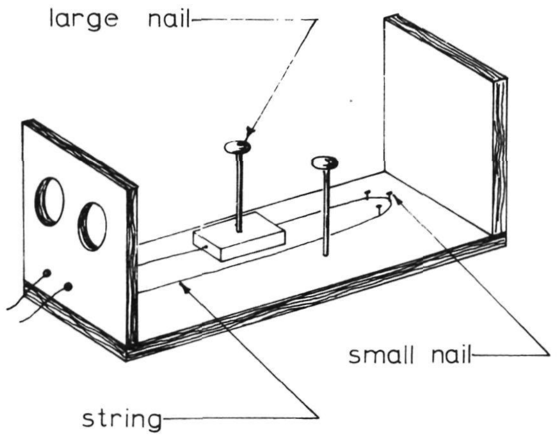


I-U. Demonstrate a hand-steadiness test. Stretch two copper wires between two blocks of wood (not more than 1-2 centimeters; 1/2-3/4 inches apart) and remove the insulation from the wires in the center. Connect a flashlight lamp and an ice pick in the circuit with a dry cell and loop of wire. Only a steady hand can insert the ice pick between the wires without touching one and closing the circuit to light the lamp.



I-U. Demonstrate a field-of-vision test. Cut a 15 centimeter (6 inch) wide strip of oak tag or light cardboard about 115 centimeters (45 inches) long. Mark the center of the oak tag as 0° and mark equally spaced degree markings from 0° in each direction to 90° at each end. Obtain a 1/2 circle of plywood (circle diameter approximately 90 centimeters; 36 inches). Curve the oak tag in a half circle and fasten it upright around the curve of the plywood. Place a marker at the 0° point and movable markers on each side of this central point.

Sit so that the eyes will be on the same level as the plywood and move the side markers away from zero to the point on each side where they are barely out of range of vision when focusing on the marker at 0°.



C. Training

The astronaut training program is divided into two major parts.

1. Spacecraft operation

Crew members are trained to operate the spacecraft, both in normal pursuit of the flight objectives, and in emergency and contingency situations.

I-U. Demonstrate a depth-perception test. Drill two 1 centimeter (1/2 inch) holes and two 3 centimeter (1 1/4 inch) holes in a 1 x 6 board about 15 centimeters (6 inches) long. Attach this board to one end of a 1 x 6 board about 45 centimeters (18 inches) long (base). Attach another 15 centimeter (6 inch) 1 x 6 to the other end of the base. Put one large nail or screw into a small block of wood. Place another similar nail or screw and 3 small nails in the base. Attach the string to opposite sides of the small wooden block and thread instrument. Look through the large holes at the end and measure depth perception by adjusting the location of the small block of wood so that the nail in it appears to be exactly opposite the nail in the base.

I-U. Make a list of actions, each taking only a second or two, such as closing a book, moving a pencil from one place to another, setting an object in a certain place. First, time three short operations by a stopwatch to calculate the minimum time for each. Then make up a timetable including about a half dozen of these activities, beginning each at a particular second. Set the stopwatch for, say, 20 seconds; set each duty beside a certain second, and count down from 20 by the stopwatch. If two participate, have one count down, and have the other perform the actions as they are listed. This activity illustrates the precision with which the various actions in a countdown for launching a space vehicle must be performed.

I-U. Demonstrate habit formation which is part of training for many complicated tasks. Daily, for a definite period of time, practice writing specific letters of the alphabet, or a sentence, while using the hand not usually used for writing. Observe the increase in proficiency as practice continues.

I-U. Write a sentence using the hand not ordinarily used for writing. (Right-handers use left hand.) Practice several times. Compare the last effort with the first.

I-U. The effect of repetition can be observed by writing a series of five-digit numbers which have been presented backwards. Note the time it takes to complete ten such numbers.

Practice for five minutes. Repeat the activity and compare the times of the first and second activities.

2. Observation

Crew members are trained to become competent observers to accomplish the scientific objectives of the flights.

U. Make a sketch of the front of some familiar building. Include as much detail as possible. Observe the building and compare it to the drawing. Relate to the training in observation given the astronauts.

I-U. Discuss examples of optical illusion and the need for being scientifically objective in reporting what is observed.

I-U. Make a rock collection. Label each specimen with its name and the exact location from which it came. Composition, structural features, associations, and classification may be added.

I-U. Take a field trip. Observe rock formations.

I-U. Make a mineral collection. Classify minerals according to hardness, streak, luster, and color.

U. Determine the specific gravity of a mineral.

U. Demonstrate the way in which astronauts are debriefed after a space flight. (In a debriefing session, the astronauts describe in detail their observations, experiences, and reactions.) Two people from the class might be asked to go to a room that is unfamilar to them, select a significant sample, and return to the classroom for debriefing. First, debrief individually, each to 1/2 of the class. After two minutes change groups. No questions are allowed at this point. Bring the class together and debrief as a team. The class may now ask questions.

Did the "astronauts" memorize facts about the trip? Were they aware of color, light intensity, temperature, etc.? Was the sample they returned really significant?

Research

Survival training

Advantages of manned space exploration and/or unmanned exploration.

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Akens. *John Glenn* (U-T)
Chappell. *Virgil I. Grissom* (I-U)
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Collins. *Carrying the Fire* (U-T)
Dille and Hopkins. *Americans in Space* (I-U-T)
Knight. *American Astronauts and Spacecraft* (I-U-T)
Pope and Emmons. *Let's Visit a Spaceship* (P)
Richey. *Apollo Astronauts* (U-T)
Sharpe. *It is I, Seagull* (U-T)
Sharpe. *Yuri Gagarin* (U-T)
Tharp. *Giants of Space* (U-T)
Thomas. *Men of Space* (U-T)
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UNIT IX

Man in Space

Outline

The testing and utilization of the capabilities of man in space are paving the way to the acquisition of new knowledge.

A. The major goal of the manned space program in the 1960's was to put United States astronauts on the Moon and return them safely to Earth, as well as to provide information and technology necessary for further space exploration.

1. Project Mercury (1958-1963) was the first manned-flight program in the plan to send man to the Moon.

   a. Goals were to investigate man's ability to survive and perform in space, to develop hardware for later space flights, to test spacecraft reentry systems, and to establish and test the round-the-world tracking system.

   b. The spacecraft carried one astronaut and life-support systems for a short-duration flight.

2. Project Gemini (1964-1966) was the second phase.

   a. Goals were to subject two men and supporting equipment to long-duration flights, to effect rendezvous and docking with other orbiting vehicles, to maneuver docked vehicles in space, and to gain additional information about physiological reactions of crew members during long flights and during extravehicular activity.

   b. The spacecraft was designed to carry two astronauts and to furnish life support for two weeks or more.

3. Project Apollo (1966-1972) was the final phase in the series of programs.

   a. Goals were to land American astronauts on the Moon, place scientific stations on its surface, develop technology for advanced space exploration, and return the astronauts safely to Earth.

   b. The spacecraft, designed for three astronauts, was much larger and more complex than the Mercury and Gemini capsules.

B. Skylab was an experimental space station program designed to expand our knowledge of space phenomena and manned Earth-orbital operations and to accomplish carefully selected scientific, technological, and biomedical investigations.

1. Scientific investigations in Earth orbit included studies of Earth-Sun interrelationships and other space phenomena.

2. Experiments were designed to gather data for use in oceanography, water management, agriculture, forestry, geography, geology, ecology.

3. Studies were conducted to determine the effects of long-duration space flights on both man and space vehicle systems.

4. Space applications experiments were designed to find ways in which the space environment can be utilized in developing new materials or new forms of known materials.

5. The Skylab cluster included the Orbital Workshop (OWS), the Apollo Telescope Mount (ATM), the Airlock Module (AM), and the Multiple Docking Adapter (MDA). The Apollo Command and Service Module (CSM) docked with it.

C. The Apollo Soyuz Test Project (ASTP) had as its prime objective testing of the compatibility of systems for docking future manned spacecraft of the USA and USSR.

D. The Space Shuttle is a space transportation system designed to carry out various missions in Earth orbit.

1. The Orbiter is designed to be launched with rocket boosters, stay in Earth orbit up to 30 days, and return to Earth to land like an airplane.

2. For the first time, personnel who are not fully trained astronauts can go into space to carry out scientific and technical tasks.

E. International cooperation in solving the problems of space flight will help to eliminate duplication of effort, cut costs of space flight programs, and encourage and facilitate the transfer of new knowledge.

Outline

The testing and utilization of the capabilities of man in space are paving the way to the acquisition of new knowledge.

Activities

**I-U.* Plan and present an assembly program about exploits in space.

I-U. What one item, other than those required, would you take on a space trip? Write a short article answering the question and giving the reasons for your choice.

I-U. Assemble plastic models of spacecraft used in the manned space program.

I-U. Write a poem or brief prose description of Earth as seen from a space ship.

A. Man to the Moon

The major goal of the manned space program in the 1960's was to put United States astronauts on the Moon and return them safely to Earth, as well as to provide information and technology necessary for further space exploration.

U. Read President John F. Kennedy's speech (May 25, 1961) in which he urges the United States to commit itself to the goal of landing a man on the Moon and returning him safely to Earth before the end of the decade. What benefits did President Kennedy see as the result of the space program? Have the early objectives of the space program been met? (See appendix, Page 111.)

I-U. Plan a trip to the Moon. What would you take with you?

I-U. Read myths about Mercury, Gemini, and Apollo. Discuss the reasons for selecting these names for spacecraft.

I-U. Report on animal astronauts.

U. Read the "Declaration of Policy and Purpose" from the National Aeronautics and Space Act of 1958. Discuss its implications and scope. (See appendix, Page 112.)

U. How fast would a paper car be moving if it went to the Moon and back in 100 days? Answer: Approximately 320km/hr (200mi/hr)

1. Project Mercury

Project Mercury (1958-1963) was the first manned-flight program in the plan to send man to the Moon.

I-U. Write a radio and/or TV program describing any one of the Mercury launches and recoveries.

a. Goals

Goals were to investigate man's ability to survive and perform in space, to develop hardware for later space flights, to test spacecraft reentry systems, and to establish and test the round-the-world tracking system.

Activities related to:

a. tracking systems may be found in Unit IV C, Pages 41-42.

b. reentry in Unit VII A, Page 79.

Research

Alan B. Shepard's suborbital flight in Freedom 7

*Suggested age level: P(5-7), I(8-9), U(10-11).

"Gus" Grissom's suborbital flight in Liberty Bell 7

John Glenn's flight in Friendship 7

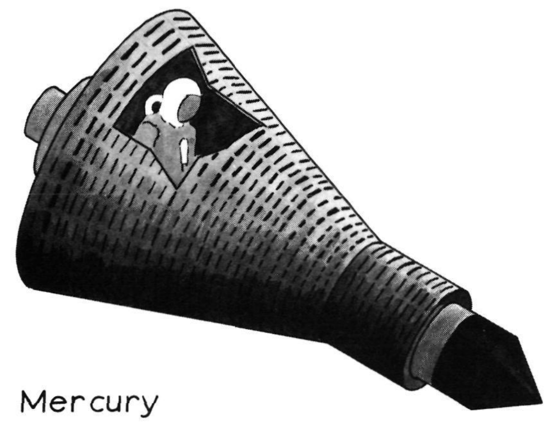
Scott Carpenter's flight in Aurora 7

Walter Schirra's flight in Sigma 7

Gordon Cooper's flight in Faith 7

b. Spacecraft

The spacecraft carried one astronaut and life-support systems for a short-duration flight.



Mercury

P-I-U. Using cardboard boxes, build a representation of the Mercury capsule. Find out about how much space was taken up with instrumentation and discuss the limitations of a space capsule of that size.

P-I-U. Draw or paint pictures of the Mercury spacecraft at various stages of their flights.

I-U. Construct model Mercury capsules.

Activities related to life-support systems may be found in Unit VII A, Pages 74-78 and in Unit VII B, Pages 78-79.

Research

Mercury capsule

2. Project Gemini

Project Gemini (1964-1966) was the second phase.

I-U. Write a "You are There" radio or TV newscast covering any one of the Gemini launches and recoveries.

I-U. Dramatize a before and after launch interview with Gemini astronauts.

Research

Gemini 3, 4, 8, 11, and 12 flights

a. Goals

Goals were to subject two men and supporting equipment to long-duration flights, to effect rendezvous and docking with other orbiting vehicles, to maneuver docked vehicles in space, and to gain additional information about physiological reactions of crew members during long flights and during extravehicular activity.

I-U. Discuss relative motion. Even though Earth-orbiting vehicles are moving at about 29,000 kilometers (18,000 miles) per hour, they are able to rendezvous and dock because they are both traveling at this speed. Recall the sensation of traveling down a multi-lane highway side-by-side with another car going at the same speed. The cars may seem to be standing still, or moving very slowly, in relation to each other.

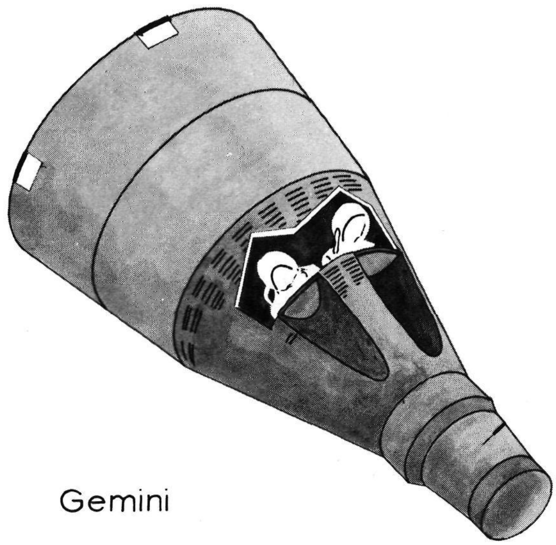
Research

Problems involved in extravehicular activity

b. Spacecraft

The spacecraft was designed to carry two astronauts and to furnish life support for two weeks or more.

I-U. Compare the size of a Gemini capsule to a Volkswagen.



Gemini

P-I-U. Draw or paint pictures of Gemini spacecraft at various points in their flights.

I-U. Construct model Gemini spacecraft.

Research

Gemini spacecraft

3. Project Apollo

Project Apollo (1966-1972) was the final phase in the series of programs.

P-I-U. Dramatize the launch and reentry of one of the Apollo flights. Include scenes of man on the Moon.

I-U. Design a flight emblem and select names for the command and lunar modules for an imaginary Apollo flight to the Moon.

U. Make a poster or bulletin board display that shows, in proper perspective, the narrow corridor through which the Apollo astonauts had to reenter the Earth's atmosphere. (Class discussion: What would happen if the spacecraft overshoots or undershoots the corridor?)

U. Discuss reasons for quarantining returning Apollo astronauts after their walk on the Moon. Why was it discontinued?

I-U. Make a crossword puzzle using words appropriate to the Apollo program.

Research

Walker for paralytics adapted from eight-legged lunar walker

Apollo flights

a. Goals

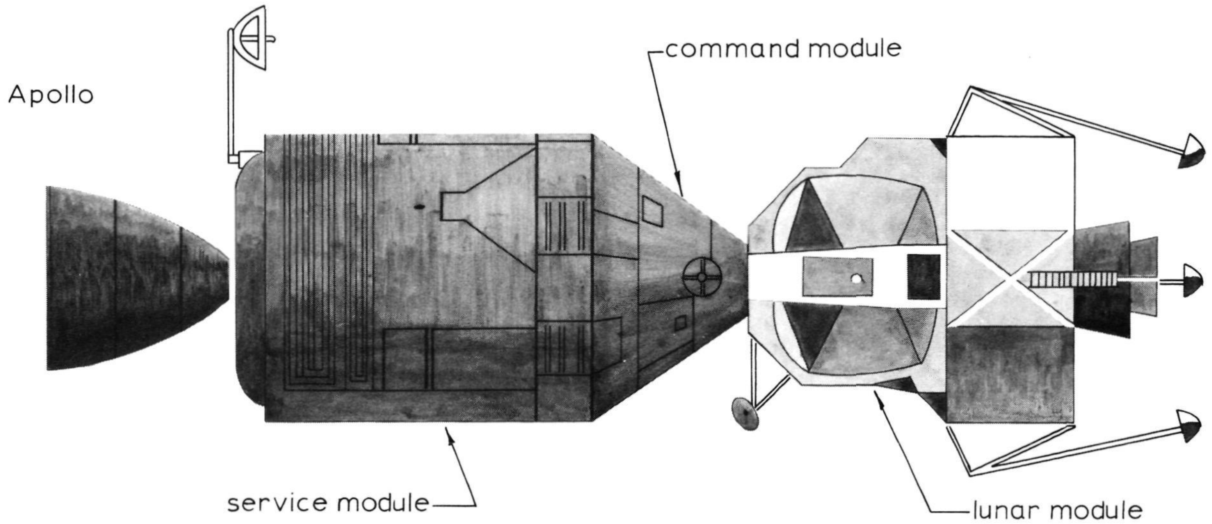
Goals were to land American astronauts on the Moon, place scientific stations on its surface, develop technology for advanced space exploration, and return the astronauts safely to Earth.

I-U. Dramatize the activities of a walk on the Moon.

b. Spacecraft

The spacecraft, designed for three astronauts, was much larger and more complex than the Mercury and Gemini capsules.

I-U. Construct models of the Apollo spacecraft.



I-U. Make a test area similar to the one used for testing the Lunar Rover by filling a shallow box with fine sand. Use windup toys with various types of wheels and tracks to test traction, maneuverability, etc. Add weight to each to see how toys perform. Relate this to the problems involved in developing the Lunar Rover.

P-I-U. Draw or paint a series of pictures illustrating episodes from an Apollo flight, from launch to recovery.

I-U. Find out the poetic names of the various Apollo Command and Service Modules and the Lunar Modules. Discuss their origin and significance.

Research

Methods used to test Apollo capsule before flight

Lunar Module

Laminar air flow systems use in surgical suites to cut down bacterial count

Cardiac preservation chamber developed by Grumman Aircraft Corporation

NASA Lyndon B. Johnson Space Center, Houston, Texas

B. Skylab

Skylab was an experimental space station program designed to expand our knowledge of space phenomena and manned Earth-orbital operations and to accomplish carefully selected scientific, technological, and biomedical investigations.

I-U. Construct a model of the Skylab space station.

P-I-U. Draw or paint a picture of a view that might be seen from Skylab.

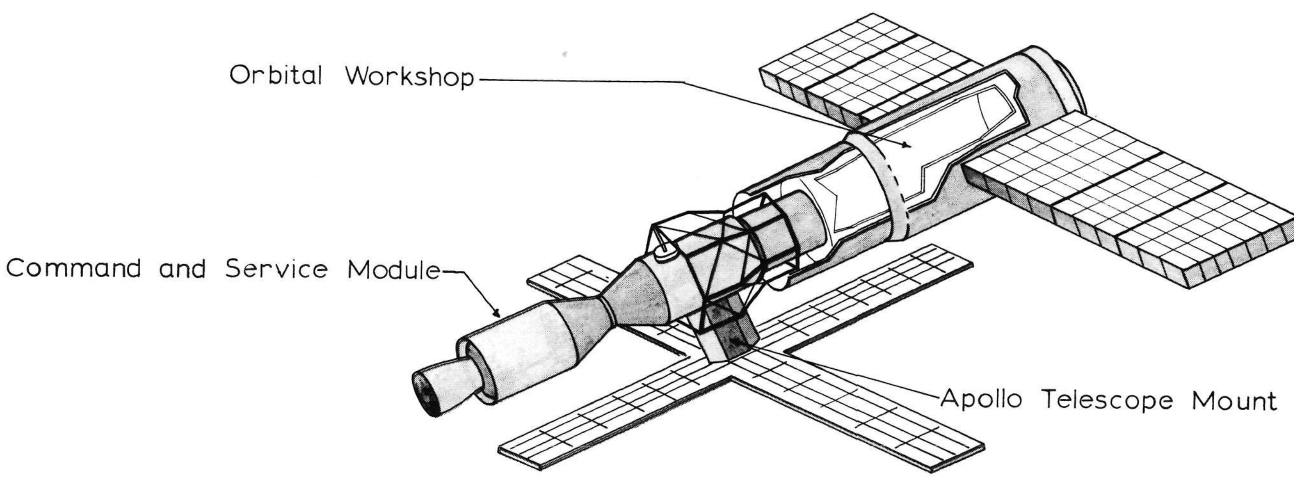
I-U. Pretend you are an astronaut on Skylab and write your diary.

I-U. Write a science-fiction story about astronauts on Skylab.

U. Discuss the problems related to the development of an effective space rescue operation. How does the Skylab program affect the need for space rescue facilities?

U. Discuss the possibilities for international cooperation in solving world problems by using data collected during the Skylab program. How would cultural differences affect the utilization of data?

I-U. Collect information on Earth-related programs developed from Skylab experiments.



I-U. Write poems describing feelings of an astronaut prior to launch.

I-U. Discuss how relatively simple tasks (such as hammering a nail or brushing teeth) will be affected by space environment.

P-I-U. Write and dramatize a story about life aboard Skylab.

Research

NASA George C. Marshall Space Flight Center, Alabama

NASA Lyndon B. Johnson Space Center, Houston, Texas

1. Earth-Sun relationships

Scientific investigations in Earth orbit included studies of Earth-Sun interrelationships and other space phenomena.

I-U. Paint the inside of a light-tight box with non-reflective black paint. Seal a pen-size flashlight in one end. Make a peephole in the top. Place a small object inside the box. Look through the peephole. The article should be invisible. Turn on the light. What makes the object visible? Discussion question: Why does space appear to be black when one is observing from above Earth's atmosphere?

I-U. Write a story, "The Day the Sun Went Out."

I-U. Compare X-ray pictures of the human body to X-ray mapping of the galaxy.

I-U. Groups of individuals might use patching plaster as a "catcher" for various stones, metal fragments, etc. After plaster hardens groups might exchange plaster "catchers" to determine what materials were trapped. Relate this to the Skylab experiment in which materials are exposed to the space environment, retrieved and returned for lab analysis of micrometeorites.

I-U. Using a spectroscope, observe various light sources and notice differences in spectral patterns.

Activities related to the telescope and the spectroscope may be found in Unit V F, Pages 56-57.

Research

Solar storms

Solar corona and prominences

Solar wind

2. Earth study

Experiments were designed to gather data for use in oceanography, water management, agriculture, forestry, geography, geology, ecology.

I-U. Obtain copies of Skylab multispectral photography, preferably of your area, and observe different ways of looking at a region. (Source: EROS Data Center)

I-U. Create a multispectral map of your community. Use different colors to indicate open land, residences, farm land, commercial buildings, water, forests, and so on.

U. Discover what methods Skylab astronauts used to study the Earth.

I-U. Place a radiometer in a sunny window. Observe the effects of differences in the amount of cloud cover on the operation of the radiometer.

Research

Find out how multispectral photography is being used to detect plant disease, thermal pollution, forest fires, water pollution, development of urban areas, etc.

Polarized light

Spectroheliometer and spectroheliograph

LANDSAT satellites (formerly ERTS, Earth Resources Technology Satellites)

3. Long-duration flight

Studies were conducted to determine the effects of long-duration space flights on both man and space vehicle systems.

I-U. Sit in one position for a long period of time. Discuss the effect on attitudes and feelings as well as on physical comfort.

I-U. Place one of two similar mice in very cramped quarters, the other in spacious quarters. Observe over a period of time to see differences, if any, in their behaviors.

I-U. What psychological effect is produced by working in a confined area for an extended period of time? Compare the reactions of several students.

P-I-U. Observe the effect of vigorous activity on the pulse rate. Determine the pulse rate by placing the first two fingers of the right hand on the left wrist at the base of the thumb and counting the number of beats for 30 seconds. Jump up and down 20-30 times and again determine the pulse rate.

U. Demonstrate visual and muscular disorientation that may result from rotation. Have a volunteer sit in a swivel chair that has arms, grasp the arms of the chair firmly, and hold head erect and facing forward. Rotate chair with a uniform motion, not necessarily fast for 30 seconds. Ask student to look straight ahead. Notice eye movements. Ask student to describe visual effects which follow rotation. Repeat rotation and then have student toss ball into a wastebasket placed directly in front of him or her and about 1.5 meters (5 feet) away.

U. Demonstrate the disorientation that may result from motion. Blindfold and seat a student in a swivel chair with arms resting on the chair arms and thumbs pointing in an upright direction. Have student point thumbs in the direction of rotation when the chair is turned. Rotate the chair smoothly in one direction. Slowly stop the chair and turn it in the opposite direction. Watch thumbs. Slowly stop the chair's rotation. Watch thumbs. Student will probably point thumbs in opposite direction to that of the last rotation although he or she is no longer moving.

U. Demonstrate disorientation and illusions caused by motion. Blindfold and seat a volunteer in a simple swivel chair. Start the chair rotating to the right at about 5 degrees per second; increase to about 90 degrees per second, or 15 revolutions per minute. Continue spinning the chair at this rate. There is no other movement of the chair. Position someone in a corner of the room to give directions. Ask the blindfolded student to report sensations as the experiment progresses. CAUTION: If these activities cause nausea or other adverse reactions, it is time to quit!

Directions to be given orally:

1. Incline head slowly to the right about 1/3 of the distance to the shoulder. Usual reaction: Smooth rapid turn to right.

2. Slowly raise head to upright position. Usual reaction: Vertical dive slowly decreasing and returning to straight and level.

3. Slowly push your head forward until your chin is on your chest. Usual reaction: Complete roll to right.

4. Slowly bring your head back upright. Usual reaction: Another roll; this time to the left. Inverted position definitely felt—then return to straight and level.

5. Silently signal the student turning the chair to allow it to come slowly to a stop. Usual reaction: Turn to left.

6. When chair has come to a complete stop, ask blindfolded student which way he is turning. Usual reaction: Left.

I-U. Compare differences in the appearance of pieces of aluminum foil that have been exposed to different kinds of conditions (salt solution, dishwasher detergent solution, classroom and outdoor air for long periods, oven heat, etc.). Relate to the testing of materials exposed to the space environment.

Research

Metabolism

Electrocardiogram

Sleep-REM's

Ergometer

Cardiotachometer

Aerosol particle contamination

Cardiovascular system

Fire eye—the ultraviolet flame detector developed by Honeywell

4. Utilization of space environment

Space applications experiments were designed to find ways in which the space environment can be utilized in developing new materials or new forms of known materials.

I-U. Observe the growth of crystals through a microscope or microprojector. Make saturated solutions of Epsom salts, salt, sugar, ammonium dichromate, or copper sulfate. Spread a minute amount of the solution thinly on a microscope slide and observe.

Discuss possible differences in crystal formation that may result because of the weightless conditions aboard Skylab.

I-U. Place a few crystals of salt, sugar, or Epsom salts on a microscope slide. While observing the slide through a microscope, add a drop of water and observe the crystals dissolving. What might be different about this process under weightless conditions?

I-U. Use a soldering iron and solder to demonstrate the way in which metals melt and flow under heating. Discuss possible differences aboard Skylab.

I-U. Take a field trip to a welding shop and observe the processes of welding and brazing. USE CAUTION: Wear safety goggles to protect eyes.

I-U. Describe something you would like to see developed; for example, edible dishes.

I-U. Discuss ways in which newly developed materials result in discoveries of new uses and applications.

Activities related to weightlessness may be found in Unit II B, Pages 23-24.

Research

Electron beam gun

Maurer camera

Use of crystals in radio transmission and reception

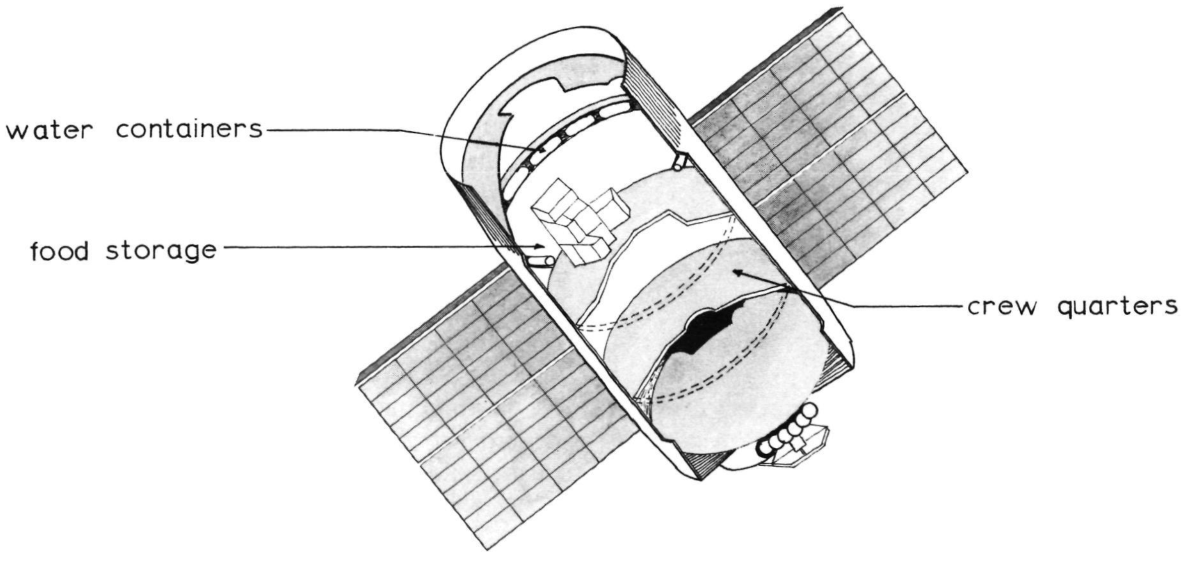
Aluminum

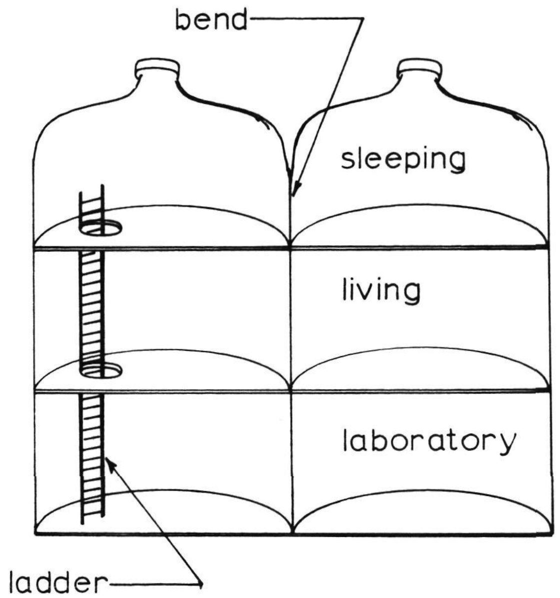
5. Spacecraft

The Skylab cluster included the Orbital Workshop (OWS), the Apollo Telescope Mount (ATM), the Airlock Module (AM), and the Multiple Docking Adapter (MDA). The Apollo Command Service Modules (CSM) docked with it.

P-I-U. Prepare a bulletin board showing the parts of the Skylab vehicle. Label areas of use.

P-I-U. Using oatmeal boxes, salt boxes, or round plastic containers, build a model of Skylab. A 4 liter (1 gallon) plastic container makes a good body—smaller plastic containers may be glued to the main body.





I-U. Construct a model of the Orbital Workshop. Split a large plastic jug. Cut some cardboard semicircles and glue in place. Put in miniature furniture, figures, etc.

P-I-U. Draw or paint pictures of the Command and Service Module (CSM) during different stages of flight from launch to docking.

I-U. Find out what the first Skylab astronauts did to repair the station's damage from launch.

P-I-U. Draw or paint pictures of crewmen at ease in their living quarters.

I-U. Write a story "The Day I Visited Skylab."

I-U. Write a story about docking at Skylab.

I-U. Write a story about extravehicular activities around Skylab.

I-U. Find out about the results of the Skylab experiments.

Research

Mobility aids included in the Orbital Workshop

Airlocks

Caissons

C. Apollo Soyuz Test Project

The Apollo Soyuz Test Project (ASTP) had as its prime objective testing of the compatibility of systems for docking future manned spacecraft of the USA and USSR.

P-I. Write and perform a dramatic play of American and Soviet astronauts meeting in space.

P-I. Discover the problems of planning a space flight involving astronauts from two cultures. Find an activity that different students do in different ways (such as which shoe is put on first). Discuss the advantages and disadvantages of each method, trying to reach a compromise that will be comfortable for both "cultures."

I-U. Bring in a student or parents whose native language is not English. Ask him or her to draw up a list of space-related words in that language. Draw up a comparable list in English. Learn the words and their translations. Write and perform a space-flight communications play using both languages.

I-U. Using a toy truck and a toy car, design a "docking module" that will link the two together while they are moving.

Research

The Docking Module

History of the ASTP

Space rescue

Experiments performed during the ASTP mission

The Soyuz spacecraft

D. Space Shuttle

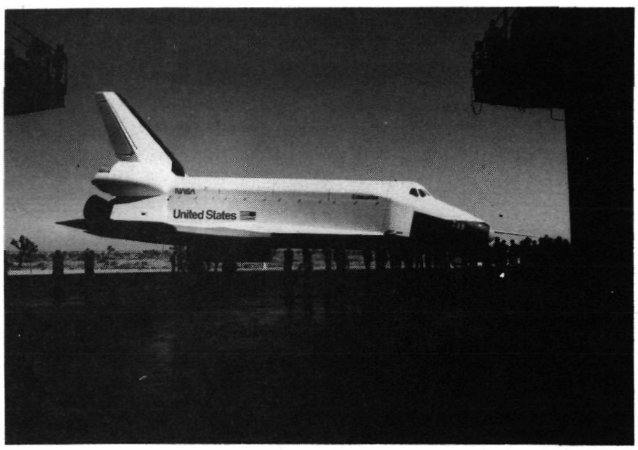
The Space Shuttle is a space transportation system designed to carry out various missions in Earth orbit.

I-U. Discuss what tasks you would do if you could go into space only once. What tasks would you be able to do if you could go many times?

I-U. Make a model of the Space Shuttle. (See U.S. NASA. *Space Shuttle.* EP-96 and SP-407)

1. The Orbiter

The Orbiter is designed to be launched with rocket boosters, stay in Earth orbit up to 30 days, and return to Earth to land like an airplane.



I-U. Discover what makes the Space Shuttle the first true aerospace vehicle.

I-U. Launch of the Shuttle will create only a 3g load. How much will a person who weighs 70 kilograms (154 pounds) "weigh" during launch? How does that compare to launch of an Apollo spacecraft?

I-U. The payload bay of Shuttle is 4.6 meters (15 feet) in diameter and 18.3 meters (60 feet) long. Discover the size of an average Earth-orbiting satellite (with solar panels closed for launch). How many satellites will fit into the cargo bay?

I-U. Make a model Spacelab.

I-U. The Space Telescope carried aboard Space Shuttle will be able to "see" ten times farther than any ground-based telescope. Find a large clear field, or use the school playground. Place a small object on the ground. Walk away until you can no longer see the object: measure the distance. Using a small-scale map of the community, find out what buildings or landmarks you would see if you could see ten times farther than measured (pretend nothing would block the view).

I-U. Discover how much living space crew and specialists have in Space Shuttle. How does that compare to Mercury, Gemini, Apollo, Skylab?

I-U. List the sciences that might be useful to a mission specialist astronaut. Why would each be helpful?

2. Non-astronaut personnel

For the first time, personnel who are not fully trained astronauts can go into space to carry out scientific and technical tasks. (Space Shuttle crews include pilot astronauts, mission specialist astronauts, and payload specialists.)

I-U. Discuss the usefulness of the Space Shuttle as a transportation system.

P-I-U. Write an essay telling why you would like to ride into space aboard the Shuttle and what you would do when you got there.

I-U. Write a story describing your adventures as a member of the Space Shuttle crew or a specialist such as a scientist, engineer, or technician.

U. Find out about the kinds of scientific research proposed for the Space Shuttle.

U. If you worked for a company that planned to place a satellite in orbit, how would you select a person to act as payload specialist aboard the Space Shuttle carrying the satellite?

Research

Development of the Space Shuttle

Space Shuttle mission profile

Spacelab and the European Space Agency (ESA)

Manipulator arm in the cargo bay

Low Cost Modular Spacecraft

Space Tug project

Space Telescope (ST)

E. International cooperation

International cooperation in solving the problems of space flight will help to eliminate duplication of effort, cut costs of space flight programs, and encourage and facilitate the transfer of information.

I-U. Locate on a map or globe the foreign nations that cooperate with the United States in manned space research.

U. Discuss the adaptations of spacecraft necessary before docking with spacecraft from other countries can be accomplished.

Research

Spacelab

ESA (European Space Agency, formerly ESRO)

History of USA-USSR cooperation

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UNIT X

Projections

Outline

Further development of space technology will result in improved living conditions on Earth, solution of problems related to Earth resource availability and control, and further space exploration.

A. New systems are being developed for further space exploration.

1. Power plants for launching and operating spacecraft are being developed to meet the needs of long-duration flights.

2. New configurations for launch vehicles and spacecraft are being developed to meet the need for more efficient use.

3. Research continues to test life-support systems and environmental conditions feasible for long-duration flight.

B. Management of resources is necessary for our survival on Earth.

1. Satellites can provide a means for educating people of the world.

2. Satellite land-use surveys and accurate mapping can aid in efficient use of soil, water, and mineral resources.

3. Tracing weather phenomena, now useful in short-range weather prediction, can become important in long-range (up to two weeks) forecasting.

C. Application of the unique characteristics of the space environment to the development of biomedical techniques and other scientific and industrial technology may be possible.

D. Lunar, solar, and interplanetary space flights expand our knowledge of the solar system.

1. Science instruments in flight or landed on the Moon and planets provide information on the Sun, the bodies in orbit around it, and their interrelationships.

2. Data collected about the Solar system may lead to our better understanding of the Earth and its phenomena.

E. Investigations of the stars, galaxies, and other phenomena of space can lead to greater understanding of the universe.

Outline

Further development of space technology will result in improved living conditions on Earth, solution of problems related to Earth resource availability and control, and further space exploration.

Activities

**I-U.* Discuss ways space technology has improved living conditions and the possibilities for future improvements.

I-U. Project ideas for future space stations.

I-U. Build a model rocket or space station.

I-U. Collect or draw cartoons related to space travel.

I-U. Discuss problems related to colonization of the Moon, Mars, or other planets.

I-U. Design and construct a lunar colony model.

I-U. Write a description of recreational activities on the Moon or on Mars.

I-U. Draw or paint pictures of life forms as imagined to exist on other planets in space.

U. Discuss the advantages of a near-Earth orbit to one in outer space.

U. Discuss the advantages of making space laboratories available to non-astronauts.

U. Develop a "Headlines of the Future" quiz. Make up headlines that may or may not be based on known facts about the solar system and the universe. See sample.

I-U. Prepare a time line showing important episodes in the space program since 1957.

Research

Space Shuttle Facilities at NASA John F. Kennedy Space Center, Florida

NASA's plans for space exploration

A. Further exploration of space

New systems are being developed for further space exploration.

I-U. Write stories and/or plays about space exploration.

I-U. Write science-fiction stories about space exploration.

U. If it were possible for a space vehicle traveling at 227,000 kilometers per hour (142,000 miles per hour) to go to the Sun and back, how long would the trip take?

1. Power plants

Power plants for launching and operating spacecraft are being developed to meet the needs of long-duration flights.

I-U. Write stories about sailing through space with sails pushed by light from the Sun.

Research

Nuclear powered rocket engines (NERVA)

Ion engines

*Suggested age level: P(5-7), I(8-8), U(10-11).

"Headlines of the Future"*

Possible Headlines

1. **Superstitious Astronaut Refuses Travel to Jupiter's Thirteenth Moon**
Yes ☐ No ☐

2. **Planetary High Jump Record for Women Set on Moon**
Yes ☐ No ☐

3. **Explorer plans Travel to Sun—Avoids Heat by Going at Night**
Yes ☐ No ☐

4. **Open-Air Concerts Big Hit on Moon**
Yes ☐ No ☐

5. **Lost Explorer Discovered on Uranus—Suffers from Extreme Seasons**
Yes ☐ No ☐

6. **Record Snow Storm Closes Schools on Venus**
Yes ☐ No ☐

7. **Astronomer Discovers New Asteroid**
Yes ☐ No ☐

8. **Record Fish Taken from Canal on Mars**
Yes ☐ No ☐

Answers and Explanations

1. *Yes.* Jupiter's thirteenth moon was discovered in 1974.

2. *Yes.* The gravitational pull of the moon is only 1/6 that of the earth, and a jumper would go high indeed.

3. *No.* The poor explorer will get burned up anyway because the sun is pouring out heat all the time, whether it is night on earth or not.

4. *No.* There are several reasons why this is not so. One is that since it appears that the moon has no atmosphere, sounds would not carry and people would hear nothing.

5. *Yes.* It is unlikely that men will ever land on Uranus, but if they did, they *would* find extreme seasons. This is true because the tilt of the axis of Uranus is very large, much more than the earth's tilt.

6. *No.* Even if there were schools in Venus, the temperature is so great (between 600 and 800°F), that rain or snow is an impossibility.

7. *Yes.* Asteroids are very numerous and are being discovered all the time, especially with the use of large telescopes.

8. *No.* At one time markings on planet Mars were thought to be canals, but this is not considered likely now. Also, there is not enough liquid water on Mars to fill a canal. Leave your fishing pole home.

*Excerpts adapted or quoted from "Headlines of the Future," by Stanley Simmons and Robert Link. Copied with permission from *The Science Teacher*, April, 1968, pp. 15, 80.

Pressure of light

Plasma engines

Arcjet engines

Solar rocket engines

NASA Lewis Research Center, Cleveland, Ohio

2. Spacecraft

New configurations for launch vehicles and spacecraft are being developed to meet the need for more efficient use.

I-U. Write stories about space stations and commuting between Earth and stations in space.

I-U. Design oatmeal box models of space stations including necessary divisions into work space, living quarters, and equipment and storage space.

I-U. Construct a table top model of a space station, decorating and furnishing the rooms with necessary equipment.

Research

Space Shuttle

Lifting bodies

3. Life-support systems

Research continues to test life-support systems and environmental conditions feasible for long-duration flight.

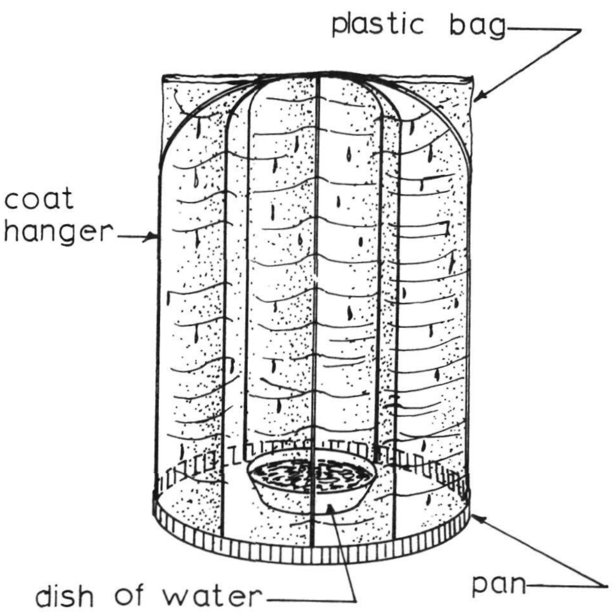
I-U. Describe a complete food cycle that might be possible for a long space flight.

I-U. Plan a balanced meal. How could all nutritional needs be supplied on long space flights?

I-U. Prepare several terraria. Use different combinations of plants and animals and different light and water treatments. Observe over a period of time and discuss reasons for changes that occur.

P-I-U. To demonstrate the way in which hydroponics, growing plants without soil, could be used to provide food during long-duration flights: obtain a supply of nutrient solution, and some quick-growing seedlings.

1. Cover a jar with aluminum foil. The roots must be kept in darkness to prevent growth of green algae and other small water plants in solution.
2. Fill jar with nutrient solution up to neck of jar.
3. Cut four holes 1/2-1 centimeter (1/4-1/2 inch) in diameter in plastic top. Place one in the center.
4. Insert a seedling in the center hole and support with cotton. Handle seedling gently.
5. After transplanting, check to see that the roots extend down into the solution.
6. Aerate the solution at least once a day. Attach a length of rubber tubing to a rubber bulb and insert the free end of the tubing into the solution. Press the bulb to force air into the solution.
7. Change the nutrient solution once a week to provide sufficient elements continuously. Discard the used solution.



B. Management of resources

Management of resources is necessary for our survival on Earth.

8. Be sure the plant receives plenty of sunshine and warmth.

I-U. Try this recipe for cookies made of algae:

60 milliliters (4 tablespoons) concentrated *Chlorella* (algae)

475 milliliters (2 cups) flour

60 milliliters (4 tablespoons) shortening

7.5 milliliters (1/2 tablespoon) salt

175 milliliters (3/4 cup) milk

45 milliliters (3 tablespoons) baking powder

Cream shortening. Add dry ingredients and milk. Roll out in 1.2 centimeter (1/2 inch) sheets.

Spread with mixture of sugar, cinnamon, and butter. Roll up and slice into pinwheels.

Bake at 175°C (350°F) for 10-15 minutes. Relate this activity to the fact that long space flights will require men to take with them the means for raising their own foods. Animals such as snails, shrimp, and fish which feed on algae may serve as food. *NOTE:* The *Chlorella* may be obtained as a powder or it can be grown using *Chlorella* cultures. If it is to be grown, it must be baked in an oven to remove the moisture and then ground into a fine powder. Either form is available from biological supply houses.

I-U. Demonstrate how waste water can be purified by distillation. Bend coat hangers to make a frame for a plastic bag. Place the bag and framework on a pan containing a small dish of water to be distilled. Place the apparatus in sunlight or under a sun lamp. Observe the condensation of pure water on the inner surface of the plastic bag.

Research

Psychological factors involved in space flight

Food production on long-range flights

How long it takes to grow tomatoes, lettuce, etc., from seeds to maturity

How long it takes for rabbits and chickens to reproduce

Hydroponic farming

U. Discuss depletion of Earth resources.

I-U. Compare Earth and its resource limitations to a spacecraft and its controlled environment.

Research

Power resources available to man

Solar power resources

1. Education

Satellites can provide a means for educating people of the world.

I-U. Discuss use of television as a teaching device. What problems need to be solved before television can be used to teach internationally?

I-U. Discuss ways in which worldwide televising of news events can contribute to education.

Research

Use of satellites in educational experiments

Education levels in various parts of world

2. Earth resources

Satellite land-use surveys and accurate mapping can aid in efficient use of soil, water, and mineral resources.

I-U. Map the neighborhood around the school and indicate land use.

U. Prepare a map of a local drainage area indicating land use.

U. Panel discussion. Use of satellite-collected data in environmental control.

U. Compare available maps of urban areas with satellite pictures. (Source: EROS Data Center)

Research

Mineral resources of your state

Tectonics and continental drift

LANDSAT satellites (Formerly ERTS—Earth Resources Technology Satellites)

3. Weather

Tracking weather phenomena, now useful in short-range weather prediction, can become important in long-range (up to two weeks) forecasting.

I-U. Write imaginary stories in which weather is predicted accurately for up to two weeks.

U. Discuss: How can weather forecasting aid in feeding Earth's population? How could weather forecasting affect world economics?

Research

Silver iodide seeding of clouds

USA imports and exports of agricultural products

C. Utilization of space environment

Application of the unique characteristics of the space environment to the development of biomedical techniques and other scientific and industrial technology may be possible.

U. Discuss value of weightless conditions of space in treatment of disease, such as heart disease, or treatment of serious burns.

U. Discuss value of weightlessness in production of materials.

D. Solar system

Lunar, solar, and interplanetary space flights expand our knowledge of the solar system.

I-U. Write science-fiction stories about space flights to various destinations in the solar system.

I-U. Write a story titled "The Moon Revisited."

Research

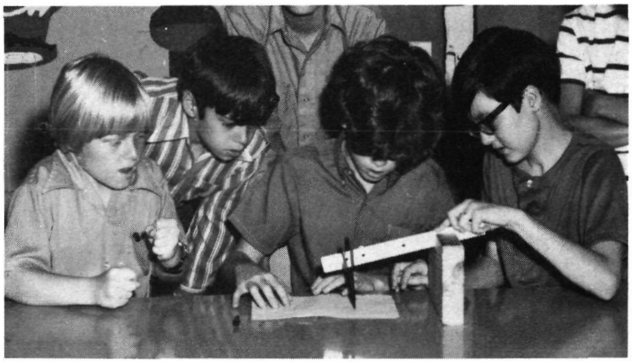
Theories about the origin of the Earth, the Moon, and solar system

1. Data collection

Science instruments in flight or landed on the Moon and planets provide information on the Sun, the bodies in orbit around it, and their interrelationships.

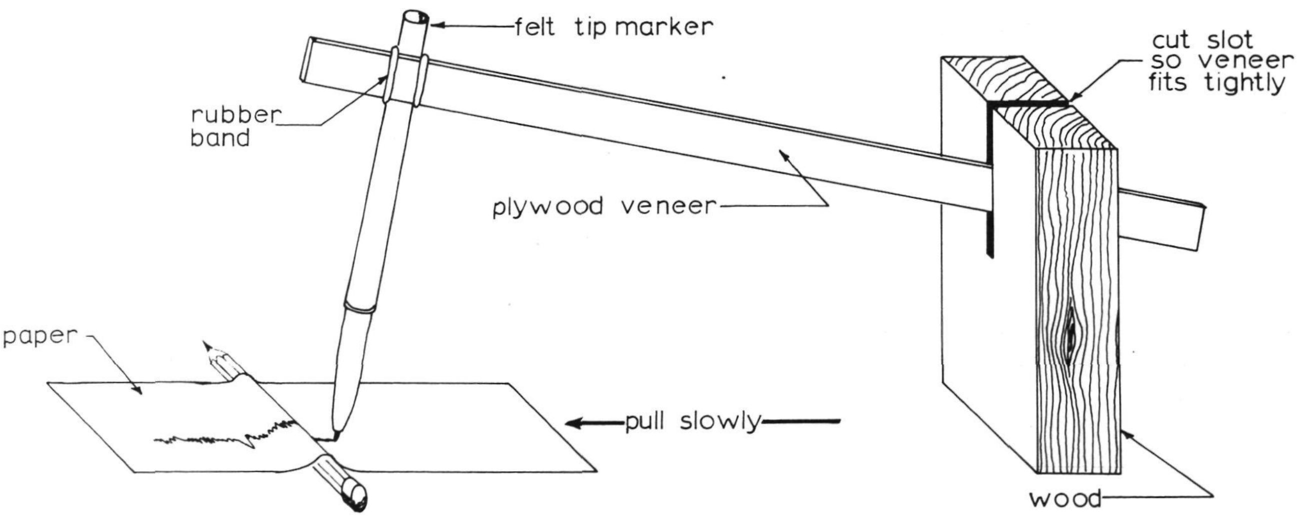
I-U. Simulate collection of a lunar soil core sample by packing alternate layers of damp sand, soil, gravel, etc., into a shoe box. Collect a soil core by forcing a hollow tube vertically into the "soil." Push the core out onto a tray and examine with a magnifying glass.

I-U. Collect soil core samples from different locations by forcing a hollow tube vertically into the soil. Push the cores out onto trays and examine with magnifying glass. Place a very small portion of each sample in a container. Add distilled water and test with litmus paper to determine relative acidity.



U. Construct a simple seismograph. Place the seismograph on the corner of a table. For good balance, the felt tip marker should be fastened to the veneer strip at the center of the marker. Holding the wood block firmly to the table, adjust the tip of the marker to just clear the table top.

Place a sheet of paper under the marker tip and insert a pencil under the paper and about 1-2 centimeters (1/2 inch) in front of the marker tip (slight adjustments may be needed). Have one student hold the seismograph, another hold the paper and pencil. As a third student strikes the table or quickly moves it, the paper should be drawn slowly forward under the marker tip. The frequencies of the vibrations will be recorded.



I-U. Attach a piece of crumpled aluminum to a post, tree, or some other kind of support out-of-doors. Allow it to remain undisturbed for two weeks or so. Carefully undo the foil and notice the variety of particles that have been trapped in the foil. Compare to particle trap left on Moon's surface.

P-I-U. Demonstrate picture transmission. Discuss spacecraft sensors that may include a scanning device that records the brightness of each tiny area it "looks at" as a value from 0 to 63 (64 gradations of light and dark). For the purposes of demonstration, simplify the scale to four values: 0 to 3, with 0 being black and 3 being white and 1 and 2 as shades of gray. To illustrate, the teacher will be the transmitting spacecraft and the students will be the "ground receivers." Have the students build up a picture by filling in the squares on a sheet of graph paper with pencil representing the brightness values given in a high-contrast photograph (i.e., school seal, flag, animal); the rows of squares on the graph paper should be designated with letters of the alphabet or arabic numerals vertically and horizontally. The teacher will direct the students to fill in the squares according to the four-value brightness scale. How much does the graph-paper version resemble the original photo? Would more gradations of black, gray, and white have helped?

U. Simulate a magnetometer aboard a spacecraft orbiting a planet whose magnetic characteristics are not known. Make a "planet" of a large styrofoam ball. Insert several small bar magnets into the ball at random locations. Using a small compass (or small bar magnet suspended on a thread), orbit the "planet" a number of times, measuring the amount of compass-needle or bar-magnet deflection that occurs along each path. Use these measurements to draw a map of the "planet's" magnetic characteristics.

Research

Information gathered from lunar rocks and soil

Techniques used to determine the age of samples

Reaction of plants and animals exposed to lunar soil

Theories about origin of lunar craters

Volcanic activity on the Moon

Apollo Lunar Surface Experiments Package (ALSEP)

Lasers

Sonar

Radar

Holography

2. Significance to Earth

Data collected about the solar system may lead to our better understanding of the Earth and its phenomena.

I-U. Show that the red surface of Mars is caused by iron oxide, which needed water, not oxygen, to form. Stuff steel wool into the closed end of three test tubes. Turn one tube upside down on a firm surface, or cork it. Turn the second upside down in a pan with 2.5 centimeters (1 inch) of water in it. Hold a burning splint into the third tube until it goes out because the oxygen has burned up. Quickly close the tube with your thumb and lower the mouth of the tube into the water, taking care that no oxygen is allowed into the test tube again (it has been replaced by carbon dioxide and nitrogen). Put the apparatus where it can't be disturbed or the test tubes knocked over. After 24 hours, what has happened to the steel wool in each tube? After 48 hours?

Research

Theories about the loss of water on Mars

Atmospheres on other planets and how they resemble different stages in Earth's atmospheric history

E. Universe

Investigations of the stars, galaxies, and other phenomena of space can lead to greater understanding of the universe.

I-U. Draw or paint pictures of imaginary figures associated with constellations.

I-U. Create imaginary figures based on constellation patterns. Draw or paint pictures of the figures and write a myth explaining the origin of the figure.

I-U. Using a variety of materials construct an imaginary being from space.

Research

High Energy Astronomy Observatory (HEAO)

Space Telescope (ST)

Theories about the origin of the universe

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Branley. *The Milky Way* (U-T)
Dwiggins. *Spaceship Earth* (I-U)
Ehricke and Miller. *Exploring the Planets* (U-T)
Halacy. *Colonization of the Moon* (I-U)
Henry. *Tomorrow's Moon* (I-U-T)
Hyde. *Off into Space!* (I)
Jastrow. *Red Giants and White Dwarfs* (T)

Ogden and DeVault. *Astronomy* (I-U)
Simmons and Link. "Headlines of the Future" (T)
Strickland. *Superworlds* (I-U)
U.S. Department of Interior. *Studying the Earth from Space* (T)
U.S. NASA. *Medical Benefits from Space Research* (U-T)
U.S. NASA. *Planetary Exploration* (U-T)
U.S. NASA. *Quasars, Pulsars, Black Holes . . . and HEAO's* (U-T)
U.S. NASA. *This Island Earth* (U-T)
U.S. NASA. *Why Survey from Space?* (I-U-T)
Young. *Life Beyond Earth* (I-U-T)
Zim. *The Universe* (I-U)

APPENDIX

From President Kennedy's Special Message to Congress on Urgent National Needs of May 25, 1961.*

Finally, if we are to win the battle that is going on around the world between freedom and tyranny, if we are to win the battle for men's minds, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as did the sputnik in 1957, the impact of this adventure on the minds of men everywhere who are attempting to make a determination of which road they should take. Since early in my term our efforts in space have been under review. With the advice of the Vice President, who is Chairman of the National Space Council, we have examined where we are strong and where we are not, where we may succeed and where we may not. Now it is time to take longer strides—time for a great new American enterprise—time for this Nation to take a clearly leading role in space achievement which in many ways may hold the key to our future on earth.

I believe we possess all the resources and all the talents necessary. But the facts of the matter are that we have never made the national decisions or marshaled the national resources required for such leadership. We have never specified long-range goals on an urgent time schedule, or managed our resources and our time so as to insure their fulfillment.

Recognizing the head start obtained by the Soviets with their large rocket engines, which gives them many months of leadtime, and recognizing the likelihood that they will exploit this lead for some time to come in still more impressive successes, we nevertheless are required to make new efforts on our own. For while we cannot guarantee that we shall one day be first, we can guarantee that any failure to make this effort will find us last. We take an additional risk by making it in full view of the world—but as shown by the feat of Astronaut Shepard, this very risk enhances our stature when we are successful. But this is not merely a race. Space is open to us now; and our eagerness to share its meaning is not governed by the efforts of others. We go into space because whatever mankind must undertake, free men must fully share.

I therefore ask the Congress, above and beyond the increases I have earlier requested for space activities, to provide the funds which are needed to meet the following goals:

First, I believe that this Nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth. No single space project in this period will be more exciting, or more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish. Including necessary supporting research, this objective will require an additional $531 million this year and still higher sums in the future. We propose to accelerate development of the appropriate lunar spacecraft. We propose to develop alternate liquid and solid fuel boosters much larger than any now being developed, until certain which is superior. We propose additional funds for other engine development and for unmanned explorations—explorations which are particularly important for one purpose which this Nation will never overlook: the survival of the man who first makes this daring flight. But in a very real sense, it will not be one man going to the moon—we make this judgment affirmatively—it will be an entire nation. For all of us must work to put him there.

*EXTRACT FROM 87th Congress Document 174 House of Representatives

National Aeronautics and Space Act of 1958, as amended*

Declaration of Policy and Purpose

Sec. 102. (a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

(b) The Congress declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities. The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with section 201(e).

(c) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives;

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment.

(d) It is the purpose of this Act to carry out and effectuate the policies declared in subsections (a), (b), and (c).

*Extract from Public Law 85-568, 85th Congress, House of Representatives, July 29, 1958.

Books

Author	Title	Publisher	Copyright Date	Age Level
Ahnstrom, D.N.	*The Complete Book of Helicopters*	World	1971	U-T
———	*The Complete Book of Jets and Rockets*	World	1970	U-T
Akens, David S.	*John Glenn: First American in Orbit*	Strode	1969	U-T
Anderson, Lonzo	*Bag of Smoke*	Knopf	1968	I-U-T
Anderson, Poul	*The Infinite Voyage: Man's Future in Space*	Crowell Collier	1969	U-T
Armstrong, Neil, *et al.*	*First on the Moon*	Little	1970	U-T
Asimov, Isaac	*The ABC's of Space*	Walker	1969	P
———	*The Double Planet*	Abelard	1967	I-U
———	*Galaxies*	Follett	1968	P-I
———	*How Did We Find out About Comets?*	Walker	1975	U-T
———	*Jupiter, The Largest Planet*	Lothrop	1973	U-T
———	*Mars*	Follett	1967	P-I
———	*The Solar System*	Follett	1974	P-I
———	*Stars*	Follett	1968	P-I
Aylesworth, Thomas G.	*Who's Out There?*	McGraw-Hill	1975	U-T
Barnaby, Ralph S.	*How to Make and Fly Paper Airplanes*	Four Winds	1969	U
Beiser, Germaine	*The Story of Gravity*	Dutton	1968	U-T
Bendick, Jeanne	*First Book of Space Travel*	Watts	1969	I
Bergamini, David	*Universe*	Silver Burdett	1969	I-U
Bergaust, Erik	*Convertiplanes in Action: The VTOL Success Story*	Putnam	1969	U-T
———	*Mars: Planet for Conquest*	Putnam	1967	I-U-T
——— (ed.)	*New Illustrated Space Encyclopedia*	Putnam	1970	U-T
———	*The Next Fifty Years on the Moon*	Putnam	1974	U-T
———	*Rescue in Space*	Putnam	1974	U-T
———	*The Russians in Space*	Putnam	1969	U-T
Berger, Melvin	*Gravity*	Coward	1969	P-I
———	*Stars*	Coward	1971	P-I
Bergwin, Clyde and William Coleman	*Animal Astronauts: They Opened the Way to the Stars*	Prentice	1963	U-T
Bono, Phillip and Kenneth Gatland	*Frontiers of Space: Pocket Encyclopedia of Space in Color*	Macmillan	1969	U-T
Bova, Benjamin	*Planets, Life & LGM*	Addison	1970	U-T
Boyle, Charles P.	*Space Among Us*	ASAE	1974	U-T
Boys' Life Editors	*The Boys' Life Book of Outer Space Stories*	Random	1964	U-T
Branley, Franklyn M.	*A Book of Mars for You*	Crowell	1968	I-U
———	*A Book of Moon Rockets for You*	Crowell	1970	I-U
———	*A Book of Outer Space for You*	Crowell	1970	P-I-U
———	*A Book of Planet Earth for You*	Crowell	1975	I-U
———	*A Book of Planets for You*	Scholastic	1972	P-I
———	*A Book of Satellites for You*	Crowell	1971	I
———	*A Book of Venus for You*	Crowell	1969	I
———	*The End of the World*	Crowell	1974	U-T
———	*Energy for the 21st Century*	Crowell	1975	U-T
———	*Experiments in Sky Watching*	Crowell	1967	U-T
———	*Experiments in the Principles of Space Travel*	Crowell	1973	U-T
———	*Gravity is a Mystery*	Crowell	1970	P-I
———	*Lodestar: Rocket Ship to Mars*	Crowell	1951	U-T
———	*Man in Space to the Moon*	Crowell	1970	I-U
———	*Mars, Planet Number Four*	Crowell	1975	U-T
———	*The Milky Way: Galaxy Number One*	Crowell	1969	U

*Complete listing of publishers' names and addresses, Pages 124-125.

Author	*Title*	*Publisher*	*Copyright Date*	*Age Level*
———	*The Moon: Earth's Natural Satellite*	Crowell	1972	U-T
———	*The Nine Planets*	Crowell	1971	U-T
———	*Pieces of Another World: The Story of Moon Rocks*	Crowell	1972	U-T
———	*Rockets and Satellites*	Crowell	1970	P-I
———	*Weight and Weightlessness*	Crowell	1972	P-I
Buehr, Walter	*Freight Trains of the Sky*	Putnam	1969	I-U-T
Cartwright, Sally	*Sunlight*	Coward	1974	P-I
Challand, Helen J. and Elizabeth R. Brandt	*Science Activities from A to Z*	Childrens	1963	I-U-T
Chandler, Tony John	*Air Around Us*	Doubleday	1969	P-I-U
Chappell, Carl L.	*Virgil I. Grissom: Boy Astronaut*	Bobbs-Merrill	1971	I-U
Chester, Michael	*Let's Go to the Moon*	Putnam	1974	P-I
Chrysler, C. Donald and Don L. Chaffee	*On Course to the Stars: The B. Chaffee Story*	Kregel	1968	U-T
Clarke, Arthur C.	*2001, A Space Odyssey*	Norton	1968	U-T
——— and Robert Silverberg	*Into Space: A Young Person's Guide to Space*	Harper	1971	I-U-T
Cobb, Vicki	*Supersuits*	Lippincott	1975	I-U
Colby, Carroll B.	*Astronauts in Training*	Coward	1969	I-U-T
———	*Moon Exploration: Space Stations, Moon Maps, Lunar Vehicles*	Coward	1970	I-U
Collins, Michael	*Carrying the Fire*	Farrar	1974	U-T
Coombs, Charles	*Skyhooks: The Story of Helicopters*	Morrow	1967	I-U
———	*Skylab*	Morrow	1972	U-T
———	*Spacetrack: Watchdog of the Skies*	Morrow	1969	I-U-T
Corbett, Scott	*What Makes a Plane Fly?*	Little	1967	I-U-T
Crawford, Deborah	*The King's Astronomer: William Herschel*	Messner	1968	U
Dalton, Richard	*All About Energy*	Third Press	1975	P-I-U
Darden, Lloyd	*The Earth in the Looking Glass*	Doubleday	1974	T
Daugherty, James	*Robert Goddard: Trail Blazer to the Stars*	Macmillan	1964	I-U
Delear, Frank J.	*The New World of Helicopters*	Dodd	1967	I-U-T
Del Rey, Lester	*Prisoners of Space*	Westminster	1968	U
Dempsey, Michael W. and Angela Sheehan	*Into Space*	World	1970	P
De Paola, Tomie	*The Cloud Book*	Holiday	1975	P-I
Dille, John and P.S. Hopkins	*Americans in Space*	Harper	1965	U-T
Dwiggins, Don	*Eagle Has Landed: The Story of Lunar Exploration*	Golden Gate	1970	I-U
———	*Spaceship Earth: A Space Look at Our Troubled Planet*	Golden Gate	1970	I-U
———	*Voices in the Sky: The Story of Communications Satellites*	Golden Gate	1969	U-T
Ehricke, Krafft and Betty A. Miller	*Exploring the Planets*	Silver Burdett	1969	I-U-T
EROS	*LANDSAT Inquiry/Order form*	EROS	n.d.	T
Feravolo, Rocco V.	*Around the World in Ninety Minutes: The Journey of Two Astronauts*	Lothrop	1968	P
———	*Wonders Beyond the Solar System*	Dodd	1968	I-U
Field, Adelaide	*Auguste Picard*	Houghton	1969	U-T
Fischer, Vera	*One Way is Down: A Book About Gravity*	Little	1967	P-I
Fisher, James	*Wonderful World of The Air*	Doubleday	1968	U
Fisk, Nicholas	*Space Hostages*	Macmillan	1969	U-T
Fitzgerald, Kenneth (comp.)	*The Space Age Photographic Atlas*	Crown	1970	U-T

Author	Title	Publisher	Copyright Date	Age Level
Freeman, Ira M.	*The Look-it-up Book of Space*	Random	1969	I-U
Freeman, Mae	*Gravity and the Astronauts*	Crown	1970	P
———	*When Air Moves*	McGraw-Hill	1968	I-U
Friskey, Margaret	*The Moonwalk Adventure*	Childrens	1970	P
Fuchs, Erich	*Journey to the Moon*	Delacorte	1970	P-I-U
Gagarin, Yuri and Vladimir Lebedev	*Survival in Space*	Praeger	1969	U-T
Gallant, Roy A.	*Exploring Mars*	Doubleday	1968	U-T
———	*Exploring the Weather*	Doubleday	1969	U
Gamow, George and Harry C. Stubbs	*The Moon*	Abelard	1971	U-T
Gardner, Martin	*Space Puzzles: Curious Questions and Answers About the Solar System*	Simon	1971	I-U
Garelick, May	*Look At the Moon*	Addison	1969	P
Gentle, Ernest and L. W. Reithmaier (ed.)	*Aviation and Space Dictionary. 5th Edition*	Aero	1973	U-T
Goodrum, John	*Wernher von Braun: Space Pioneer*	Strode	1969	U-T
Grissom, Virgil I.	*Gemini: A Personal Account of Man's Venture Into Space*	Macmillan	1968	U-T
Gurney, Gene	*Americans to the Moon: The Story of Project Apollo*	Random	1970	U-T
———	*The Launching of Sputnik, October 4, 1957: The Space Age Begins*	Watts	1975	U
———	*Walk in Space: The Story of Project Gemini*	Random	1971	U-T
——— and Clare Gurney	*Unidentified Flying Objects*	Abelard	1970	I-U
Haggerty, James J.	*Apollo: Lunar Landing*	Rand-McNally	1969	U-T
Halacy, Daniel S. Jr.	*Colonization of the Moon*	Van Nostrand	1969	I-U
———	*They Gave Their Names to Science*	Putnam	1967	U-T
Hammond, Inc. (ed.)	*Earth and Space*	Hammond	1970	I-U-T
Hellman, Hal	*Light and Electricity in the Atmosphere*	Holiday	1968	U-T
Hendricks, Stanley	*Astronauts on the Moon: The Story of the Apollo Moon Landings*	Hallmark	1970	P-I
Hendrickson, Walter B. Jr.	*Apollo 11: Men to the Moon*	Harvey	1970	I-U-T
———	*Manned Spacecraft to Mars and Venus: How They Work*	Putnam	1975	U
———	*What's Going on in Space?*	Harvey	1969	I-U
———	*Who Really Invented the Rocket?*	Putnam	1973	I-U-T
Henry, George E.	*Tomorrow's Moon*	Silver Burdet	1969	I-U-T
Hey, Nigel S.	*The Mysterious Sun*	Putnam	1971	U-T
Highland, Harold	*How and Why Wonder Book of Planets and Interplanetary Travel*	Grosset	1970	I-U
Hill, Robert W.	*What the Moon Astronauts Do*	Day	1971	I-U
Holder, William G.	*Saturn V, The Moon Rocket*	Messner	1970	U-T
Holl, Adelaide	*Moon Mouse*	Random	1969	I-U
Hone, Elizabeth B., *et al.*	*Teaching Elementary Science: A Source Book for Elementary Science. 2nd Edition*	Harcourt	1971	I-U-T
Hoyt, Mary Finch	*American Women of the Space Age*	Atheneum	1966	U-T
Hyde, Margaret O.	*Exploring Earth and Space. 5th Edition*	McGraw-Hill	1970	I-U
———	*Flight Today and Tomorrow, 3rd Edition*	McGraw-Hill	1970	U-T
———	*Off Into Space!*	McGraw-Hill	1969	I
Hyde, Wayne	*The Men Behind the Astronauts*	Dodd	1965	U-T
Iger, Eve M.	*Weather on the Move*	Addison	1970	U
Jacobs, Leland B. (ed.)	*Poetry for Space Enthusiasts*	Garrad	1971	P-1
Jacobs, Lou, Jr.	*By Jupiter! The Remarkable Journey of Pioneer 10*	Hawthorn	1975	U-T

Author	*Title*	*Publisher*	*Copyright Date*	*Age Level*
______	*Jumbo Jets*	Bobbs-Merrill	1969	U-T
______	*SST Plane of Tomorrow*	Golden Gate	1969	U-T
Jastrow, Robert	*Red Giants and White Dwarfs*	Harper	1971	T
Johnson, Raymond J. (ed.)	*The Illustrated Encyclopedia of Aviation and Space*	American Family	1971	I-U-T
Johnson, Ryerson	*Mouse and Moon*	Hale	1968	P
Kaufmann, John	*Winds and Weather*	Morrow	1971	I-U
Key, Alexander	*Rivets and Sprockets*	Westminster	1964	I-U
Knight, David C.	*Comets*	Watts	1968	U-T
______	*Eavesdropping on Space: The Quest of Radio Astronomy*	Morrow	1975	U-T
______	*The First Book of the Sun*	Watts	1968	I-U
______	*Let's Find Out about Weather*	Watts	1967	P-I
______	*Thirty-two Moons: Natural Satellites of the Solar System*	Morrow	1974	U-T
______	*American Astronauts and Spacecraft: A Pictorial History from Project Mercury through the Skylab Manned Missions*	Watts	1975	I-U-T
Kohn, Bernice	*Communications Satellites: Message Centers in Space*	Four Winds	1975	P-I
Kondo, Herbert	*The Moon*	Watts	1971	U-T
Land, Barbara	*The Telescope Makers: From Galileo to the Space Age*	Crowell	1969	U-T
Lehman, Milton	*This High Man*	Pyramid	1970	T
Lewis, Claudia	*Poems of Earth and Space*	Dutton	1967	I-U
Ley, Willy	*Gas Giants: The Largest Planets*	McGraw-Hill	1969	U-T
______	*Inside the Orbit of the Earth*	McGraw-Hill	1968	U-T
Lomask, Milton	*Robert H. Goddard: Space Pioneer*	Garrard	1972	I-U
Lord, Beman	*The Spaceship Returns*	Walck	1970	I-U
Lukashok, Alvin	*Communication Satellites: How They Work*	Putnam	1967	I-U-T
May, Charles	*Women in Aeronautics*	Nelson	1962	T
May, Julian	*Astronautics*	Follett	1968	P-I
______	*Climate*	Follett	1968	P-I
______	*Rockets*	Follett	1967	P
McCauley, John F.	*Moon Probes*	Silver Burdett	1969	I-U-T
McDonald, Robert L. and Walter H. Hesse	*Space Science*	Merrill	1970	I
Milgrom, Harry	*Understanding Weather*	Macmillan	1970	I-U
Miller, Katherine	*Apollo*	Houghton	1970	I-U
Moore, Carleton	*Cosmic Debris*	Silver Burdett	1969	I-U-T
Newell, Homer E., Jr.	*Space Book for Young People*	McGraw-Hill	1968	I-U
Newlon, Clarke	*1001 Questions Answered About Space*	Dodd	1971	U-T
Nourse, Alan E.	*The Asteroids*	Watts	1975	I-U
______	*The Backyard Astronomer*	Watts	1973	I-U
______	*The Giant Planets*	Watts	1974	I-U
Ogden, Herbert S. and M. W. De Vault	*Astronomy*	Steck-Vaughn	1969	I-U
Olney, Ross	*Americans In Space: A History of Manned Space Travel*	Nelson	1970	U-T
______	*Astronomy: The Inquiring Mind*	Nelson	1967	I-U
Pacilio, James V.	*Discovering Aerospace*	Childrens	1965	I-U
Parker, Bertha M.	*Satellites and Space Travel*	Harper	1967	T
Pickering, James S.	*Famous Astronomers*	Dodd	1968	U-T
Pollinger, Gerald	*Strange But They Flew*	Putnam	1967	I-U

Author	*Title*	*Publisher*	*Copyright Date*	*Age Level*
Pope, Billy N. and Ramona W. Emmons	*Let's Visit a Spaceship*	Taylor	1971	P-I
Rand McNally Editors	*Around the World: A View From Space*	Rand	1969	I-U-T
Richards, Norman	*Giants in the Sky*	Childrens	1967	U-T
Richey, B. J.	*Apollo Astronauts: First Men to the Moon*	Strode	1969	U-T
Rosenfeld, Sam	*Ask Me A Question About Rockets, Satellites and Space Stations*	Harvey	1971	I-U
———	*Science Experiments for the Space Age*	Harvey	1972	I-U-T
———	*Science Experiments with Air*	Harvey	1969	U
Ross, Frank, Jr.	*Model Satellites and Spacecraft: Their Stories & How to Make Them*	Lothrop	1969	U-T
———	*Space Science and You*	Lothrop	1970	U-T
Settle, Mary Lee	*Story of Flight*	Random	1967	P-I-U-T
Shapp, Martha and Charles Shapp	*Let's Find out About Airplanes*	Watts	1968	P-I
Sharpe, Mitchell R.	*It is I, Seagull, Valentina Tereshkova*	Crowell	1974	U-T
———	*Yuri Gagarin: First Man in Space*	Strode	1969	U-T
Shelton, William R.	*Man's Conquest of Space*	Nat. Geog.	1968	U-T
Silverberg, Robert	*Four Men Who Changed the Universe*	Putnam	1968	U-T
———	*The World of Space*	Meredith	1969	U-T
Simmons and Link	"Headlines of the Future"	*Science Teacher*	April 1968	T
Simon, Seymour	*Weather and Climate*	Random	1970	I-U
Simon, Tony	*The Moon Explorers*	Scholastic	1970	I-U-T
Siuru, Wm. Jr. and Wm. E. Holder	*Skylab: Pioneer Space Station*	Rand	1974	U-T
Sleator, William	*The Angry Moon*	Little	1970	P-I
Slobodkin, Louis	*Round Trip Space Ship*	Macmillan	1968	I-U
———	*The Space Ship Returns to the Apple Tree*	Macmillan	1958	P-I-U
———	*Space Ship Under the Apple Tree*	Macmillan	1957	P-I
———	*The Three-Seated Space Ship*	Macmillan	1964	P-I-U
Slote, Alfred	*The Moon in Fact and Fancy*	World	1971	I-U
Smith, Norman F.	*Uphill to Mars, Downhill to Venus*	Little	1970	U-T
Smithline, Frederick	*Answers About the Moon, Stars, and Planets*	Wonder	1969	I-U
Sootin, Harry	*Long Search: Man Learns about Air*	Norton	1967	U
Sparks, James C.	*Moon Landing, Project Apollo*	Dodd	1970	U-T
———	*Winged Rocketry*	Dodd	1968	U-T
Stambler, Irwin	*Project Viking: Space Conquest Beyond the Moon*	Putnam	1969	U-T
Stoiko, Michael	*Pioneers of Rocketry*	Hawthorn	1974	U-T
Stone, A. Harris and Herbert Spiegel	*The Winds of Weather*	Prentice	1969	I-U
Stone, George K.	*More Science Projects You Can Do*	Prentice	1970	I-U
Strickland, Joshua	*Superworlds*	Grosset	1975	I-U
Sullivan, Navin	*Pioneer Astronomers*	Scholastic	1972	I-U
Talcott Mountain Science Center	*Space Science Involvement*	American Radio	1973	T
Taylor, L. B., Jr.	*For All Mankind: America's Space Programs of the 1970s and Beyond*	Dutton	1975	U-T
Tharp, Edgar	*Giants of Space*	Grosset	1970	U-T
Thomas, Shirley	*Men of Space: 8 volumes*	Chilton	1960-68	T
Turnhill, Reginald	*The Language of Space: A Dictionary of Astronautics*	Day	1970	U-T

Author	*Title*	*Publisher*	*Copyright Date*	*Age Level*
U.S. Department of Interior	*Studying the Earth from Space.* *stock #2401-2060*	GPO	1972	T
U.S. NASA	*Aeronautics.* (Space in the Seventies series) EP-85	GPO	1971	T
———	*Aerospace Bibliography* (6th ed.) EP-48	GPO	1973	T
———	*Apollo.* EP-100	GPO	1975	I-U-T
———	*Apollo Expeditions to the Moon.* SP-350	GPO	1975	U-T
———	*Apollo-Soyuz Test Project.* NF-52	GPO	1975	U-T
———	*Apollo 13: "Houston, We've Got a Problem"* EP-76	GPO	1970	U-T
———	*Apollo 16 at Descartes.* EP-97	GPO	1972	U-T
———	*Applications Technology Satellite-6.* NF-53	GPO	1975	U-T
———	*Astronaut Selection and Training*	NASA*	n.d.	U-T
———	*Code Name: Spider.* EP-68	GPO	U-T	
———	*Exploration of the Solar System.* EP-122	GPO	1974	T
———	*Exploring Space with a Camera.* SP-168	GPO	1968	U-T
———	*Food for Space*	NASA*	n.d.	U-T
———	*Improving Our Environment*	NASA**	1973	U-T
———	*International Programs*	NASA*	1975	T
———	*Life Beyond Earth and the Mind of Man.* SP-328	GPO	1974	T
———	*Living in Space.* NF-27	GPO	1969	U-T
———	*Man in Space* (America in Space: The First Decade series) EP-57	GPO	1969	U-T
———	*Mars and Earth.* NF-61	GPO	1976	U-T
———	*Mars as a Member of the Solar System.* NF-59	GPO	1976	U-T
———	*Mars as a Planet.* NF-60	GPO	1976	U-T
———	*Medical Benefits from Space Research.* EP-46	GPO	1968	U-T
———	*NASA Aeronautics.* NF-46	GPO	1974	U-T
———	*NASA Ames Research Center.* NFO-2	NASA***	1967	U-T
———	*NASA and Energy.* EP-121	GPO	1974	U-T
———	*NASA Hugh L. Dryden Flight Research Center.* NFO-4	NASA****	1967	U-T
———	*NASA Goddard Space Flight Center.* NFO-5	NASA***	1972	U-T
———	*NASA John F. Kennedy Space Center.* NFO-6	NASA***	1967	U-T
———	*NASA Langley Research Center.* NFO-7	NASA***	1968	U-T
———	*NASA Lewis Research Center.* NFO-8	NASA***	1967	U-T
———	*NASA George C. Marshall Space Flight Center.* NFO-10	NASA***	1967	U-T
———	*New Horizons.* EP-117	GPO	1975	U-T
———	*The Now Frontier, Linking Earth and Planets* (Mariner, Venus, Mercury)	NASA†	1974	U-T
———	*The Now Frontier, Pioneer to Jupiter*	NASA‡	1973	U-T
———	*Observing Earth from Skylab.* NF-56	GPO	1975	I-U-T
———	*Opportunities as Candidates for Mission Specialist Astronaut*	NASA**	1976	U-T
———	*Opportunities as Candidates for Pilot Astronauts*	NASA**	1976	U-T
———	*Orders of Magnitude.* SP-4403	GPO	1976	U-T
———	*Our Prodigal Sun.* EP-118	GPO	1975	U-T
———	*Pioneer Mission to Jupiter*	NASA**	1972	T

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———	*Planetary Exploration.* (Space in the Seventies series). EP-83	GPO	1971	T
———	*Quasars, Pulsars, Black Holes . . . and HEAO's.* EP-120	GPO	1974	T
———	*Rendezvous in Space: Apollo-Soyuz*	NASA**	1975	T
———	*Satellites at Work.* (Space in the Seventies series). EP-84	GPO	1971	T
———	*Saturn V.* NF-33	GPO	1967	U-T
———	*Skylab*	NASA*	1972	U-T
———	*Skylab, A Guidebook.* EP-107	GPO	1973	T
———	*Skylab and the Sun.* EP-119	GPO	1974	T
———	*Solar Cells* NFS-6	NASA**	1968	U-T
———	*Space Benefits and Older Citizens*	NASA*	1972	T
———	*Space Benefits-Safety*	NASA*	1972	U-T
———	*Space Benefits/today and tomorrow*	NASA*	1972	U-T
———	*Space Shuttle.* EP-96	GPO	1972	U-T
———	*Space Shuttle. SP-407*	GPO	1976	U-T
———	*Space Shuttle Wallsheet.* NF-44	GPO	n.d.	U-T
———	*Space Suit*	NASA***	n.d.	U-T
———	*The Spectrum.* NF-54	GPO	1975	U-T
———	*This Island Earth.* SP-250	GPO	1970	U-T
———	*This New Ocean: A History of Project Mercury.* SP-4201	GPO	1966	T
———	*Two Over Mars.* EP-90	GPO	1970	T
———	*The Viking Mission.* NF-62	GPO	1976	U-T
———	*Viking Mission to Mars.* NF-76	GPO	1975	U-T
———	*Waste Management*	NASA***	n.d.	U-T
———	*What's New on the Moon?* EP-131	GPO	1976	I-U-T
U.S. NOAA	*The NOAA Story*	GPO	1976	I-U-T
———	*Space, Environmental Vantage Point*	GPO	1974	I-U-T
Valens, Evans G.	*Cybernaut: A Space Poem*	Viking	1968	U-T
Verne, Jules	*From the Earth to the Moon and Around the Moon* (Children's Illustrated Classics series)	Dutton	1970	U-T
Victor, Edward	*Airplanes*	Follett	1966	P-I
Von Braun, Wernher and F. I. Ordway, III	*History of Rocketry and Space Travel*	Crowell	1974	U-T
Walters, Helen B.	*Hermann Oberth: Father of Space Travel*	Macmillan	1962	U-T
Weart, Spencer	*How to Build Sun*	Coward	1970	U-T
Weaver, Kenneth F.	"Journey to Mars"	Nat. Geog.	Feb. 1973	U-T
———	"Skylab, Outpost on the Frontier of Space"	Nat. Geog.	Oct. 1974	U-T
———	"Voyage to the Planets"	Nat. Geog.	Aug. 1970	U-T
Whittingham, Richard	*Astronomy Factbook*	Hubbard	1970	U-T
Wilford, John Noble	*We Reach the Moon*	Norton	1969	U-T
Withers, Carl	*Painting the Moon: A Folktale from Estonia*	Dutton	1970	P-I
Worden, Alfred M.	*I Want to Know about a Flight to the Moon*	Doubleday	1974	P-I-U
Young, Richard S.	*Life Beyond Earth*	Silver Burdett	1969	I-U-T
Zarem, Lewis	*Green Man From Space*	Hale	1955	U-T
Ziegler, Ursina	*Squaps*	Atheneum	1969	I-U
Zim, Herbert S.	*The Sun*	Morrow	1975	I-U
———	*The Universe*	Morrow	1973	I-U

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Films

Title	Length	Copyright Date	Distributor	Age Level
Adventures in Research	18min.	1975	NASA	U
Apollo 15: In the Mountains of the Moon	28min.	1971	NASA	U
Apollo 16: Nothing so Hidden	29min.	1972	NASA	U
Apollo 17: On the Shoulders of Giants	28min.	1973	NASA	U
Apollo-Soyuz	28min.	1975	NASA	I-U
Beyond the Moon	11min.	1970	BFA	I-U
Eagle Has Landed: The Flight of Apollo 11	28min.	1969	NASA	I-U
Earthquake Below (Rediscovery)	14min.	1975	NASA	I-U
Earth-Sun Relationship	6min.	1974	NASA	P-I
ERTS—Earth Resources Technology Satellite	27min.	1973	NASA	U
Exploring the Planets	24min.	1970	ACI Films	I-U
Flight Without Wings	14min.	1969	NASA	U
Flood Below (Rediscovery)	14min.	1975	NASA	I-U
4 Rms—Earth View	28min.	1975	NASA	I-U
From Balloon Gondola to Manned Spacecraft	27min.	1967	NASA*	U
How Many Meals to the Moon	22min.	1968	Modern	U-T
Hurricane Below (Rediscovery)	14min.	1974	NASA	I-U
If You Could See the Earth	11min.	1967	Ency. Brit.	P-I
Journey to a New World	13min.	1970	McGraw-Hill	I-U
Jupiter Odyssey	28min.	1974	NASA	I-U
Life?	14min.	1976	NASA	I-U-T
Life Beyond Earth and the Mind of Man	25min.	1974	NASA	U-T
Mars, and Beyond	15min.	1976	NASA	U-T
Mars—Is There Life?	15min.	1976	NASA	U-T
Mars—The Search Begins	28min.	1974	NASA	U-T
The Moon: Adventure in Space	16min.	1970	AIMS	I-U
Our Solar System	5min.	1973	NASA	I-U
Partners with Industry	14min.	1975	NASA	U-T
Pioneers and Modern Rockets	24min.	1970	ACI Films	I-U
Pollution Below (Rediscovery)	14min.	1975	NASA	I-U
Satellites and Men in Orbit	24min.	1970	ACI Films	I-U
Seeds of Discovery	28min.	1970	NASA	U
Skylab	28min.	1972	NASA	U
The Solar System: Measuring its Dimensions	28min.	1970	McGraw-Hill	P-I-U
Space in the 70's—Aeronautics	28min.	1971	NASA	U
Space in the 70's—Exploration of the Planets	25min.	1971	NASA	U
Space in the 70's—Man in Space—The Second Decade	28min.	1971	NASA	U
Space in the 70's—Space Down to Earth	27min.	1970	NASA	U
Spaceport—U.S.A.	23min.	1970	NASA	U
Spaceship Skylab—Wings of Discovery	11min.	1969	AIMS	I-U
Survival in Outer Space	9min.	1974	NASA	U
Target Moon	24min.	1970	ACI Films	I-U
The Time of Apollo	28min.	1974	NASA	I-U
Tornado Below (Rediscovery)	14min.	1975	NASA	I-U
Who's Out There?	28min.	1975	NASA	U
The World was There (Project Mercury)	27min.	1975	NASA	U

Filmstrips

Title	Copyright Date	Distributor	Age Level
Aerospace series			
The Story of Flight			
How an Airplane Flies			
Aircraft Engines: Piston and Jet			
How Rockets Work			
How Satellites Stay in Orbit			
Aircraft Engines: Piston and Jet (Aerospace series)	1967	Coronet	I-U
Astronomical Measurement I, II (Astronomy: Solar System and Beyond Series)	1970	Ward's	I-U
Astronomy: Solar System and Beyond series			
Astronomical Measurement I			
Astronomical Measurement II			
The Sun			
Planets in Motion			
Meteors, Comets, and Asteroids			
The Geography of the Universe			
Beyond the Nearby Stars (Sierra Elementary Astronomy series)	1968	Spitz	I-U
Constellations We can See	1962	Popular Science	I-U
Finding Out About The Universe	1963	SVE	P
The Geography of the Universe (Astronomy: Solar System and Beyond series)	1970	Ward's	I-U
How an Airplane Flies (Aerospace series)	1970	Coronet	I-U
How Rockets Work (Aerospace series)	1970	Coronet	I-U
How Satellites Stay in Orbit (Aerospace series)	1970	Coronet	I-U
Meteors, Comets, and Asteroids (Astronomy: Solar System and Beyond series)	1970	Ward's	I-U
Orbiting the Sun (Sierra Elementary Astronomy series)	1968	Spitz	I-U
Our Solar Family	1963	Popular Science	P-I-U
Planets in Motion (Astronomy: Solar System and Beyond series)	1970	Ward's	I-U
Reach for the Moon and Touch a Star	1967	NASA*	U
Satellites and Their Work (Aerospace series)	1970	Coronet	I-U
The Sierra Elementary Astronomy series			
Orbiting the Sun Part 1 & 2			
Beyond the Nearby Stars Part 1 & 2			
Tracking the Stars Part 1 & 2			
Story of Flight (Aerospace series)	1970	Coronet	I-U
The Sun (Astronomy: Solar System and Beyond series)	1970	Ward's	I-U
Tracking the Stars (Sierra Elementary Astronomy series)	1968	Spitz	I-U

8mm Film Loops

Title	Distributor	Age Level
Eclipse of the Moon (Space Science series)	Film Assoc.	U
Eclipse of the Sun (Space Science series)	Film Assoc.	U
Experimental Aircraft	Wards	U
Experimental Aircraft	Thorne	I-U
Airplanes (1919-1930)		
Helicopters (1921-1940)		
Ornithopters		
Experimental Weightlessness (Space Science series)	Film Assoc.	U
Free Fall in Space (Space Science series)	Film Assoc.	U
Mars and Jupiter (Space Science series)	Film Assoc.	U
Meteorology Science Kit	Jeppesen Sanderson	U
Meteors and Meteorites (Space Science Series)	Film Assoc.	U
Solar Flares (Space Science series)	Film Assoc.	U
Solar Prominences (Space Science series)	Film Assoc.	U
Space Science series		
Solar Prominences		
Eclipse of the Sun		
Eclipse of the Moon		
Mars and Jupiter		
Experimental Weightlessness		
Free Fall in Space		
Solar Flares		
Meteors and Meteorites		

Teacher Resource List

Adler Planetarium—information sheets; booklets
Aerojet General Corporation—booklets
Aerospace Corporation—pamphlet
Aerospace Industries Association—pamphlets
American Map Co.—charts
American Society for Aerospace Education—*Journal of Aerospace Education, Directory of Aerospace Education*

Bell Telephone Co.—films; booklets
Milton Bradley—poster cards; flannel board aids

Cenco Educational Aids—programed materials
Centuri Engineering Company—*American Rocketeer,* newsletter; pamphlets
Cessna Aircraft—booklets; pictures; games
Civil Air Patrol—pamphlets; newsletter; bibliography
Cram Company, George F.—globes, pamphlets
Creative Educational Society—study prints

Denoyer-Geppert—globe; pamphlets; charts

Edmund Scientific Co.—models; maps; charts; pamphlets
Estes Industries—*Model Rocket News,* newsletter; models; pamphlets

Federal Aviation Administration—see U.S. Federal Aviation Administration

General Electric—charts; pamphlets

Hammond, Inc.—charts; "spacescapes" kits; booklets
Hubbard Scientific Company—models; charts; study prints; star finder; transparencies "Solar System Guide"

Jeppeson Sanderson—booklets, pictures

National Aerospace Education Association—pictures; charts; *Skylights,* newsletter; bibliography; pamphlets
National Geographic Society—bibliographies; maps; reprints; school bulletin

Popular Science Publishing Co., Inc.—transparencies

Rand McNally and Company—globe; posters; maps; atlas; pamphlets
RCA/Government and Commercial Systems—booklets
Revell, Inc.—models; pictures

Scholastic Book Services—charts; booklets
Smithsonian Institution Press—booklets
Society for Visual Education—pictures
Strafford Industries, Inc.—maps

Times Mirror School and Library Service—study prints
TRW Publishing Company—poster
Tudor Publishing Company—poster

U.S. Dept. of the Interior, EROS Data Center—photos of Earth from space
U.S. Federal Aviation Administration—bibliographies; pamphlets; filmstrips
U.S. Government Printing Office—bibliographies; booklets; books; pamphlets
U.S. National Aeronautics and Space Administration—bibliographies; exhibits; lecture-demonstration programs; speaker services; films; publications; pictures; charts; and *Report to Educators*

Publishers, Producers, Distributors

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ACI Films, Inc.
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New York, NY 10036

Addison-Wesley Publishing Co.
Reading, MA 01867

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900 E. Achsah Bond Dr.
Chicago, IL 60605

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329 Aviation Rd.
Fallbrook, CA 92028

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El Monte, CA 91734

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2350 E. El Segundo Blvd.
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Washington, DC 20036

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U.S. National Aeronautics and Space Administration

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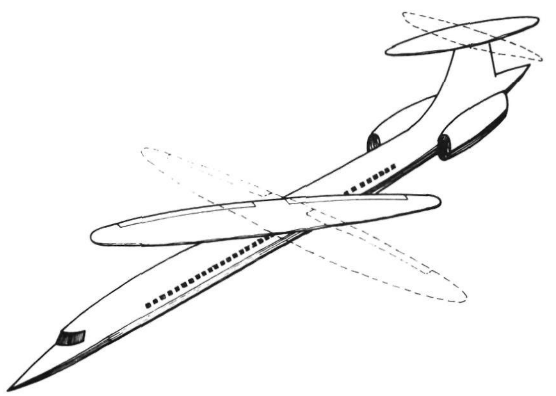
GLOSSARY

ABLATIVE COOLING—Temperature reduction which results from vaporization or melting of specially designed surface materials.

ANTISYMMETRICAL WING—A wing designed to be at the conventional right angle to the fuselage at takeoff and, after the aircraft has attained speed and altitude, rotate to about 45 degrees so the wing on one side of the fuselage would point more in the direction of flight and on the other side would trail toward the rear. (*See* diagram.)



BINARY COMPUTER—A computer that uses only two digits and operates on a base 2 notational system.

CIRCADIAN RHYTHMS—An organism's day/night cycle of living.

CLOSED ECOLOGICAL SYSTEM—A system for maintenance of life through reutilization of available material without further input from outside the system.

CORRIDOR—(*See* REENTRY CORRIDOR)

DISH ANTENNA—A radio or radar antenna with a saucer-like shape.

GREAT CIRCLE ROUTE—A path that follows an arc the center of which is at the center of the Earth.

HERO ENGINE—A reaction engine probably developed by the Greek scientist, Hero. It consists of a container of water that can be heated to force steam out through angled nozzles.

LIFE-SUPPORT SYSTEM—A system that provides an environment that will maintain life.

MAGNETOPAUSE—Boundary of the magnetosphere surrounding Earth. (*See* diagram, Page 10.)

MAGNETOSPHERE—An area arched about the radiation belts, relatively close to the Earth on the Sun side. On the night side it tails off to a distance of millions of miles. It encloses both the Earth's radiation belts and the Earth's magnetic tail. (*See* diagram, Page 10.)

MULTISPECTRAL PHOTOGRAPHY—Use of film sensitive to different regions of the spectrum (visible, infrared, ultraviolet, etc.) to produce multiple photographs of a region.

MULTISTAGING—A system in which two or more rocket units fire in sequence, each unit firing after the one back of it has exhausted its propellant.

REENTRY CORRIDOR—Narrow region, determined by velocity and altitude, along which spacecraft must travel to return safely to Earth's surface.

REGENERATIVE COOLING—The cooling of a part of an engine by the circulation of the fuel or propellant around the part to be cooled as the fuel is being delivered to the combustion chamber.

SCHLIEREN PATTERN—An irregular pattern of streaks in a transparent medium caused by variations in density which result from differences in pressure and temperature.

SOLAR CELL—A photovoltaic cell that converts sunlight into electrical energy.

SOLAR STORMS—Storms of electrical particles thrown out into space during periods of disturbance on the Sun's surface.

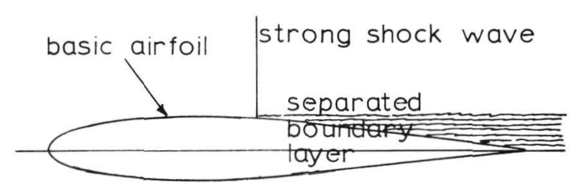
SOLAR WIND—Streams of protons and electrons flowing outward from the Sun.

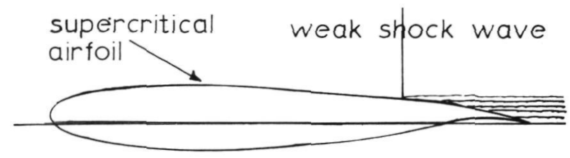
SPECTRAL PATTERN—A pattern of lines and colors in the spectrum that is unique for a specific substance.

SPIN STABILIZATION—Stabilizing the attitude of a spacecraft by spinning it around its front-to-back axis. The whole spacecraft acts as a gyroscope.

STABILITY—The property of an aircraft which, when it has been disturbed, causes it to remain at or return to its original position or attitude.

SUPERCRITICAL WING—An airfoil that has less curvature on the upper surface than the basic airfoil. This reduces shock waves and extra drag caused by the supersonic flow of air across the upper surface of the wing at speeds approaching the speed of sound. The supercritical design permits aircraft to operate with greater speed and efficiency. (*See* diagram.)





SYNCHRONOUS ORBIT—An orbit over the equator in which the speed of the satellite or spacecraft matches exactly the rotation of the Earth, so that it stays over the same location on the ground.

VARIABLE SWEEP WING—An aircraft wing whose sweepback angle can be changed in flight.

X-RAY MAPPING—Locating and recording the quantity and quality of X-ray emissions from our galaxy.

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EP - 147