Introduction

Spacewalking has captured the imagination of generations of children and adults since science-fiction authors first placed their characters on the Moon. But true spacewalking did not actually begin until the mid-1960s with the exploits of Alexei A. Leonov of the Soviet Union and Edward H. White II of the United States. Since those first tentative probings outside a space capsule, astronauts and cosmonauts have logged thousands of hours on extravehicular activities, and some have even walked on the surface of the Moon. The stories of their missions in space are fascinating, but just as interesting is the spacesuit technology that made it possible for them to "walk" in space.

Today, spacesuits are used by astronauts on many missions such as servicing the Hubble Space Telescope and retrieving satellites. The new International Space Station will depend upon astronauts and cosmonauts to conduct over 1,200 hours of spacewalks over the next several years to assemble and maintain Space Station components. Although no firm plans exist, NASA hopes to return to the Moon to establish a permanent base and later begin human surface exploration of Mars. Each of these ventures places distinct demands on spacesuits systems and the tools astronauts use.

This publication serves as a guide for technology education teachers. While not specifically aimed at other subject areas, teachers of physical science and mathematics will find the Exploration Briefs and the Idea Bank useful as a source of activity ideas.

The guide begins with brief discussions of the space environment, the history of spacewalking, NASA's current spacesuit, and work that astronauts do during spacewalks. These are followed by a technology education design brief that challenges students to design and build a spacesuit prototype for an extraterrestrial environment no human has ever visited before. In the process of doing this, students will have to investigate the properties of that environment and determine what protective measures must be taken to permit a future explorer to work there safely. Once accomplished, students will choose materials and technologies that can be used for constructing and testing the prototype. The design brief is followed by Teacher Tech Briefs that provide a source of ideas on how to build spacesuit test apparatus and by Exploration Briefs that provide activity frameworks to help students understand important topics in spacesuit design.

The guide concludes with a glossary of terms, suggested reading list, NASA educational resources including electronic resources, and an evaluation questionnaire. We would appreciate your assistance in improving this guide in future editions by completing the feedback questionnaire electronically or mailing the form to us.

Measurement

This activity guide makes use of the metric system for measurement. However, British units for measurement may be listed in materials and tools lists when particular items are more easily found in British measurement sizes. The pascal or metric unit for pressure may be unfamiliar to readers. A *pascal* is equal to a force of one newton exerted over an area of one square meter. Because the pascal is a relatively small unit, the more convenient unit of kilopascal (1,000 pascals) is used here instead. To convert kilopascals to the British-system unit of pounds per square inch, divide by 6.895.

Earth and Space

If we define an astronaut as someone who travels through space, everyone on Earth is an astronaut. Even though we may be standing still on Earth's surface, we are actually traveling through space at speeds of thousands of kilometers per hour. Indeed, our planet may be thought of as a spaceship on a never-ending voyage. As "astronauts" traveling through space on the surface of Earth, we take for granted the complex environment that sustains life. Earth's gravitational attraction holds a dense atmosphere of nitrogen, oxygen, carbon dioxide, and water vapor in a thick envelope surrounding Earth's entire surface. The weight of this atmosphere exerts pressure, and its movements distribute heat from the Sun to balance global temperatures. Its gases filter out harmful radiation and disintegrate all but the largest meteoroids. Earth's atmosphere is a shell that protects and sustains the life forms that have evolved on its surface. Without the atmosphere's protection, life as presently known would not be possible.

When Earth astronauts leave the surface of their planet and travel into space, they must carry some of their environment with them. It must be contained in a physical shell because their body masses are too small to hold it in place by gravitational attraction alone. The shell that is used is called a spacecraft—a rigid collection of metal, glass, plastic, and composites. Though far simpler in function than Earth's environment, a spacecraft's environment serves well for short missions lasting a few days or weeks. On some flights, the shell is deliberately opened and the astronauts pass through an airlock to venture outside. When doing so, they must be protected by a still smaller and very specialized version of their spacecraft called the Extravehicular Mobility Unit (EMU). This smaller spacecraft is composed of a spacesuit with a life-support system. It differs from the first spacecraft, or mother ship, in its anthropomorphous (human) shape and its flexibility. Astronauts wearing EMUs

Earth as seen by the crew of the Apollo 17 *Moon mission.*

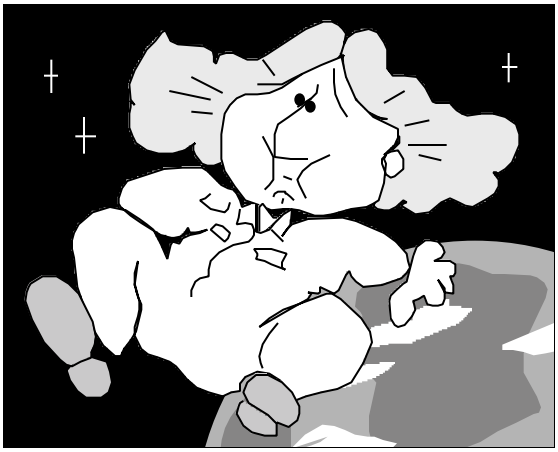
need to be able to move arms, hands, and legs to perform an array of tasks in space. They must be able to operate many types of scientific apparatus, collect samples, take pictures, assemble equipment and structures, pilot themselves about, and repair and service defective or worn-out satellites and other space hardware. The tasks of astronauts outside their mother ship are called extravehicular activities, or EVAs.

The Outer Space Environment

Outer space is just what its name implies. It is the void that lies beyond the uppermost reaches of the atmosphere of Earth and between all other objects in the universe. Although it is a void, outer space may be thought of as an environment. Radiation and objects pass through it freely. An unprotected human or other living being placed in the outer space environment would perish in a few brief, agonizing moments.

The principal environmental characteristic of outer space is the vacuum, or nearly total absence of gas molecules. The gravitational attraction of large bodies in space, such as planets and stars, pulls gas molecules close to their surfaces leaving the space between virtually empty. Some stray gas molecules are found between these bodies, but their density is so low that they can be thought of as practically nonexistent.

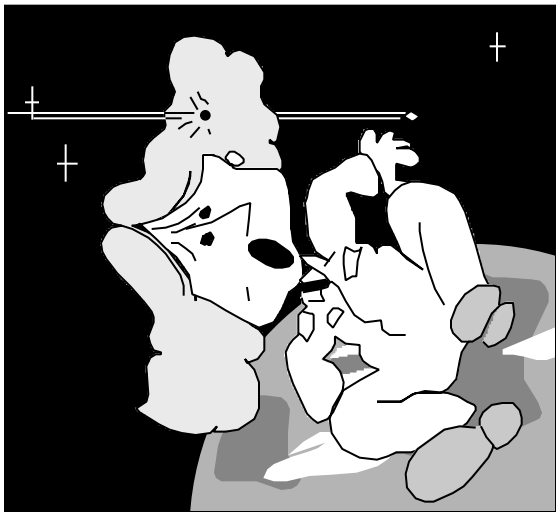
On Earth,the atmosphere exerts pressure in all directions. At sea level, that pressure is 101 kilopascals. In space, the pressure is nearly zero. With virtually no pressure from the outside, air inside an unprotected human's lungs would immediately rush



out in the vacuum of space. Dissolved gases in body fluids would expand, pushing solids and liquids apart. The skin would expand much like an inflating balloon. Bubbles would form in the bloodstream and render blood ineffective as a transporter of oxygen and nutrients to the body's cells. Furthermore, the sudden absence of external pressure balancing the internal pressure of body fluids and gases would rupture fragile tissues such as eardrums and capillaries. The net effect on the body would be swelling, tissue damage, and a deprivation of oxygen to the brain that would result in unconsciousness in less than 15 seconds.

The temperature range found in outer space provides a second major obstacle. The sunlit side of objects in space at Earth's distance from the Sun can climb to over 120° Celsius while the shaded side can plummet to lower than minus 100° Celsius. Maintaining a comfortable temperature range becomes a significant problem.

Other environmental factors encountered in outer space include: microgravity, radiation of electrically charged particles from the Sun, ultraviolet radi-



ation, and meteoroids. Meteoroids are very small bits of rock and metal left over from the formation of the solar system and from the collisions of comets and asteroids. Though usually small in mass, these particles travel at very high velocities and can easily penetrate human skin and thin metal. Equally dangerous is debris from previous space missions. A tiny paint chip traveling at thousands of kilometers per hour can do substantial damage.