23

Space Transportation Systems

Basic Concepts

- Define *spacecraft*.
- State what makes a spacecraft fly.
- Cite the definition of *orbiting*.
- Identify the two types of space transportation modes.
- List the different types of space vehicles.

Intermediate Concepts

- Describe the space environment.
- Explain the types and applications of orbits used to circle the earth.

Advanced Concepts

- Examine the impacts space technology has had on daily life.

Space transportation is the use of rockets and orbiting vehicles to explore the regions beyond the limits of the atmosphere. The space extending from 50 miles to 10,000 miles beyond the atmosphere is known as ***near space***. Beyond 10,000 miles is ***outer space***.

The History of Space Transportation

The pioneering of space travel came around the turn of the twentieth century. It was concluded that ***spacecraft***, or space vehicles, built around a large rocket would be the most effective means of escaping the earth's gravitational pull. Rockets were not necessarily a new idea. The Chinese used rockets as a weapon in warfare over 700 years ago. Eventually, rockets were used by militaries throughout the world. These rockets were effective in war, but they were incapable of launching humans into space. Three men living in different countries around the same time developed theories and models of rockets that would be capable

Near space: The space extending from 50 miles to 10,000 miles beyond the atmosphere.

Outer space: The space extending from 10,000 miles beyond the atmosphere.

Spacecraft: A vehicle used for space travel.

of space travel. These men were a Russian teacher, Konstantin E. Tsiolkovsky; an American professor, Robert H. Goddard; and a German experimentalist, Hermann Oberth.

Tsiolkovsky was the first to put his ideas on paper. In his books, *Dreams of Earth and Sky* and *Exploration of Cosmic Space by Means of Reaction Devices*, he discussed the idea of using rockets to explore the universe. In 1903, the same year as the Wright brothers' *Flyer* was flown, he first proposed the use of liquid hydrogen and oxygen as fuels for rockets. These liquid propellants are used in most rockets today. Tsiolkovsky had the practical possibilities in mind and a theory of how things would work, but he never built a rocket.

Robert Goddard, however, designed and built his own rockets. In 1926, Goddard launched the world's first liquid-fuel rocket. See **Figure 23-1.** He also demonstrated how rockets could carry scientific instruments into the upper atmosphere. His work led to hundreds of patents and paved the way for manned and unmanned space vehicles.

After World War I, Oberth was at work in Germany on the development and testing of rockets. His discoveries led to the publication of *The Rocket into Interplanetary Space*, which explained how rockets could escape the earth's gravitational pull. The discoveries of these three men became the basis for all later space transportation developments. The first successful spaceflight came in 1957.

An examination of the people involved in early rocket development and space exploration would not be complete without the mention of Wernher von Braun. Von Braun was a German rocket expert who had studied under Hermann Oberth. His work in Germany led to the development of the V-2 rocket the German army used during World War II. The V-2 rockets were capable of destroying targets over 120 miles away from their launch site. Von Braun had hoped his inventions would lead to exploration, however, and not destruction. Toward the end of World War II, he and his team of engineers surrendered to American forces. His "rocket team" developed many of the rockets that launched American satellites, probes, and even space stations into space.

Figure 23-1. Dr. Robert H. Goddard was a pioneer of American rocketry. He is shown with his first liquid-fuel rocket, which he launched in Auburn, Massachusetts, on March 16, 1926. Both the Smithsonian Institute and Charles Lindbergh financed Goddard's inventions and test flights. (National Aeronautics and Space Administration)

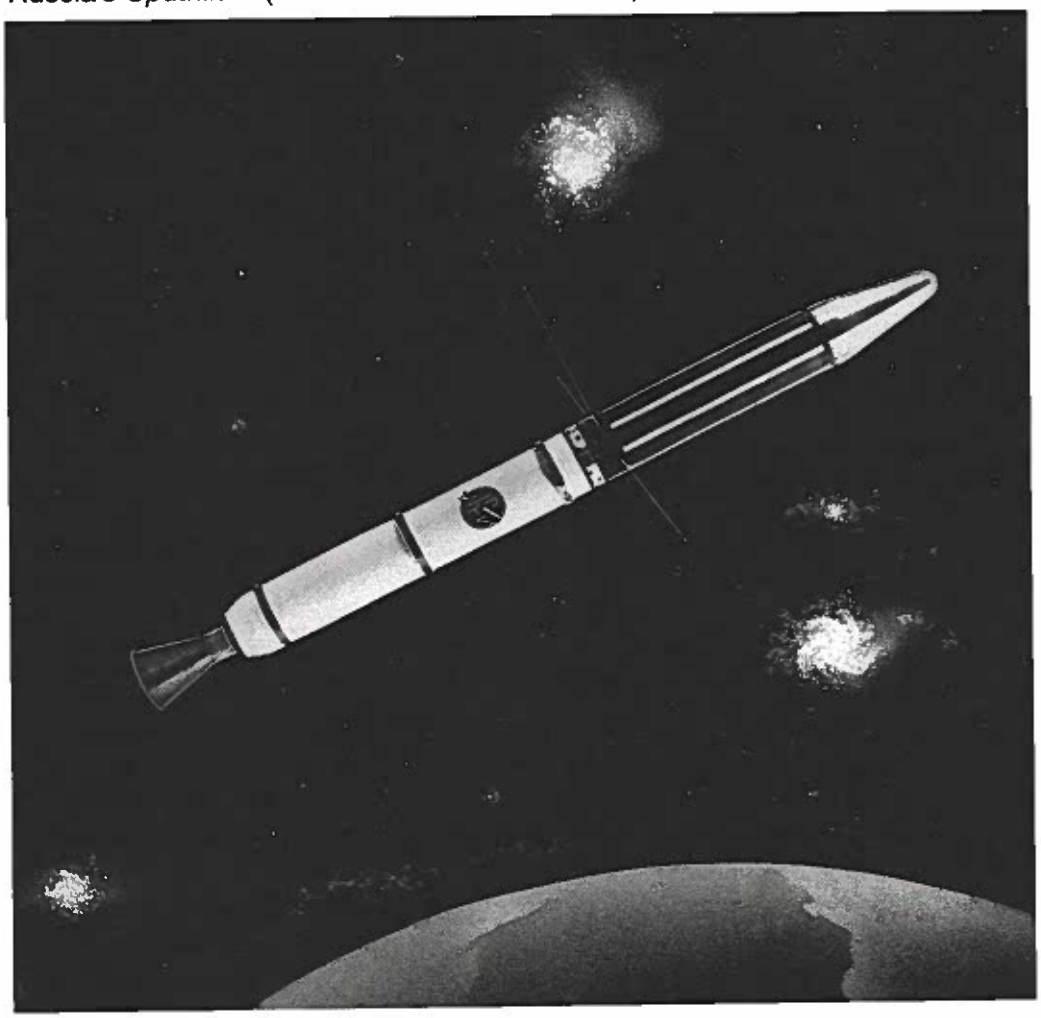
These rockets were not the first, however, to deliver an object into space. October 4, 1957 marked the beginning of a new age, a new dimension in transportation and exploration. The bulletins flashed around the world, carried by radio, newspapers, and television. The Soviet Union had launched the first successful artificial satellite and placed it in orbit around the earth. The satellite was called *Sputnik 1.* See **Figure 23-2.** The word *sputnik* means "traveler."

This event came as a surprise to many nations, including the United States. Reacting to a deep concern that the Soviet Union was taking the lead in the exploration of space, the U.S. federal government mobilized a program in rocket development. The response of the United States was to put the nation's first satellite, *Explorer 1*, into orbit. See **Figure 23-3.** For several years, a contest was waged between the United States and the Soviet Union. Each country was trying to outdo the other in putting new satellites into earth's orbit.

On April 12, 1961, the Soviet Union amazed the world by announcing it had just put a man into earth's orbit. At that time, the United States, feeling very much in second place because of the Soviets' accomplishments, set a

Figure 23-2. This full-scale mock-up of *Sputnik 1* was placed on display in the Soviet pavilion at the Paris air show.

Figure 23-3. *Explorer 1*, shown in orbit in this artist's view, was less than 6′ in length. It was the first U.S. satellite and was launched in 1958, one year after Russia's *Sputnik 1*. (National Aeronautics and Space Administration)

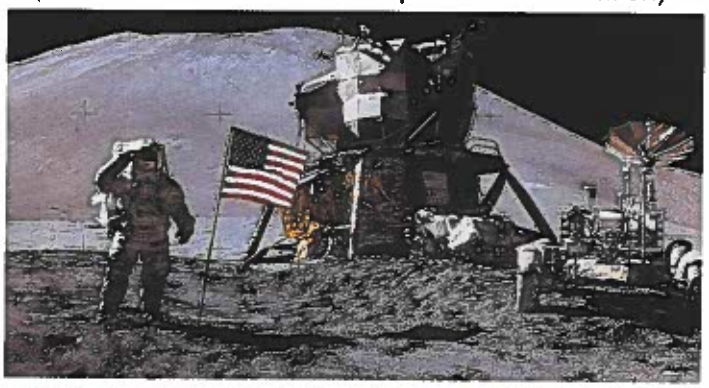


GREEN TECH

Because the typical chemicals used in rocket fuel create harmful emissions, scientists have been looking into alternative fuels. Some ideas have included aluminum, wax, and kerosene.

much more difficult goal: placing a human being on the moon! John F. Kennedy, then president of the United States, placed a high priority on the project and set it in motion. After some eight years of intensive planning and work, the United States launched the first manned flight to the moon. See **Figure 23-4.**

Figure 23-4. The historic moon landing in 1969. On July 20, U.S. astronaut Neil Armstrong became the first man to set foot on the moon. Armstrong was the commander of the *Apollo 11* spaceflight. The success of the spaceflight depended on new advanced technology. The technology had to enable the flight crew to complete a lunar landing and then return the space travelers safely to earth. Astronaut David Scott, commander of the mission, stood beside the U.S. flag at the landing site. The vehicle on the right served as a "space buggy," allowing the astronauts to explore a larger area than they could on foot. (National Aeronautics and Space Administration)



Career Connection

Astronauts

Transportation, Distribution & Logistics

Traveling to space and conducting missions is not an average job. It makes sense then that the astronaut selection process does not target average applicants. The National Aeronautics and Space Administration (NASA) selects candidates for astronaut training every two or three years. Applicants can be either civilian or military personnel and must have at least a bachelor's degree in engineering, biological science, physical science, or mathematics. They must be in good physical condition and pass rigorous medical physicals.

Astronaut candidates can fill one of two roles: pilots or mission specialists. Pilots must have previous jet-piloting experience, most often gained in the military. They can also serve as commanders and have responsibility for the crew and mission. Mission specialists must have advanced degrees, work experience, or both to apply. Their role includes maintaining the orbiter's systems, conducting space walks, and conducting experiments in space.

Candidates receive several years of training, which includes survival training, mission simulations, and payload training. Civilian astronauts are paid on the government pay scale, earn $60,000 to $130,000 a year, and must serve for five years. Military astronauts are paid according to their rank and serve a specified tour of duty with NASA.

The moon launch was the culmination of several space projects the National Aeronautics and Space Administration (NASA) oversaw. NASA is the primary organization in charge of the U.S. space program. It was created in 1958 as a result of the Soviet launch of *Sputnik 1*. NASA was formed by combining several government agencies, including the National Advisory Committee for Aeronautics (NACA), into one organization. It has several overall goals, which include more than just traveling and exploring space. The mission of NASA includes advancing the level of understanding about the earth and universe. Another goal is to conduct research in space. An often-overlooked goal that has impacted all of us is the development and transfer of new technology. See **Figure 23-5.**

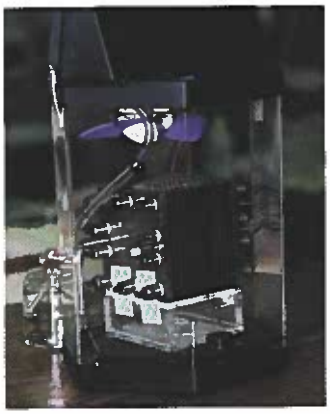
NASA is not the only space agency in the world. Many other countries either have an agency of their own or are in a partnership with other countries. The Canadian government organized the Canadian Space Agency (CSA) in 1990. Canada even developed the robotic arm for NASA's space shuttle program. Japan, Russia, and Italy also have their own space organizations. The European Space Agency (ESA) includes a number of member countries. Great Britain, Germany, France, Spain, and many other countries are members of the ESA. Today, these space agencies regularly send satellites, probes, and spacecraft past the earth's atmosphere. The space race between the Soviet Union and the United States may have ended when *Apollo 11* landed on the moon, but the technology has continued to advance. Each launch and mission adds new information about both earth and space.

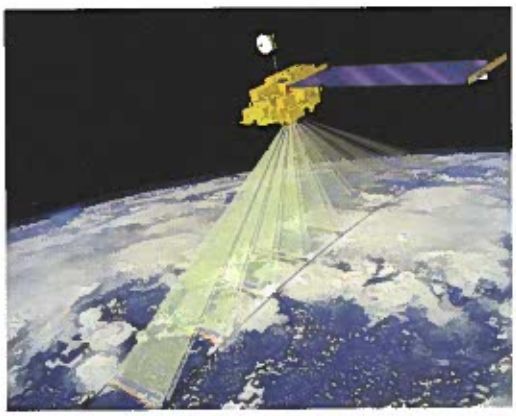
The Space Environment

The atmosphere of the earth has several characteristics important to space travel. See **Figure 23-6.** The different regions of the earth's atmosphere include the troposphere, stratosphere, mesosphere, thermosphere, and exosphere.

Figure 23-5. Transferred technology resulting from the space program is widely used. Inventions such as racing suits, pacemakers, and Teflon® coating are examples of products known as spin-offs. These products were developed by the National Aeronautics and Space Administration (NASA) for the space program, but later found successful uses here on earth. Shown are three of the hundreds of devices and processes developed in this way. A—Robotic surgery. B—Hydrogen fuel cells. C—Earth Observation System (EOS) satellites use arrays of sensors to monitor global climate change. (NASA)

A 

B 

C 

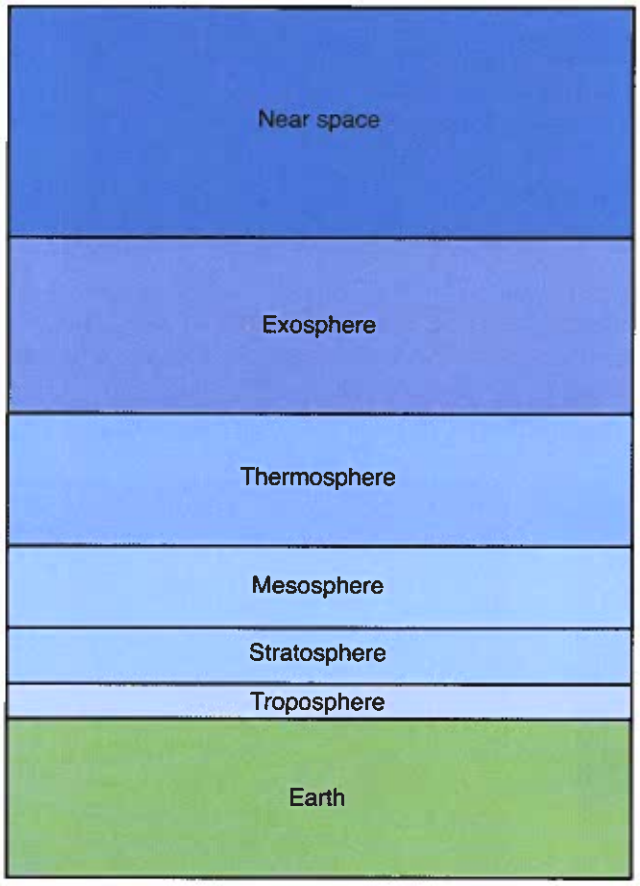
Troposphere: The closest atmospheric region to the earth. It begins at the earth's surface and stretches about 10 miles (16 km) above the earth's surface.

Stratosphere: The atmospheric region ranging from the troposphere to about 30 miles (50 km) above the earth's surface.

Atmospheric Regions

The ***troposphere*** is the closest layer to the earth. It begins at the earth's surface and stretches about 10 miles (16 km) from the earth. Most clouds and weather patterns originate in this region. The next region, the ***stratosphere***, ranges from the troposphere to about 30 miles (50 km) above the earth's surface. In this region, there is an absence of water vapor and clouds. The stratosphere also contains an ozone layer that helps absorb ultraviolet (UV) radiation from the sun. The ***mesosphere*** is located above the stratosphere and reaches about 50 miles (80 km) above the earth's surface. It is the coldest atmospheric layer. Clouds of frozen water vapor can actually exist in this region. The next region is a layer that extends from about 50 miles to about 300 miles out. This layer is known as the ***thermosphere***. In this region, the atmosphere is so thin that no sound is transmitted. The extreme outer region of the atmosphere, before getting to outer space, is a region known as the ***exosphere***. It is hard to estimate the top boundary of the exosphere because it gradually becomes outer space. Outer space is very different from the areas inside the earth's atmosphere. It contains virtually no air particles.

Figure 23-6. There are five different layers in the space environment surrounding the earth. The closest, the troposphere, is 10 miles from earth's surface. The farthest, the exosphere, is 500 miles from earth.



The Space Environment and Vehicle Design

Space environment characteristics affect the design and development of a spacecraft. Among the most important characteristics are the extremes of temperature and radiation levels. These have a direct effect on the materials used in the construction of space vehicles. Both temperature and radiation can damage the spacecraft in various ways. The space environment can affect the structure, instruments, and communication. Besides the effect it would have on the craft itself, there is also a concern for the health of personnel on manned spaceflights. Radiation, in particular, can seriously affect health, if precautions are not taken.

One other space environment concern is both natural and human made. Spacecraft designers must consider the possibility of the craft running into either a meteoroid or a piece of space debris. Meteoroids are the remains of comets in space. Space debris includes the human-made pieces of satellites, hardware, and rockets that have not fallen to earth. It is a major concern for spacecraft engineers and designers. The collision with an object in space could be very dangerous for a spacecraft. NASA's Orbital Debris Program Office tracks space debris and conducts research to help

Curricular Connection

Social Studies: Spin-offs

The National Aeronautics and Space Administration (NASA) spin-offs are not accidental occurrences. Spin-offs are often planned and encouraged as a way for the public to benefit from NASA discoveries and inventions. Interesting and beneficial NASA spin-offs are highlighted in *Spin-off*, an annual NASA publication. Since the space program has begun, there have been literally hundreds of commercial spin-offs. Many of these products you may use daily without realizing their history as NASA inventions, including scratch-resistant eyeglass lenses, flat-panel televisions, improved golf balls and tennis shoes, and shock-absorbing helmets. Spin-offs have also greatly impacted the health and medical industries. Pacemakers, portable X-ray and magnetic resonance imaging (MRI) scanners, one type of laser eye surgery, and infrared thermometers are all NASA spin-offs. Spin-offs can also be found at work and in school. These spin-offs include power tools, smoke detectors, bar codes, and energy-saving air conditioning. NASA spin-offs can be found in almost all aspects of our lives.

control the debris. It estimated that there are over 10,000 pieces of human-made debris over 4" in diameter in space, some of which are quite large. This office also believes there to be tens of millions of pieces less than 1/2" in length. Spacecraft now must be designed to not leave debris in space and to be disposable.

Another very important characteristic of space is weightlessness. ***Weightlessness*** occurs due to the forces around bodies in space. See **Figure 23-7.** Both pull and push effects take place. Gravitational forces pull the body toward the earth, and a centrifugal force pulls the body away. When gravitational forces are equal to a centrifugal force, weightlessness occurs. When you are jumping up and away from a diving board, you experience weightlessness as you reach the height of your jump.

Weightlessness has always appeared to be fun, as we see films of the astronauts in space or read about their experiences. It could be fun for a time. Weightlessness can also become frustrating as astronauts go about their daily routines. For instance, drinking liquid and taking a shower could be difficult.

Spacecraft Flight

Many inputs are needed in the launching of a spacecraft. Tools, energy, materials, money, and people are all needed to begin the process. It is the scientific principle outlined in Sir Isaac Newton's third law of motion, however, that allows the spacecraft to lift off. Newton's law states that for every action, there is an equal and opposite reaction.

Mesosphere: The atmospheric region ranging from the stratosphere to about 50 miles (80 km) above the earth's surface.

Thermosphere: The atmospheric region extending from the mesosphere to about 300 miles above the earth's surface.

Exosphere: The extreme outer region of the atmosphere, before outer space. This region is located from the thermosphere to over 500 miles from the earth's surface.

Weightlessness: The condition occurring when gravitational forces are equal to a centrifugal force.

Launchpad: A nonflammable platform from which a rocket, launch vehicle, or guided missile can be launched.

Figure 23-7. Astronauts practice working in a weightless environment by performing tasks in a large water tank. Their suits are carefully weighted to provide neutral buoyancy. (National Aeronautics and Space Administration)

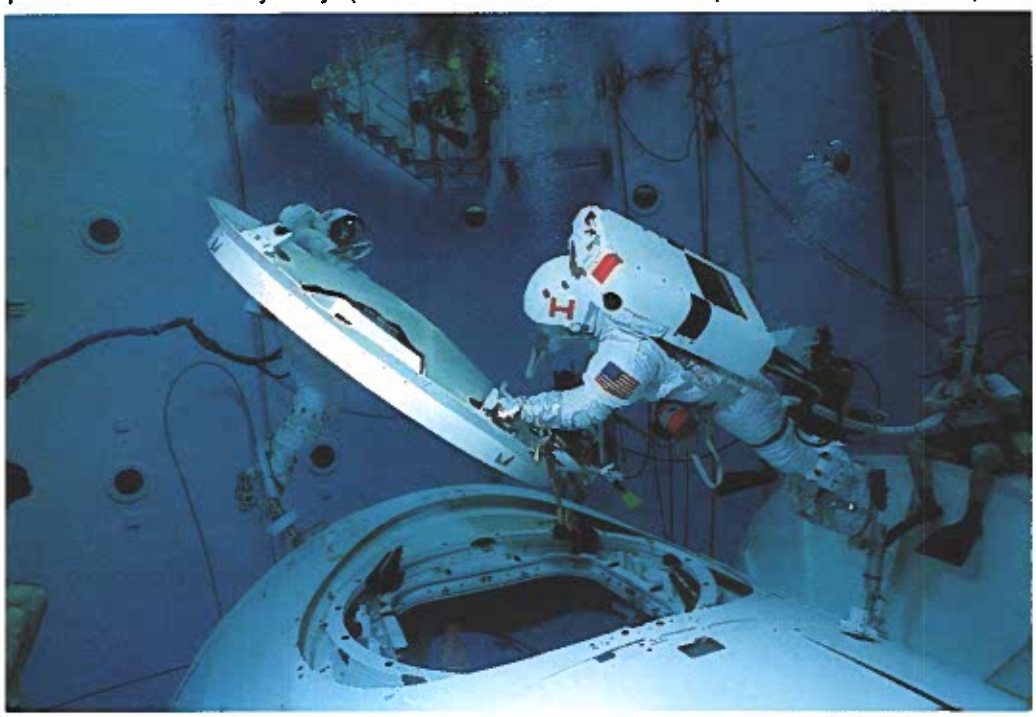
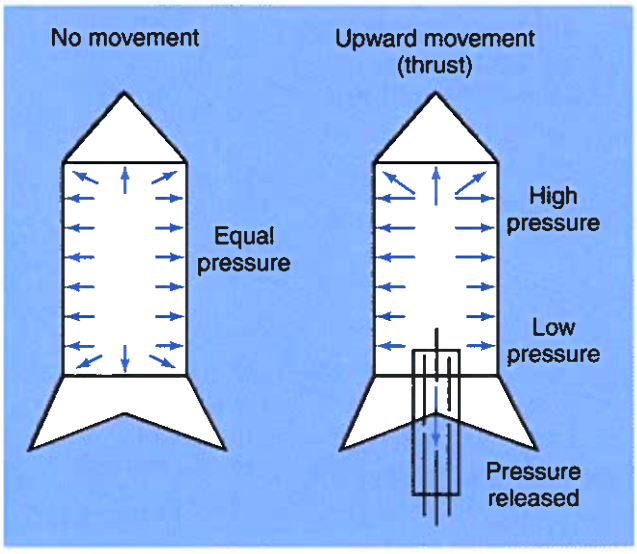


Figure 23-8. The unequal pressures inside a rocket engine propel it forward. If the rocket is aimed skyward, an upward motion is the reaction to such a force. The escaping of the gases from inside the rocket is the action. The upward movement of the rocket is the reaction. This movement is known as thrust. Thrust is a force that produces motion in a body. It is measured in pounds or newtons.



The burning of fuel creates the pressure inside a rocket engine. As the fuel burns, the pressure increases, causing a great pressure buildup within the engine. The exhaust of the engine allows for the release of pressure so there is higher pressure at the front of the rocket engine than at the tail. When the pressures within a rocket engine are unequal, the rocket will move toward the direction from which the higher pressure is exerted. See **Figure 23-8.**

In order for the spacecraft to leave the ***launchpad,*** the platform designed to support the space vehicle on the ground and withstand the impact of takeoff, the reaction must be greater than the action. The thrust must be greater than the gravitational pull of earth and the weight of the vehicle. In the case of the space shuttle, the rockets must overcome a large amount of weight. The weight of the loaded shuttle, tanks, and rocket boosters at takeoff is over 4.5 million pounds. The rocket boosters and shuttle main engines both operate at takeoff and together generate over 7.8 million pounds of thrust. This amount of

Technology Link

Medicine: Astronaut Health

Astronauts spend their entire time in space contained in a human-made system. Whether they are inside the shuttle or inside a space suit while conducting a space walk, they are enclosed in an environment hundreds of miles from earth. You can imagine then that any germs, bacteria, or foreign substances in the orbiter can become a major concern for the health and well-being of the astronauts.

Monitoring of the shuttle air and the astronauts' health is vitally important. The National Aeronautics and Space Administration (NASA) division of AstroBionics is responsible for creating sensors that monitor oxygen and carbon dioxide (CO_2) gas levels, heart rate, blood pressure, and other health statistics. These sensors are known as biosensors. NASA's goal is to create biosensors that can be implanted into astronauts and monitored from earth.

Physical fitness is just as important in space as it is on earth, and possibly even more important because spaceflight causes 1–2% bone loss per month in space. Astronauts who spend extended periods of time in space must remain physically active in order to reverse the effects of spaceflight. Since there is no gravity in space, however, there is very little resistance for the astronauts' muscles. NASA has developed several pieces of equipment that enable the astronauts to work out. The astronauts can lift weights with the Resistance Exercise Device (RED), run on a treadmill using the Vibration Isolation System (VIS), and ride a Cyclergometer, which is a cycle built for zero gravity.

Lastly, it is possible for astronauts to become either injured or ill while in space. The shuttle is equipped with two medical kits. One kit, the medications and bandage kit (MBK) contains pills, gauze, and bandages to be used if an astronaut is ill or has a minor injury. The other kit, the emergency medical kit (EMK) is used for more serious injuries or infections. It contains injectable medications, medical instruments, thermometers, and supplies for minor surgery. If serious problems occur, doctors are available at the Johnson Space Center and can talk the other astronauts through any procedure that might need to be completed.

thrust enables the shuttle to generate a speed of over 16,800 miles per hour (mph). Such a high speed allows the shuttle to escape the gravitational pull of the earth.

Once this upward force ceases, gravitational forces will cause it to fall back to earth. Therefore, the spacecraft needs to achieve a very high speed so it can escape the earth's gravitational pull. At this time, the gravitational forces and the centrifugal forces are equal. As a result, the spacecraft will stay in orbit. To ***orbit*** is simply to stay in a path that circles an object, which in many cases, is the earth.

Orbit: To stay in a path circling an object in space.

Orbiting

If a spacecraft increases its speed while in orbit, a greater centrifugal force will result, and the spacecraft could possibly be slung out of orbit, into space. If the spacecraft loses speed, the centrifugal force will decrease, and the spacecraft will achieve a lower orbit or reentry into the earth's

Low earth orbit (LEO): An orbit between 180 and 250 miles above the earth.

Geosynchronous (GEO) orbit: A geostationary orbit. It is often used for communication satellites, which are stationed in one spot and rotate along with the earth.

Apogee: The point in the path of an elliptical orbit farthest from the earth.

Perigee: The point in the path of an elliptical orbit closest to the earth.

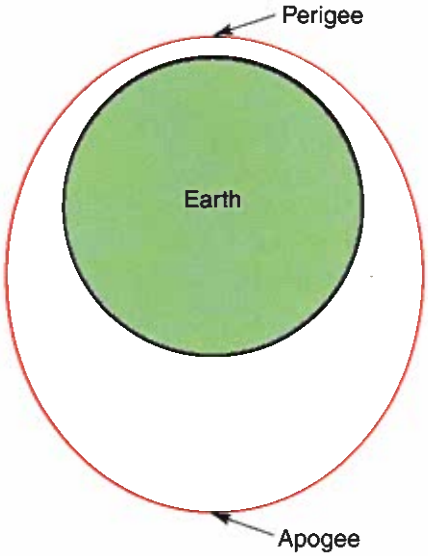
atmosphere. The concept of orbiting is like swinging a ball on a string. You can demonstrate this by taking a small ball tied to a string about 3′ long and, while holding the end of the string in your hand, whirling the ball around. As you whirl the ball around slowly, with the string extended to its full length, you can understand what a satellite in orbit experiences. You have two forces acting: a centrifugal force and gravitational pull. If you decrease the speed of the ball moving in its circular path, the ball falls out of its orbit. If you increase the speed of the ball's orbit, the centrifugal force is greater, and you will probably lose control of the ball on the string. Thus, the ball will fly away from you at a rapid speed. Like a satellite, it will fly out of orbit if traveling at too great a speed.

There are several different types of orbits a spacecraft can follow. ***Low earth orbit (LEO)*** involves orbiting between 180 and 250 miles above the earth. This orbit requires the least launch energy and is the lowest in which to place a satellite. Objects in LEO are able to make a complete revolution around the earth in 90 minutes. The International Space Station (ISS), as well as many weather satellites, are located in LEO. Polar orbits are a type of LEO that orbits in a north-south direction and crosses the two poles. Since they are orbiting north to south and the earth is rotating east to west, satellites in this orbit can view the entire earth. Satellites used for imaging are often in polar orbits.

Geosynchronous (GEO) orbits, or geostationary orbits, are used for most communication satellites because they are stationed in one spot and rotate along with the earth. GEO satellites are placed in what is known as the Clarke Belt. Arthur C. Clarke calculated the distance from the earth that would be required to keep an object in one place. When objects are placed in the Clarke Belt, 22,300 miles from the earth, they make one revolution every 24 hours. Because of GEO orbits, our television satellite dishes can be aimed in one direction and do not have to be rotated.

Elliptical orbits follow an oval path. See **Figure 23-9.** The highest point of the path is the farthest away from earth. This point is called the ***apogee***. The point closest to the earth is called the ***perigee***.

Figure 23-9. Many satellites and spacecraft follow elliptical orbits. They come close to the earth for a period of time and are farther from the earth at other times. The apogee is the point farthest from earth. The perigee is the point closest to earth.



Space Vehicles

The spacecraft is the term for the space vehicle that actually travels into space. Spacecraft include sounding rockets, satellites, space probes, space shuttles, and space stations. They differ greatly in size, shape, and purpose. Some spacecraft are designed to fly by distant planets, while others are used to deliver objects into orbit. There are some used only to get into space, and there are others that are unloaded and used once they are in space. One vehicle unloaded and used in space is a jet

pack. A ***jet pack*** is strapped to the back of an astronaut. Jet packs are vehicles that are not used to transport people into space, but they are essential for human transportation while people are in space. Some spacecraft are actually operated by human beings, and some are not. Therefore, the two modes of space transportation are manned and unmanned vehicles.

Jet pack: A space vehicle strapped to the back of an astronaut.

Unmanned Space Vehicles

Unmanned space vehicles include launch vehicles, satellites, space probes, and sounding rockets. They have been used for space exploration. The following paragraphs will briefly introduce you to the different unmanned spacecraft.

Unmanned space vehicle: A space vehicle not operated by human beings.

Launch vehicles

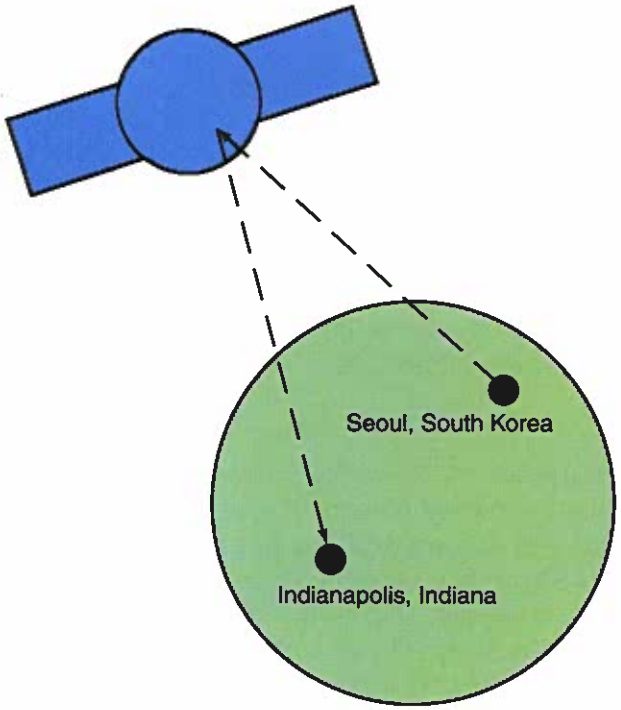
Launch vehicles are the workhorses of the space program. These vehicles are used to place other spacecraft into the atmosphere or even outer space. Whether the spacecraft is a satellite, a piece of a space station, or the space shuttle, it requires a launch vehicle to get it off the ground. The first launch vehicles were ballistic missiles that were converted to rockets. Today, the United States uses three main launch vehicles. These vehicles are the Delta, Titan, and Atlas/Centaur rockets. Each type of rocket has different capabilities and uses. Delta rockets were used to send the *Pathfinder* spacecraft to Mars. See **Figure 23-10.** The most powerful launch vehicle the United States used was the Saturn V, which is no longer in service. The Saturn V was used to send humans to the moon.

Figure 23-10. Currently, rockets are the only reliable method of launching spacecraft. The National Aeronautics and Space Administration (NASA) widely uses the Delta rocket as a launch vehicle. This launch carried the *Deep Impact* spacecraft into space. The objective of the Deep Impact program is to collide with a comet and investigate its chemical makeup. (NASA)

Satellites

A satellite is simply any object that orbits around another object in space. The earth is a satellite of the sun, and the moon is a satellite of the earth. Since 1957, with the launch of *Sputnik 1*, humans have been placing artificial satellites in orbit around earth. These artificial satellites are of many designs and purposes. Communication satellites bounce telephone, television, and radio waves from one transmitter on earth to another. See **Figure 23-11.** Environmental satellites are launched into space to monitor the conditions of the earth. Astronomical satellites are used for scientific research about our solar system and beyond. See **Figure 23-12.** Navigational satellites are used more frequently with the availability of global positioning system (GPS) receivers.

Figure 23-11. Because of satellites, we can have instant communication around the world. A signal from Indianapolis, Indiana, bounced off the satellite, can be picked up almost instantaneously in Seoul, South Korea.



Space probes

Space probes are launched very far from the earth, where they can escape the earth's gravitational attraction. They are used for research purposes. These probes are sent to explore outer space. Probes can be designed to fly by, orbit, land, or rove. Flyby probes travel near objects, but not close enough to be affected by their gravitational pull. *Voyager* 2 was a flyby probe launched in 1977. Its mission lasted until 1989, and it reached Jupiter, Saturn, Uranus, and Neptune. Orbiting probes travel to a distant planet and then orbit around the planet. See **Figure 23-13.** Landing probes are designed to touch down at their destinations. The Surveyor probes landed on the moon prior to the human landing. Roving probes are usually placed inside landing probes. See **Figure 23-14.**

Sounding rockets

Sounding rockets were the first type of spacecraft to be launched. They are able to travel above the range of aircraft. The rockets used today range from 7′ to 65′ tall. Sounding

GREEN TECH
Littering is not just a problem on earth. Recent studies have shown several thousand man-made objects are floating around in orbit.

Figure 23-12. An astronomical satellite may be launched to take pictures of the moon, other planets, or landing sites for astronauts. The most famous astronomical satellite may be the Hubble Telescope. The Hubble Space Telescope orbits the earth every 97 minutes at an altitude of 353 miles. It has provided extraordinary high-quality images of space objects light-years away from earth. (National Aeronautics and Space Administration)

Figure 23-13. The *Odyssey* spacecraft has been orbiting the planet Mars since late 2001. In this artist's conception, the spacecraft passes over the South Pole of Mars. (National Aeronautics and Space Administration's Jet Propulsion Laboratory)

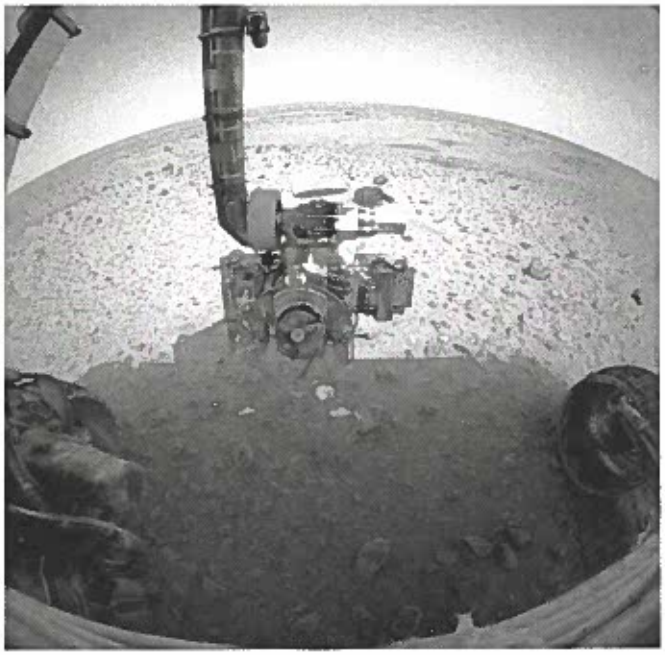


Figure 23-14. Once a rover has landed on the surface, it can be driven remotely from earth. Two exploration rovers, *Spirit* and *Opportunity*, landed successfully on opposite sides of Mars in January 2004 and provided more than a year of photographic surveying and data gathering. The *Spirit* rover was used to explore Mars and collect information about the soil. This photo, taken by *Spirit*, shows the rover's robotic arm deploying a microscopic imager. The imager takes high-resolution, extreme close-up images to help scientists analyze rocks and soils on the Martian surface. (National Aeronautics and Space Administration's Jet Propulsion Laboratory)

rockets carry payloads that are ejected during flight and fall back to earth. During the fall, the payload is used to conduct experiments or gather data. Sounding rockets gather information about the sun and stars. They use electronic devices to retrieve information. Sounding rockets can measure temperatures, take photographs, and record important data. They also gather information about the sun's radiation and solar activity. Sounding rockets have collected some very valuable information about space that has aided scientists in new discoveries.

Manned Space Vehicles

Manned space vehicle: A vehicle sent to space with a crew in it.

Manned space vehicles are those vehicles sent to space with a crew in them. In the late 1950s and early 1960s, several manned spacecraft flights were tested. A space project known as Project Mercury tested several manned spaceflights. U.S. astronauts Alan Shepard and Gus Grissom were the first two Americans in space. They were in space for just 15 minutes each in 1961. In 1962, however, John Glenn became the first American to orbit the earth. His orbit was in a Project Mercury capsule named *Freedom 7*. By the end of 1963, three other astronauts had orbited the earth. When Project Mercury came to an end, it had accomplished its goals of orbiting the earth, giving Americans a chance to test their ability to function in space, and returning crew members and spacecraft safely to earth. Project Gemini was the second of the projects for manned spaceflights. Its main purpose was to continue exploration of space and resolve some other technological problems before attempting to land anyone on the moon. The *Gemini*, meaning "twin," could hold two astronauts, unlike the Mercury capsule. Project Gemini saw many space firsts, including the first American space walk. It was a stepping-stone for Project Apollo. The goal of Project Apollo was to put a man on the moon and bring him home safely. On July 20, 1969, after centuries of dreaming of setting foot on the moon, this dream came true. Three Americans, Neil Armstrong, Michael Collins, and Edwin Aldrin, were aboard *Apollo 11* as it traveled to the moon. Collins stayed above the surface of the moon in the command module. Armstrong and Aldrin landed and set foot on the lunar surface in the lunar module. See **Figure 23-15.** The Apollo capsule was the main vehicle used to transport people into space until the early 1980s.

Figure 23-15. The manned spacecraft *Apollo 11* landed on the moon in July 1969. A—The crew, left to right, Neil Armstrong, commander; Michael Collins, command module pilot; and Edwin Aldrin, Jr., lunar module pilot. They spent 21.6 hours on the moon before returning safely to earth. B—Aldrin descended the steps of the lunar module ladder in preparation for a walk on the moon. (National Aeronautics and Space Administration)

A

B

The space shuttle

In 1981, the first reusable space transportation vehicle was put in use. This vehicle is known as the space transportation system (STS), or the space shuttle. The space shuttle was developed primarily to be a reliable and reusable means of space transportation. It has been used for transporting data-gathering equipment into space. The STS has been used to transport pieces of the ISS into space, as well as to deliver crew members to the station. It was also useful in docking with space equipment in need of repair.

A space shuttle was made up of two solid rocket boosters, an external fuel tank, and an orbiter. See **Figure 23-16.** The components of the space shuttle were assembled and moved to the launch site on a mobile launchpad. Once it was ready to be launched, the countdown procedure began. Approximately one hour after the initial countdown, the orbiter achieved orbit. See **Figure 23-17.**

A total of six orbiters were built. The first shuttle, *Enterprise*, was built for testing and has never been in space. See **Figure 23-18.** The other five, *Columbia*, *Discovery*, *Atlantis*, *Endeavor*, and *Challenger*, have all been to space on several missions. Unfortunately, of the five orbiters built for space, only three remain. Shuttles were used for over twenty years. During this time, there were two catastrophic events. In 1986, after a very successful year of space travel, tragedy struck *Challenger*. *Challenger* burst into flames just seconds after liftoff. See **Figure 23-19.** The following year, the United States sent no astronauts into space. The space program was grounded, while NASA examined, researched, and retested space shuttle transportation. Shuttle flights resumed in the 1990s, with a number of the scientific missions including crew members from several nations. In 2003, after 15 years of successful operations, tragedy struck again. The space shuttle *Columbia* broke up over Texas during reentry. In 2011, the last three space shuttles were retired.

Space stations

The Soviet Union launched *Salyut 1*, the world's first space station, in 1971. Two years later, on May 14, 1973, the United States

Figure 23-16. The space shuttle consisted of two booster rockets, an external fuel tank, and an orbiter.

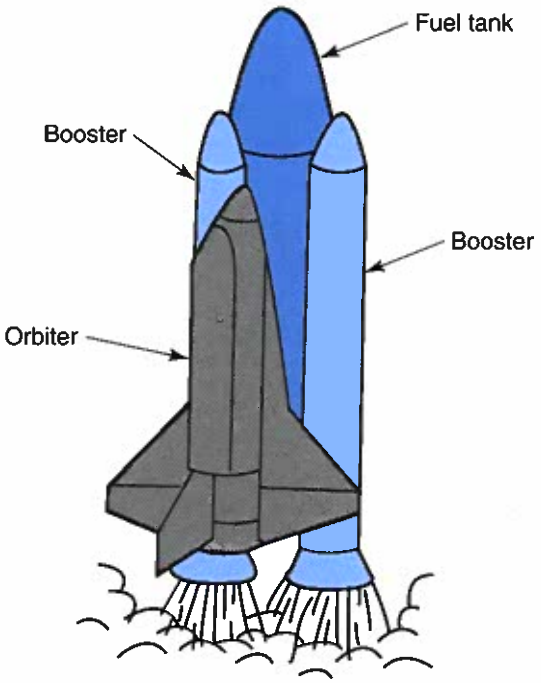
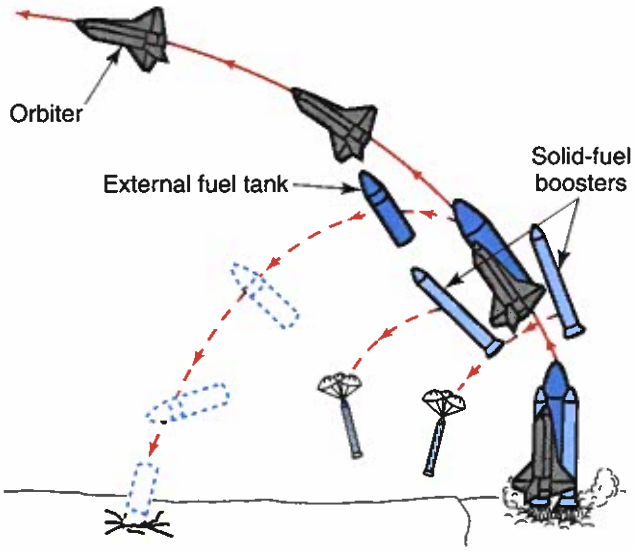


Figure 23-17. A launch of the shuttle. At liftoff, the rocket engines ignited at the same time. Two minutes after liftoff, the rockets separated from the space shuttle. A parachute opened, and the rockets slowly dropped into the ocean, where tugboats collected them. Nine minutes into flight and just prior to entering orbit, the shuttle's external fuel tank separated. As it reentered the earth's atmosphere, it burned up.



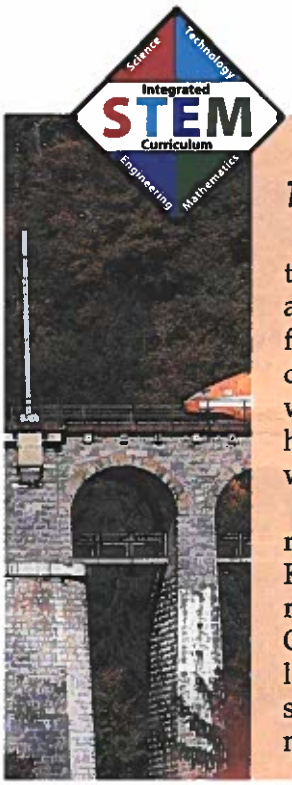
Skylab: A space station the United States launched into orbit on May 14, 1973.

International Space Station (ISS): The newest space station. It is a joint effort of 16 countries, with the United States in charge of the operations.

Figure 23-18. The shuttle *Enterprise*, built for testing, has been installed in the Smithsonian Institution's Udvar-Hazy Air and Space Museum near Washington, D.C. It is shown here being readied for exhibition. *Enterprise* is the centerpiece of the Museum's large space exploration wing.

Figure 23-19. The actual launch of the space shuttle *Challenger* on January 28, 1986. An accident 73 seconds after liftoff claimed both vehicle and crew. The nation looked on in horror, as this tragic accident killed all seven crew members. (National Aeronautics and Space Administration)

launched a space workshop and laboratory into orbit. This space station is known as ***Skylab***. Throughout the six years *Skylab* was orbiting the earth, three different crews were launched to work in its laboratories and perform experiments. The final launch was the longest mission, lasting 84 days. This mission was a great success. During this time, many studies were conducted, leading to important discoveries. Over the six years, this pioneer space station had compiled some very important and impressive statistics and records. It set the pace for future programs in space. The Soviet Union had one other very successful space station, named *Mir*. *Mir* was a major improvement over both *Salyut 1* and *Skylab*. The station was occupied continuously for over nine years. Dr. Valeri Polyakov, a Russian cosmonaut, set a new record for number of days in space. He was aboard *Mir* for 438 straight days. American astronauts visited *Mir* often to study the station. The information they gathered was essential to the development of the newest space station, the ISS. See **Figure 23-20.** The ***International Space Station (ISS)*** is a joint



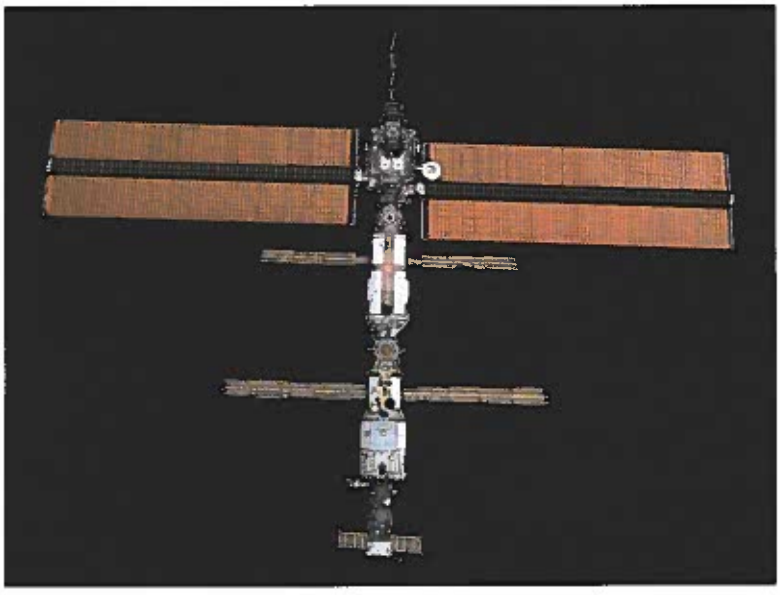
STEM Connection

Technology: The X Prize

Space transportation has generally been a government-funded activity. In 1996, however, this changed. The X Prize Foundation was formed, in order to encourage private investors and companies to enter the space transportation industry. The encouragement was in the form of a $10 million prize. The prize was offered to the first team of engineers that could design and fly an efficient and safe space plane. The vehicle had to be privately financed without government aid. It had to reach the height of 62 miles above earth and return safely home. The vehicle had to then be flown into space again within 14 days after the first flight, without major modifications to the vehicle.

There were a total of over 20 teams that registered for the X Prize competition. These teams represented seven countries around the world, including the United States, the United Kingdom, Russia, and Israel. The designs varied from planes that took off on traditional runways, planes launched on rockets, and planes deployed in the air from other aircraft. On October 4, 2004, the spacecraft *SpaceShipOne* claimed the Ansari X Prize. *SpaceShipOne* was launched from the aircraft *White Knight* on September 29, 2004 and again on October 4. The spacecraft was designed by Burt Rutan and Scaled Composites and reached an altitude of 71.5 miles. This historic pair of flights may serve as the start of space tourism.

Figure 23-20. The International Space Station (ISS) is being built in stages over a period of years. The assembly of the ISS began in 1998, when astronauts attached the first two pieces, the Russian *Zarya* control module and the U.S. *Unity* connecting module, in space. This photo was taken after installation of a key component—the 240′-long, 38′-wide solar array (the "wings" at the top of the photo). By the end of the assembly, there will be a total of 46 U.S. and Russian spaceflights aimed at constructing the station. The station will allow for a constant presence in space. Astronauts and cosmonauts have already spent a combined 1000 straight days on the ISS. This allows for science experiments that have never before been possible. (National Aeronautics and Space Administration's Marshall Space Flight Center)



effort from 16 countries around the globe. It is three times larger then *Mir* and will include U.S., Russian, Canadian, Japanese, and ESA components. The United States is in charge of the operations of the station.

Extravehicular Mobility Units (EMUs)

Extravehicular activity (EVA): A spacewalk.

In many space missions, especially in the assembly missions to ISS, it is necessary for the astronauts to walk in space. These spacewalks are often called ***extravehicular activities (EVAs).*** Because of the extreme conditions of space, the astronauts must wear specialized suits. The suits have 13 layers of material and are equipped with a heating and cooling system. They cost over $10 million apiece. In order for the spacewalker to navigate in space, the suits are equipped with jet packs. See **Figure 23-21.** In the early 1980s, two astronauts strapped backpacks on their backs. This type of jet pack device was known as an Extravehicular Mobility Unit (EMU). The astronauts are able to move around with EMUs by releasing bursts of compressed nitrogen gas, which is shot through tiny thrusters.

Figure 23-21. A jet pack or Extravehicular Mobility Unit (EMU) allows an astronaut to move around outside the space shuttle without a tether line. EMUs became the first human spaceships. Today, a smaller device known as a Simplified Aid for EVA Rescue (SAFER) is used as a jet pack. These are smaller than EMUs and are only used in case of emergency. If a tether line were to break, the astronaut could use the SAFER to propel himself back to the ship. These two astronauts are wearing EMUs as they work outside the payload bay of the shuttle *Endeavor*. On the right is the Remote Manipulator System robot arm Canada developed for the shuttle program. (National Aeronautics and Space Administration)

Summary

Space transportation has developed over a time when humans' dreams came true. For centuries, humans have dreamed of a manned flight to the moon. This dream moved a step closer to reality in 1957, when Russia launched its first successful satellite into orbit. They named it *Sputnik 1*. That day in October added a new dimension to space transportation and exploration.

Galvanized into action, the United States soon had a space program underway to research and develop space technology. The National Aeronautics and Space Administration (NASA) then, as now, controlled the program. The United States successfully placed its first satellite in orbit in 1958 and, 11 years later, placed a manned spaceship on the moon. Since that time, NASA has launched over 100 space shuttle missions. It has also launched two space stations into orbit.

The two types of space transportation modes are manned and unmanned vehicles. Unmanned space vehicles are satellites, space probes, and sounding rockets. Manned space vehicles are space shuttles, space stations, and jet packs. Both modes of space transportation are used to research, experiment with, and explore space. They represent the future of our travels into space.

Key Words

All the following words have been used in this chapter. Do you know their meanings?

apogee
exosphere
extravehicular activity (EVA)
geosynchronous (GEO) orbit
International Space Station (ISS)
jet pack
launchpad
low earth orbit (LEO)
manned space vehicle
mesosphere
near space
orbit
outer space
perigee
Skylab
spacecraft
stratosphere
thermosphere
troposphere
unmanned space vehicle
weightlessness

Test Your Knowledge

Write your answers on a separate sheet of paper. Do not write in this book.

1. Write the definition of *spacecraft*.
2. Summarize Robert Goddard's influence on space transportation.
3. *True or False?* The National Aeronautics and Space Administration (NASA) is the only space agency in the world.
4. When is a spacecraft said to be in orbit?

Matching questions: For Questions 5 through 10, match the phrases on the left with the correct term on the right.

5. Ten miles from the earth's surface.
6. A region that contains an ozone layer.
7. A region that has clouds of frozen water vapor.
8. A region in which no sound is transmitted.
9. The outer region of the atmosphere, before outer space.
10. A region beyond the atmosphere.

A. Exosphere.
B. Mesosphere.
C. Outer space.
D. Stratosphere.
E. Thermosphere.
F. Troposphere.

11. *True or False?* Space debris is a serious concern in space travel.
12. Discuss several environmental factors of space affecting the design of spacecraft.
13. Cite the principle allowing a rocket engine to work.
14. Describe two types of orbits.
15. *True or False?* The farthest point away from the earth in the elliptical path of orbit is known as a perigee.
16. Name the two modes of space transportation.
17. _____ was the first successful satellite to orbit the earth.
18. *True or False?* Satellites are used only for television broadcasting.
19. What is the main purpose of a space probe?
20. *True or False?* The *Gemini* spacecraft was the first manned space vehicle.
21. State the purpose of the space transportation system (STS).
22. The first U.S. space station was _____.

STEM Activities

1. Design and construct your own version of a space station. Check with your resource center for books and other materials on its design.
2. Choose a specific space mission and create a display showing the history and technology used in the spaceflight.