Aerospace Dimensions

SPACECRAFT

MODULE 6

Civil Air Patrol

Maxwell Air Force Base, Alabama

Aerospace Dimensions
SPACECRAFT

MODULE 6

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INTRODUCTION

The Aerospace Dimensions module, ***Spacecraft***, is the sixth of six modules, which combined, make up Phases I and II of Civil Air Patrol's Aerospace Education Program for cadets. Each module is meant to stand entirely on its own, so that each can be taught in any order. This enables new cadets coming into the program to study the same module, at the same time, with the other cadets. This builds a cohesiveness and cooperation among the cadets and encourages active group participation. This module is also appropriate for middle school students and can be used by teachers to supplement STEM-related subjects.

Inquiry-based **activities** were included to enhance the text and provide concept applicability. The activities were designed as group activities, but can be done individually, if desired. The activities for this module are located at the end of each chapter.

Contents

International Space Station

National Academic Standard Alignment

Science Standards	Mathematics Standards	English Language Arts Standards	Social Studies Standards	Technology Standards
Science as Inquiry	3. Geometry Standard: • Use visualization, spatial reasoning and geometric modeling to solve problems	1. Reading for Perspective	2. Time, Continuity, and Change	1. Understanding of the characteristics and scope of technology
Physical Science: • Motions and forces • Properties and changes of properties in matter	4. Measurement Standard: • Apply appropriate techniques, tools, and formulas to determine measurements	2. Understanding the Human Experience	3. People, Places, and Environments	3. Understanding of the relationships among technologies and the connections between technology and other fields of study
Life Science: • Regulation and behavior	10. Representation Standard: • Use representations to model and interpret physical, social, and mathematical phenomena	4. Communication Skills	6. Power, Authority, and Governance	4. Understanding of the cultural, social, economic, and political effects of technology
Earth and Space Science: • Earth in the solar system		12. Applying Language Skills	8. Science, Technology, and Society	6. Understanding of the role of society in the development and use of technology
Science and Technology: • Abilities of technological design			9. Global Connections	7. Understanding of the influence of technology on history
Science in Personal and Social Perspectives: • Personal Health • Science and technology in society				8. Understanding of the attributes of design
Unifying Concepts and Processes: • Evidence, models, and explanation • Constancy, change, and measurement				9. Understanding of engineering design
				10. Understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving

1 UNMANNED SPACECRAFT

Learning Outcomes

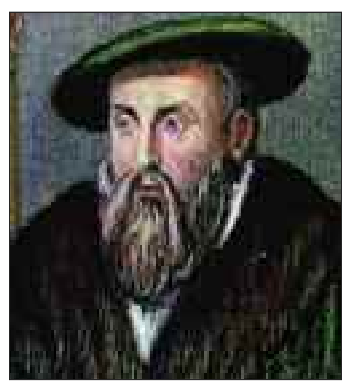
- Define satellite.
- Describe an orbit.
- Define apogee and perigee.
- Identify Sputnik.
- Define a space probe.
- Describe the related parts that make up a satellite system.
- Describe the global positioning system.
- Describe the X-37's potential uses.

Important Terms

apogee - the highest point of an orbit
COMSAT - communications satellite
GNSS - Global Navigation Satellite Systems, the term used for navigational satellites
GOES - Geostationary Operational Environmental Satellite
GPS - Global Positioning System, a navigational system used by all areas of society
ITSO - International Telecommunications Satellite Organization, the world's largest commercial satellite communications provider; now called INTELSAT
LANDSAT - satellite that locates natural resources and monitors conditions on the Earth's surface
NAVSTAR GPS - as of 2010, the only fully-operational GNSS
orbit - the path a satellite takes around a celestial body
perigee - the lowest point of an orbit
satellite - natural or artificial object in space that orbits the Earth
space probe - satellites that either fly by, orbit, or land on a celestial body, other than Earth
Sputnik - the first artificial satellite (from Russia)

SATELLITES

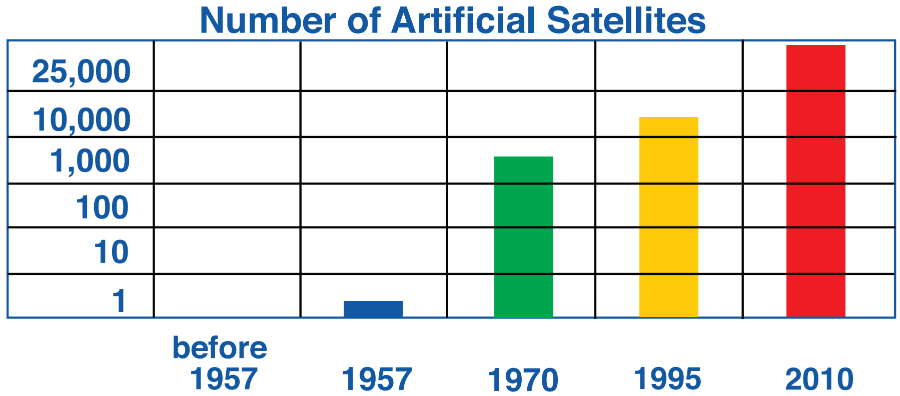
Origin


Johannes Kepler

The word **satellite** comes from the French language meaning a guard or attendant. In 1611, while studying the planets and stars, the German astronomer, Johannes Kepler, discovered several objects moving around Jupiter. He named them satellites of Jupiter — the guardians of the giant planet.

In today's world, most of us realize the impact satellites have on our lives. We know that they affect our televisions and our telephones, and even help us in predicting the weather. They are a part of our daily lives. Today, astronomers still use the term satellite for natural objects in space. An example of a natural object in space is the Moon. In fact, the Moon is the Earth's only natural satellite.

In 1957, the Russians launched ***Sputnik***, the first artificial (manmade) satellite. Since then, astronomers have used the term satellite for either a natural or an artificial object in space. We commonly call any object that orbits the Earth a satellite.



Artificial Satellites

As mentioned earlier, the Earth has only one natural satellite, but as you can tell from this chart, there are thousands of artificial satellites. Since 1957, about 40 countries have launched more than 24,000 artificial satellites. Today, there are only about 3,000 usable satellites orbiting the Earth. There are approximately 5,000-6,000 other manmade objects still orbiting Earth, but they are unusable and considered space junk. Because satellites normally only stay in orbit for 5-20 years, the rest of the 24,000 have fallen out of orbit and incinerated during reentry into Earth's atmosphere.

Telstar I

TDRSS (COMSAT)

In the early days of artificial satellites, the satellites were unmanned. These unmanned satellites are sometimes referred to as unmanned spacecraft. These satellites or spacecraft have many different missions and are placed in categories based on those missions. Some of those categories are communications, navigation, Earth observing, and weather.

In 1958, the first communication satellite **(COMSAT),** *Score*, taped messages from orbit to Earth. It operated for only 13 days, but our nation was excited. In 1962, *Telstar* 1 became the first commercial satellite. It retransmitted as many as 60 two-way telephone conversations at one time. Today, the COMSAT business is huge and growing. National and international corporations are financing the construction, launch, and operation of several types of COMSATs, including direct television and video conferencing.

The **International Telecommunications Satellite Organization** (ITSO) is the world's largest commercial satellite communications provider. Now called INTELSAT, it manages a constellation of communications satellites to provide international broadcast services. In 1989, they launched a satellite that accommodated 15,000 two-way

***Syncom* IV Communications Satellite**

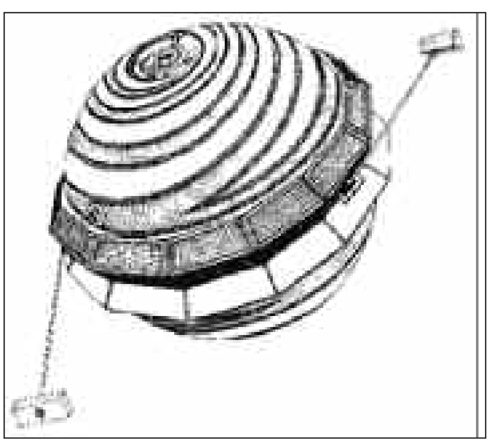
***Mariner* 10 Mars Observer**

Image of a GPS Satellite on orbit about the Earth

voice circuits and two television channels simultaneously. Now, the ITSO (INTELSAT) consists of 53 satellites and provides services to more than 200 countries.

Another COMSAT is the Tracking and Data Relay Satellite System (TDRSS). The TDRSS consists of nine active satellites and provides a simultaneous full-time coverage for the Space Shuttle and other NASA low-Earth-orbiting spacecraft. This system relays data and communications between the satellites and Earth.

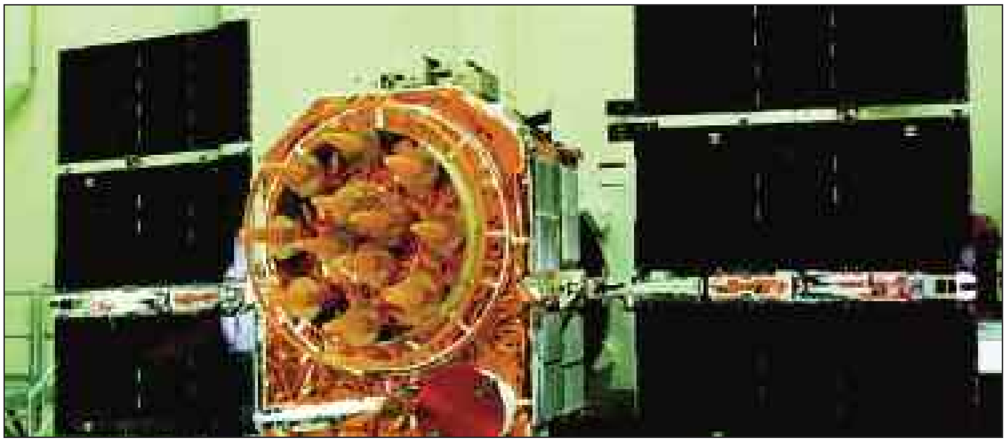
NASA established a Deep Space Network (DSN) which consists of an international network of antennas that supports interplanetary spacecraft missions and astronomy observations for exploration of the universe. There are three deep space communication facilities placed approximately 120 degrees apart. This allows them to provide continuous comrnunications for planetary spacecraft.



Transit Navigational Satellite

Communication satellites provide reliable and timely communications information around the world. The communications payload consists of the electronics and controls that ensure all signals are received, amplified, and retransmitted error-free to the appropriate destination. Successful communication links require a direct line of sight with both the transmitting and receiving stations on Earth or other satellites. Communication today normally involves an intermediate ground station rather than a direct satellite link.

By the late 1960s, navigational satellites came into existence. The first navigational satellite, *Transit*, was developed to provide *Polaris* missile submarines with the ability to fix accu-



NAVSTAR Global Positioning System

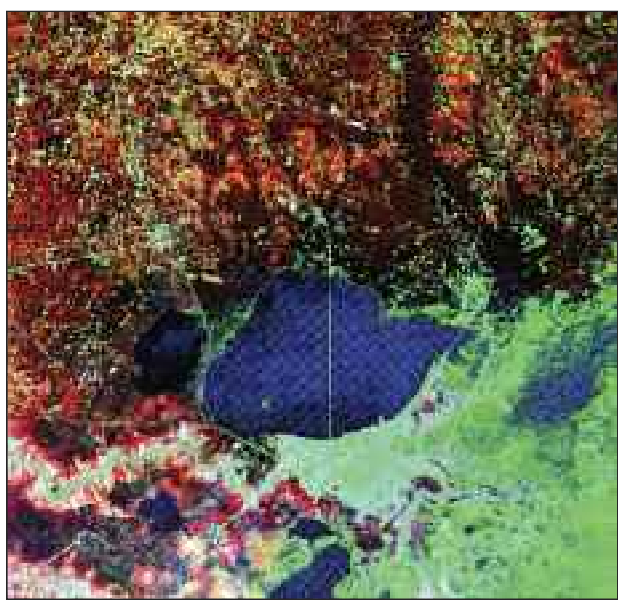
GOES 8 weather satellite atop an *Atlas* I rocket being prepared for launch in 1994

rate positions. **Global Navigation Satellite Systems (GNSS)** is the term now used for navigational satellites. GNSS allows receivers to determine location (latitude, longitude, and altitude) to within a few meters and provides precise time, as well as position. As of the summer of 2010, the United States **NAVSTAR Global Positioning System (GPS)** was the only fully-operational GNSS.

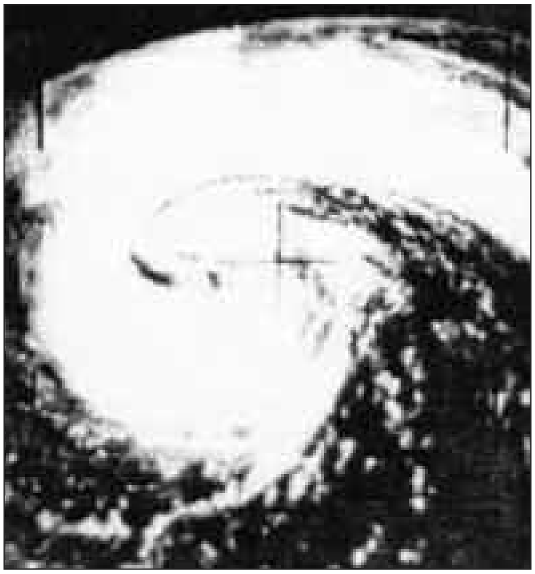
Another category of satellites is the natural resources satellites. They locate natural resources and monitor other conditions on the Earth's surface. This is the task of the **LANDSAT** series of satellites. Some of the missions of Landsats are: measure and record radiant energy, monitor agricultural conditions, aid urban planners in future development, and manage coastal resources.

Another area where satellites have had a dramatic impact on our lives is in weather. Weather satellites have significantly upgraded the capability and accuracy of weather information. This, in turn, gives us timely information which we can use for making daily decisions. The pictures we see on television weather reports come from **Geostationary Operational Environmental**

LANDSAT: a Earth Observing Satellite



LANDSAT 4 image of the Gulf Coast of southern Louisiana and Mississippi



Early hurricane imagery from *Tiros* I

Satellites (GOES). GOES gives us pictures of the Earth's surface, pictures of clouds, and information which helps with weather forecasting.

NASA sent the first weather satellite, *Tiros* I, into space on April 1, 1960. It sent back an image of a hurricane that same day. Weather satellites have come a long way since then. The weather satellites of today have tremendously added to the accuracy of our weather forecasters. They provide the technology and information that have particularly helped with forecasting severe weather. Accurately predicting severe weather saves property and lives.

Over the years, satellites have been used for obtaining scientific information in an effort to gain a better understanding of space. Here are a few of the most important satellites and their missions. Explorer was the first and oldest US satellite series. *Explorer* 1 was launched in 1958. It discovered the Van Allen Radiation Belts. Later that year, *Explorer* 3 provided more information about radiation in space and investigated the presence of micro meteoroids. In 1959, *Explorer* 6 gave us our first photograph of Earth from space.

One group of satellites, the Orbiting Solar Observatory (OSO), provided continuous solar observations for most of the 1960s and 1970s. The OSO series also furthered our studies of x-rays, gamma rays, and ultraviolet rays.

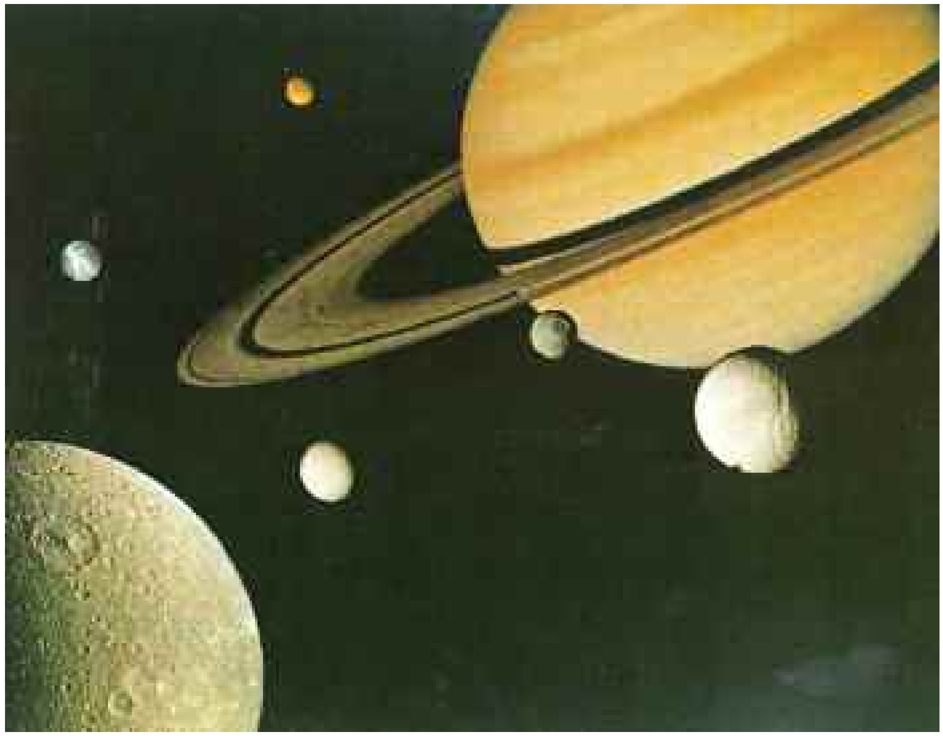
Satellites or spacecraft that either fly by, orbit, or land on a celestial body, other than Earth, are called **space probes**. We've had several probes that we should briefly mention. The *Rangers* were the first probes to take pictures of the Moon in preparation for the Apollo landings. The *Mariner* series flew by Venus and Mercury and gave us pictures of the clouds of Venus and Mercury's cratered surface.

In the 1970s, the *Pioneer* probes gave us pictures of Jupiter and Saturn.

***Pioneer* leaving our solar system**

***Mariner* II**

In 1975, the *Viking* series explored the environment of Mars. The *Vikings* analyzed and photographed the surface of Mars with the primary emphasis on the search for life. In the late 1970s, *Voyager* 1 and 2 also encountered Jupiter and Saturn. The *Voyagers* provided greatly improved pictures and data of these two planets.

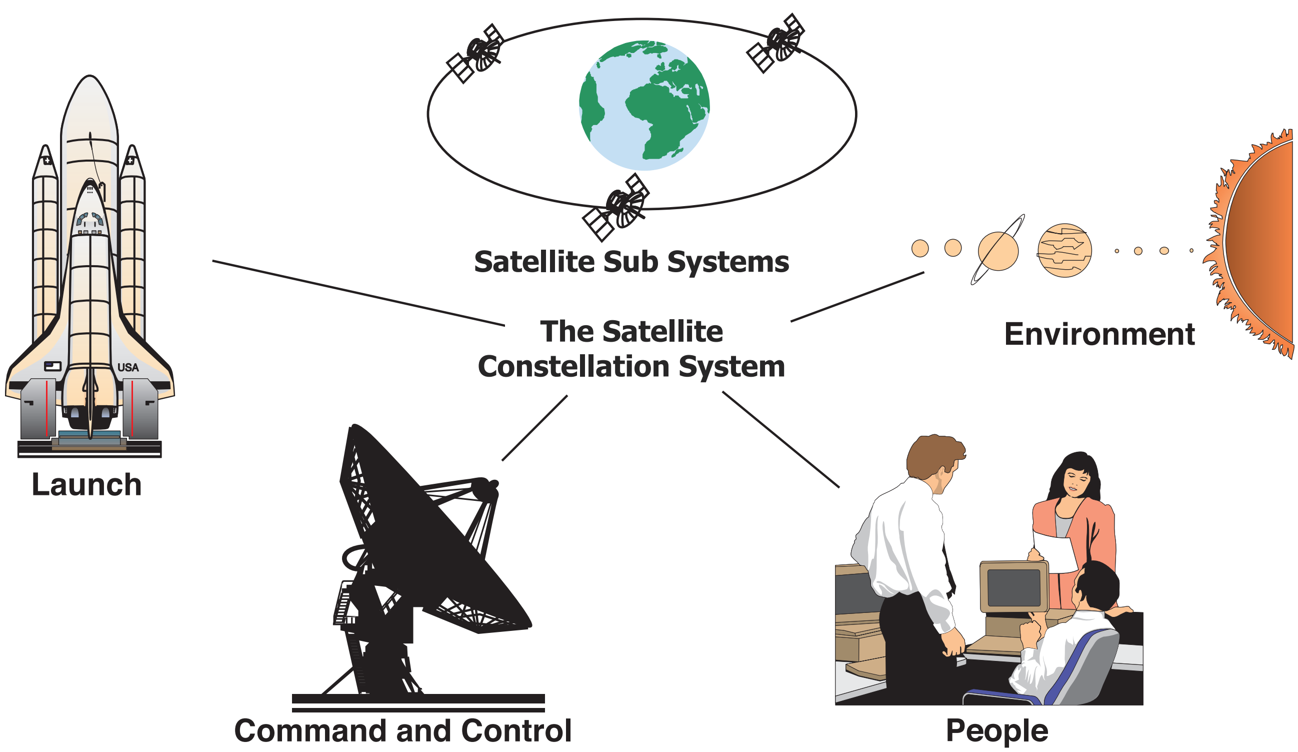


Pictures of Saturn and Jupiter provided by *Voyager*

Satellites as a System

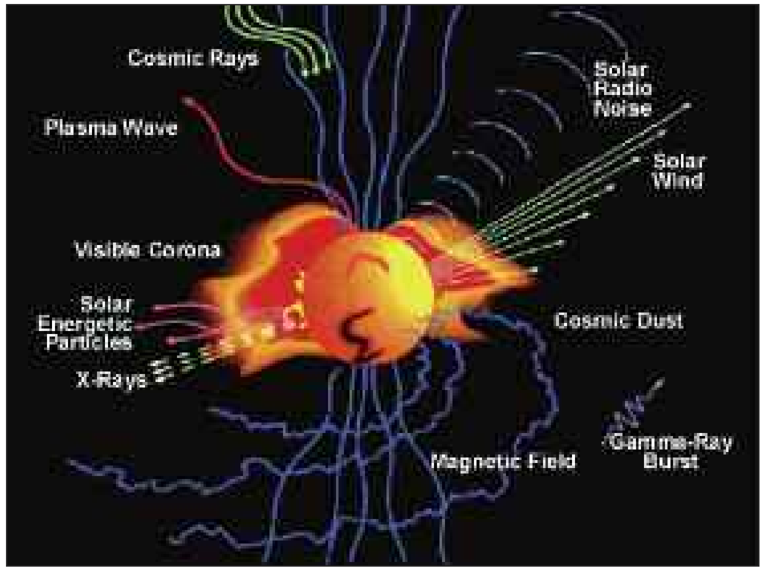
Satellites as a system refers to a satellite's related parts in a set or a system. These systems are made up of people, the space environment which is orbited, subsystems that support the spacecraft in space, an Earth-bound and a space command and control system, and, finally, a means to get the spacecraft to orbit — a launch.

There are many people involved in the design, manufacture, launch, and operation of any satellite. Plus, this system also includes the customers. As users of the information, they define the over-



all purpose and requirements for the satellites.

The space environment is something we can't control. It is extremely dangerous for both humans and satellites. For satellites, atmosphere is a concern because low Earth orbiting satellites must battle atmospheric drag, and of course gravity, which will continue to pull the satellites toward Earth. Radiation, charged particles, and solar flares are also potentially dangerous for satellites. Radiation is heat energy emitted from the sun that is both good and bad. The heat gives energy to the solar-powered satellites, but can bring harm to the satellite's protective coatings over time. The same is true with charged particles and solar flares. Over time these phenomena can harm the satellite's protective shields and damage electrical equipment.



Space Environment

Micrometeorites and space debris can also harm satellites. Some 20,000 tons of natural materials make it into the Earth's atmosphere every year. Most of it burns up, but some does hit the Earth. Manmade debris or junk is also a threat. It is estimated there are over a billion tiny pieces of junk, such as slivers of metal and paint chips in space. Why do we care? We care because in 1983 a paint chip of .008 inches hit the Space Shuttle *Challenger* and caused a crater twenty times its size (.16 inches) in an orbiter window. Traveling at over 1500 miles per hour at impact, a paint chip has tremendous energy. Efforts are underway to minimize the amount of debris each mission leaves behind.

Asteroids

The subsystems refer to the support that is given to the spacecraft in space. These include the structure, the propulsion system, attitude control, the power system, thermal control, and a command and control system.

Image of a propulsion system being used for acceleration in deep space

The first aspect that ties the subsystems together is the satellite's mission. The mission defines the satellite's purpose, what services will be provided, why the satellite is being built, and how it should be designed. The first step of the design is to determine the payload requirements. The payload refers to the sensors and instruments used to perform the mission, which also determine the other requirements of the satellite.

The structure of a satellite is like a building. It has a frame and windows, and it is insulated to help control the temperature. It must be sturdy enough to survive the launch, yet light enough to get into orbit. It supplies the support for the other subsystems.

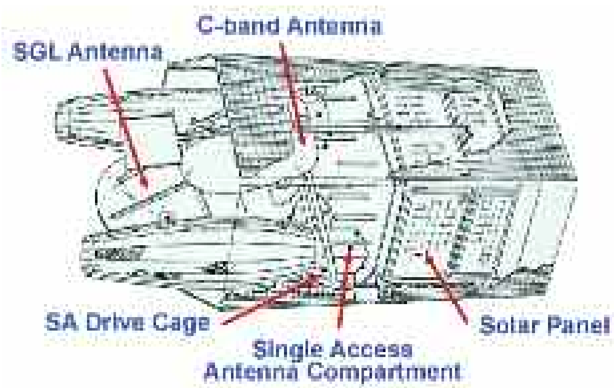
The propulsion system provides the boost to get the satellite into orbit. It takes an enormous amount of power to get into the correct orbit and stay there.

To make minor corrections in direction, the attitude control system is used. It steers and controls where the satellite is pointed.

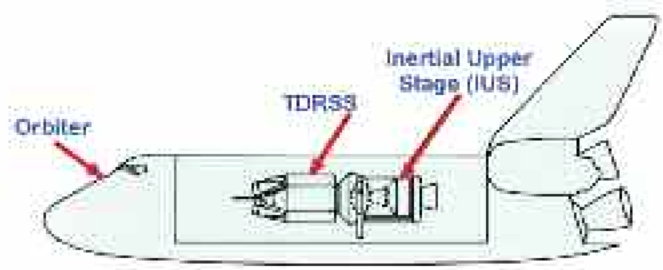
Obviously, the power is another important subsystem, and electrical power is the essential ingredient. The main source of electricity while the satellite is in orbit is the Sun. The solar power is collected from the satellite's solar cells and converted to energy to power the satellite.

A satellite experiences extreme temperature differences while in orbit. There are times when the Earth moves between a satellite and the Sun. When this happens, the temperature drops dramatically. Many measures can be used to control the temperature, but the most common are insulation and heaters. Both of these help keep the temperature within safe limits. This temperature data is all part of the thermal control subsystem.

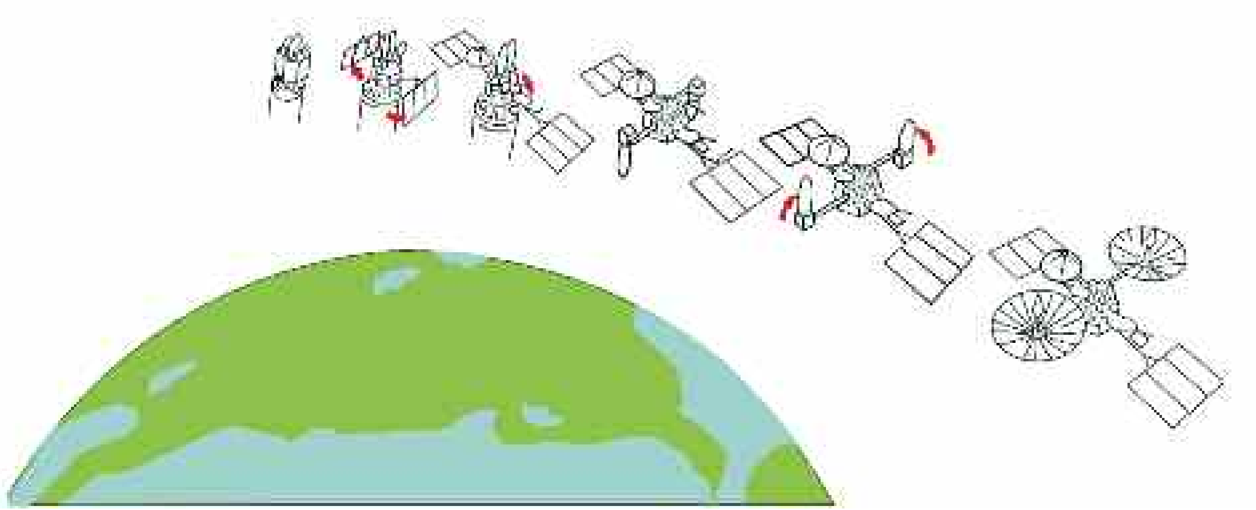
The command and control function of a satellite is a communication system. The command por-



A folded TDRSS Satellite



TDRSS Satellite tucked neatly into the Cargo Bay of the Space Shuttle

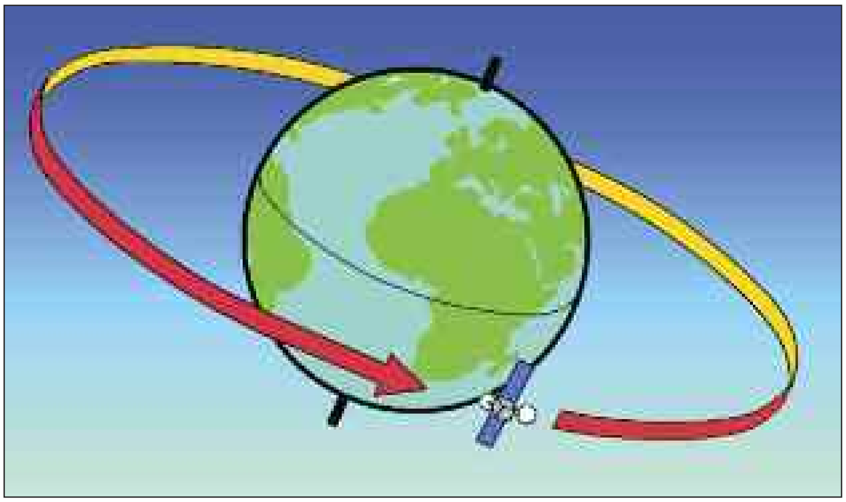


The Satellite unfolds until its antennas and solar panels stretch to dimensions larger than the size if a house.

tion is the signal from the ground station to the satellite. The commands sent to the satellite are computer programs. The satellite collects the information and sends it back to the ground station. This is called telemetry and this is the information that tells a controller how the satellite is functioning.

The last part of the system is the launch, which gets the satellite into orbit. The mission requirements determine the orbit needed to accomplish the mission. To meet these requirements, a satellite must be launched from a particular launch site at a particular time. There is a launch window in which this can occur, but it is usually a short period of time. There may be only one or two launch windows per day.

Orbits and Trajectories



Satellites orbit the Earth

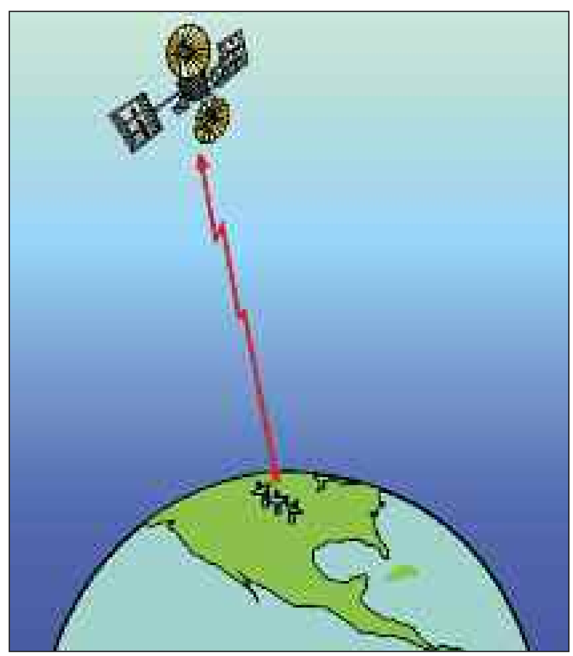
Copernicus

An **orbit** is the movement or path a satellite takes around a celestial body. We commonly call any object that orbits the Earth a satellite. Studying the orbital motion of satellites helps us understand the capabilities and limitations of these satellites.

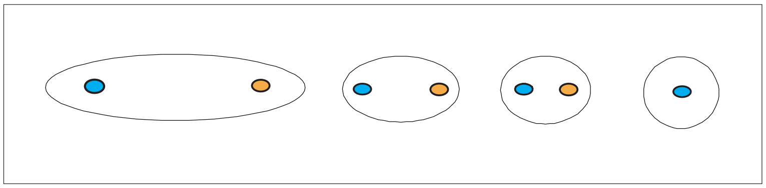
Greek astronomer Ptolemy (A.D. 127-145) gave us the first theory of motion of celestial bodies. His theory, the geocentric theory, placed the Earth at the center of the universe. He was wrong, but it was the first organized concept of the motion of celestial bodies. Celestial bodies are planets, stars, comets, and any other large objects in space.

In the 1400s, Copernicus developed a heliocentric theory of the universe. This theory placed the Sun at the center, and all the rest of the universe revolved around it. Copernicus was not entirely correct, because the universe does not revolve around the Sun as do the planets and other objects inside our solar system.

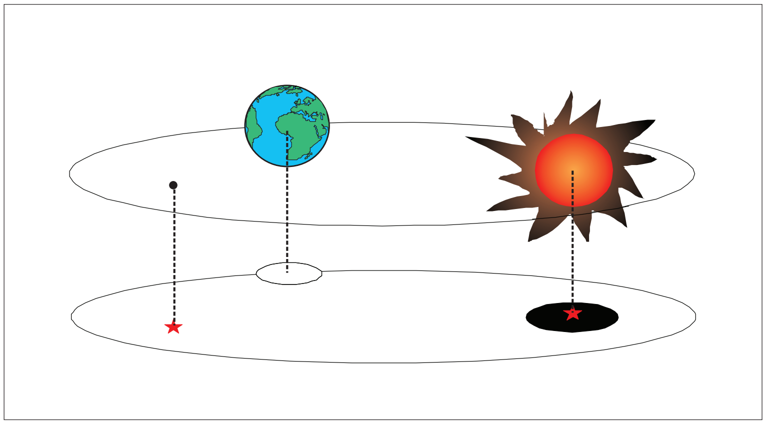
These ancient astronomers determined that the motion of celestial bodies was not random. Kepler (information and photo on page 1) studied the motion and



Telemetry



Varying Ellitical orbital shapes

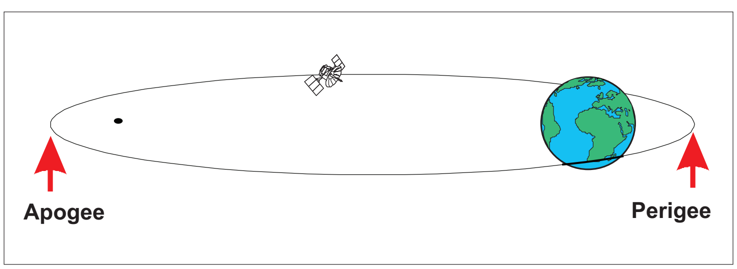


Elliptical orbits

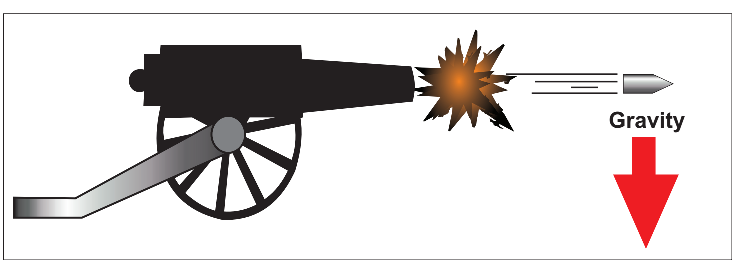
measured the movement of planets. In the 1600s, he created rules of motion which we call Kepler's laws. All celestial bodies, including artificial satellites, obey Kepler's laws. Kepler's First Law states: The orbit of each planet is an ellipse, with the Sun at the focus.

In an elliptical orbit, the satellite's altitude, velocity, and speed are not constant. Therefore, the shape varies. The shape can range from being very elliptical to almost circular. During an orbit, the orbiting object reaches a high point and a low point. Its highest point is called the **apogee**, and its lowest point is called its **perigee**. The apogee represents the point where the object is the farthest away from the body being orbited. The perigee represents the point where the object is the closest.

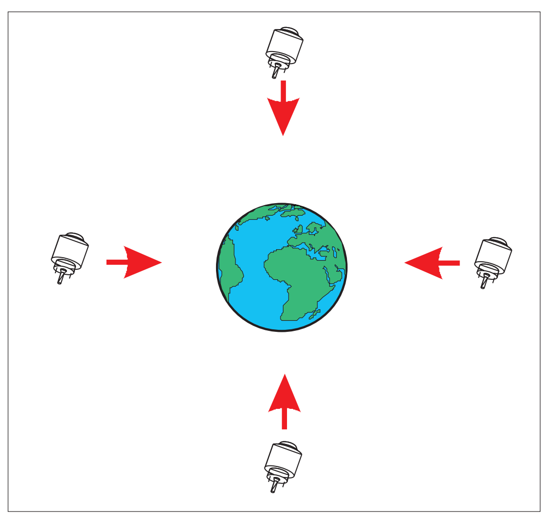
Several years after Kepler, Sir Isaac Newton developed his laws of motion. Newton's Laws of motion are very helpful to understanding the movement of satellites. These laws are discussed in detail in Module Four, Rockets. However, Newton's First Law of Motion, called the law of inertia, helps to explain how a satellite stays in orbit and how it leaves an orbit. The first law states that an object at rest remains at rest and an object in motion remains in motion unless acted on by an unbalanced force. Another of Newton's laws, the Law of Universal Gravitation, explains the gravitational attraction or pull between bodies in the universe. The Earth's gravitational force is always toward the center of the planet. The Earth's gravity is the dominant force affecting the motion of a satellite in an Earth orbit.



Elliptical orbit



Gravity pulling the bullet toward the center of the Earth



The Earth's gravitational force pulling toward the center of the planet

Gravity gives the orbit its shape. An example of a bullet fired from a gun helps to explain this. As the bullet is traveling in a straight line, gravity pulls the bullet toward the center of the Earth. The combination of the bullet's speed and gravity creates a curved flight path. (See associated Activities One and Two at the end of the chapter.)

The Spacecraft as a Vehicle

To get a better understanding of spacecraft and spaceflight, one must first have a basic knowledge of the environment in which this craft will operate. From an altitude of approximately 62 miles above the surface of the Earth, space is extremely hostile. The pressure is near zero and the temperature in deep space can approach -400°F.

The Hubble Space Telescope: a space vehicle that needs many subsystems working together to keep it operating for years

If a spacecraft is going to operate in that environment, without a "pilot" or "crew," it will, for all purposes, be a robot. If the vehicle is unmanned, then it must be controlled from a command center on Earth. The spacecraft can be scientific, technological, or a weapon of war.

To initiate a spacecraft mission, it must first be launched from one of many sites around the world. If the flight plan is designated as "suborbital," the spacecraft will be programmed to re-enter the atmosphere and return for a landing on the Earth's surface.

***MESSENGE*R spacecraft**

If a mission is scheduled to go beyond the Earth's gravity, it can remain in orbit around the Earth (like the GPS satellites). It can also explore the solar system and beyond if space agencies, like NASA and the European Space Agency (ESA), have the funding. Unmanned exploration can extend into galactic space.

One example of deep space exploration recently was the flight to Mercury which occurred in January of 2008. NASA's *MESSENGER* spacecraft gave scientists an entirely new look at a distant planet once thought to have characteristics similar to those found on our moon. After a journey of more than 2 billion miles and three and a half years, *MESSENGER* went into orbit around Mercury, and provided scientists with a better understanding of our solar system.

There is a phrase that states “form follows function.” This means that a form, living or inanimate, will have a certain shape if it is to function well in a given environment. A classic example is the shark. It is designed for high speed, high maneuverability, and very low hydrodynamic (water) drag. Compare the shark to a fighter plane, such as the F-16. The aircraft is very sleek, has large control surfaces for maneuverability, and has low aerodynamic drag. Space, on the other hand, has only minute amounts of water or air molecules and the dynamic drag is very low. That is the reason most spacecraft are very unusual in shape. They can be disks, blocks, rectangular, cylindrical, etc. An example is the Helios spacecraft. It is capable of flying at thousands of miles per hour, yet it is not designed to encounter any form of drag.

Image of the Helios spacecraft: designed to operate in an environment with extremely low temperature, extremely low pressure, and no aerodynamic drag

The Gray Nurse Shark as an example of “form following function”

The F-16: designed to pass through the air with a very low aerodynamic drag

The Unmanned Spacecraft That Functions Like A Manned Vehicle

NASA’s *X*-37 is an advanced technology flight demonstrator, which may help define the future of space transportation. The *X*-37 will test and validate technologies in the environment of space, as well as test system performance of the vehicle during orbital flight, reentry, and landing. The *X*-37 will aid in the design and development of NASA's Orbital Space Plane. This aerospace craft is designed for several missions, but one of the most significant is to provide a crew rescue and transport capability to and from the International Space Station.

The *X*-37 will operate at the speed of Mach 25 and test technologies in the hostile space environment without posing a threat to a human flight crew. Among the technologies to be demonstrated with the *X*-37 are improved thermal protection systems, avionics, the autonomous guidance system, and an advanced airframe.

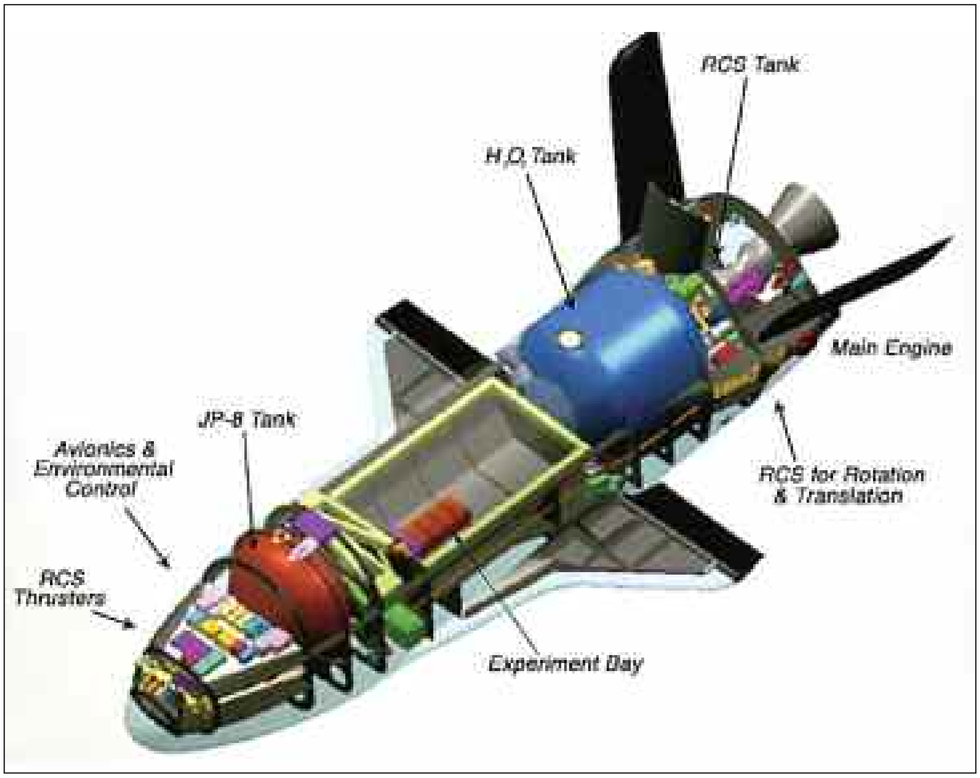
The X-37 Space Plane

As part of the *X*-37 project, the Boeing company's Phantom Works division in Huntington Beach, CA, is developing two vehicles: the *X*-37 approach and landing test vehicle and the *X*-37 orbital test vehicle. These autonomous space planes, which will have no crew, will play a key role in NASA's effort to dramatically reduce the cost of sending humans and life-support systems into space.

The *X*-37 is becoming American's military space plane that can be used for space-based surveillance and reconnaissance. The on-board engine is the Rocketdyne AR-2/3, which is fueled by hydrogen peroxide and the jet fuel, JP-8.

The *X*-37's unmanned, remote-controlled landing back on Earth

The *X*-37 was originally designed to be carried into orbit in the Space Shuttle cargo bay, but underwent redesign for launch on a Delta IV or comparable rocket after it was determined that a shuttle flight would be uneconomical.



Cutaway image of the *X*-37

The original vehicle, which was used in earlier atmospheric drop glider tests, had no propulsion system. Instead of an operational vehicle's payload bay doors it had an enclosed and reinforced upper fuselage structure to allow it to be mated with a mothership. Most of the thermal protection tiles were made of inexpensive foam rather than ceramic; a small number of the *X*-37's tiles were actual Thermal Protection Shield (TPS) tiles. TPS blankets were used in areas where heating would not have been severe enough to require tiles.

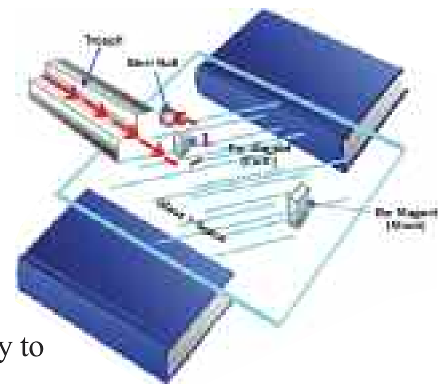
On April 7, 2006, the X-37 made its first free-glide flight. During landing, an anomaly caused the vehicle to run off the runway and it sustained minor damage. Following an extended down time while the vehicle was repaired, the program moved from the Mojave Desert, CA, to Air Force Plant 42 (KPMD) in Palmdale, California for the remainder of the flight test program.

On November 17, 2006, the US Air Force announced it would develop the *X*-37B from the original NASA *X*-37 A. The Air Force version is designated *X*-37B Orbital Test Vehicle (OTV). The *X*-37B was continued in development by the Air Force Rapid Capabilities Office and includes partnerships with NASA and the Air Force Research Laboratory. Boeing is the prime contractor for the OTV program. The first orbital flight of the *X*-OTV-1 occurred on April 22, 2010 on an *Atlas* V rocket from *SLC*-41 at Cape Canaveral Air Force Station in Florida. This mission marked the beginning of military operations in space.

From *Sputnik* 1, which was launched on October 4, 1957, to the present, the exploration of unmanned space flight continues. Whether it be for pure science or military superiority, the limit has been raised to include the final frontier of space. Aerospace education is no longer just a study of man and his/her exploration of the unknown, but also of vehicles that can go to other planets and return data that can eventually bring us closer to how the universe came about. It is hard to imagine what life will be like 1,000,000 years from now, but almost daily what was science fiction is now becoming science fact.

1 ACTIVITY SECTION

Activity One - Escape Velocity



Purpose: This activity will demonstrate what it takes to achieve escape velocity, such as to leave the gravitational pull of the Earth to enter another area of space.

Materials: cardboard trough (shaped like an M), two supports of equal size (books or blocks), piece of glass (windowpane), steel ball bearing, and two strong bar magnets

Procedure: Be sure to study the diagram before you begin the activity to place the items in the correct positions.

1. Tilt the trough slightly upward and release the ball bearing toward the first magnet. What happens? Does the steel ball have enough escape velocity to pull free of the first magnet?
2. To increase the speed of the steel ball, increase the upward tilt of the trough even more and release the ball near the upper end. What happens as the steel ball coasts through space, and approaches the second magnet?

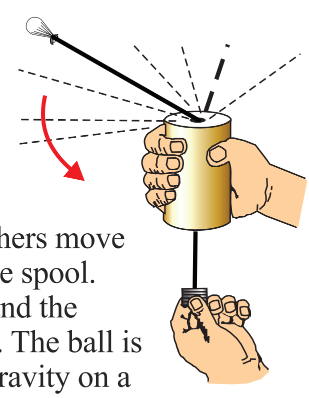
Summary: Escape velocity is commonly described as the speed needed to “break free” from a gravitational field. The more speed that is applied to the space vehicle (steel ball) in this activity, the greater the chance of escaping the gravitational pull of Earth (the first bar magnet) as you coast through space (glass pane) and approach the Moon (the second bar magnet) with its own gravity field. High velocity is needed for a satellite to go into orbit in space.

Activity Two - Why Do Satellites Stay in Orbit?

Purpose: This activity will demonstrate why satellites stay in orbit around the Earth.

Materials: a large thread spool, string, five metal washers, a nylon stocking, and a small rubber ball

Procedure:



1. Cut a piece of nylon to put around the rubber ball.
2. Tie one end of a string around the nylon.
3. Put the other end of the string through the spool and attach the washers to it.
4. Hold the spool in one hand; the washers in the other.
5. Begin to whirl the ball over your head.
6. Gradually let go of the washers. As you increase the speed of the ball, the washers move closer to the spool. As you slow down, the washers begin to fall away from the spool.
7. While the ball is whirling, have someone cut the string between the washers and the spool. The ball will fly away from the spool in a straight line due to its inertia. The ball is held in orbit around the spool by the string. This corresponds to the force of gravity on a satellite, which causes an inward pull.

Summary: The forward motion of the ball is its momentum. If the gravity of the string were not acting on the ball, the ball would continue in one direction. The swinging of the ball gives it its forward motion. When these two forces are equal, the ball remains in orbit, without falling into or flying away from the Earth (you). When the gravity (washers) is removed, the forces become unbalanced and the ball will fly off in a straight line. A satellite’s forward motion is controlled by rockets. When the rockets are not fired, inertia keeps the satellite going in one direction. When the rockets are fired, the velocity is increased and the satellite can be propellled out of orbit.

2 MANNED SPACECRAFT

Learning Outcomes

- Identify various manned space flight projects and their missions.
- Identify the American and Russian joint manned spacecraft mission.
- Describe the accomplishments of Alan Shepard and Neil Armstrong.
- State specific facts about the Hubble Space Telescope.
- Discuss the overall mission of the International Space Station.
- Identify various space shuttle launches and their missions.
- Describe China's effort in space.

Important Terms

Apollo - US manned spaceflight project that put man on the Moon
Apollo-Soyuz - manned spaceflight project linking American and Soviet spacecraft in space
Gemini - US manned spaceflight project that achieved the first walk in space, and the first two-man capsule
Mercury - US first manned spaceflight project
Skylab - US manned spaceflight project that put a laboratory into space
Space Shuttle - US Space Transportation System (STS) for transporting into space and returning to Earth

FIRST IN SPACE

The Soviet Union's space flight programs developed along the same lines as the American programs and occurred approximately the same times. However, the Soviets had several firsts in the space race.

In 1957, the Soviets launched the first satellite, *Sputnik*, into space. After that, the Soviets launched nine more *Sputniks* in about 3 1/2 years. The last two were accomplished in preparation for their first manned space flight.

The Soviets also put the first man in space in April 1961. Major Yuri Gagarin was the first man to escape the Earth's atmosphere. Although he only stayed up for one orbit, he described sights no human eyes had ever seen before. Then in June 1963, the Soviets put the first

Yuri Gagarin, the first human in space

woman, Valentina Tereshkova, into space. She completed 48 orbits and was in space for three days before returning safely to Earth.

In March 1965, Russian Cosmonaut, Alexei Leonov, became the first person to "walk in space." He spent 20 minutes outside of his spacecraft. This occurred about two months before the Americans "walked in space."

The Soviets launched their first space station, *Salyut* 1, in April 1971. The Soviets sent seven Salyuts into space to complete their space station missions. *Salyut* 7 fell back to Earth in 1991.

The Soviets next space station model was *Mir*, the Russian term for peace. *Mir* was launched in February 1986. *Mir* did not carry as many specific instruments, so there was more room and comfort for the cosmonauts (the Russian term for American astronauts). In 1998, the United States sent several Space Shuttles to dock with *Mir.* American astronauts spent over two years aboard *Mir* on different occasions.

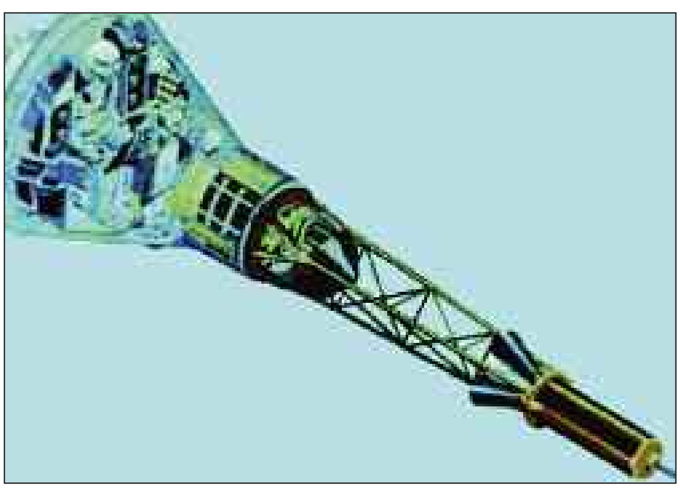
The Soviet Space Station, *Mir*

Mir was scheduled to fall to Earth in 1999. However, the Soviets boosted *Mir* so that it would stay in space longer. In 2001, as *Mir's* rocket boosters propelled it out of orbit, it burned up entering the Earth's atmosphere. Its remains ended up in the Pacific Ocean. This ended a 15-year 2.2 billion mile journey and the historic era of the Russian space station program.

PROJECT MERCURY

The United States launched its first satellite in 1958, and by 1961 the US was ready to attempt manned spaceflight. America's first manned spaceflight program was called **Project Mercury**. Mercury's mission was to find out if a human could survive space travel, and what, if any, effects would space travel have on the human body.

Project Mercury lasted two years and consisted of six manned flights. The first flight involved sending one astronaut into space. This first flight was suborbital and lasted for only 15 minutes, but on May 5, 1961, astronaut Alan Shepard became the first American in space. Project Mercury's third manned flight was also its first orbital flight. During



Cutaway image of the Mercury capsule

Alan Shepard in Mercury flight suit.

this flight, astronaut John Glenn became the first American to orbit the Earth. He remained in orbit for four hours and fifty-five minutes, while orbiting the Earth three times.

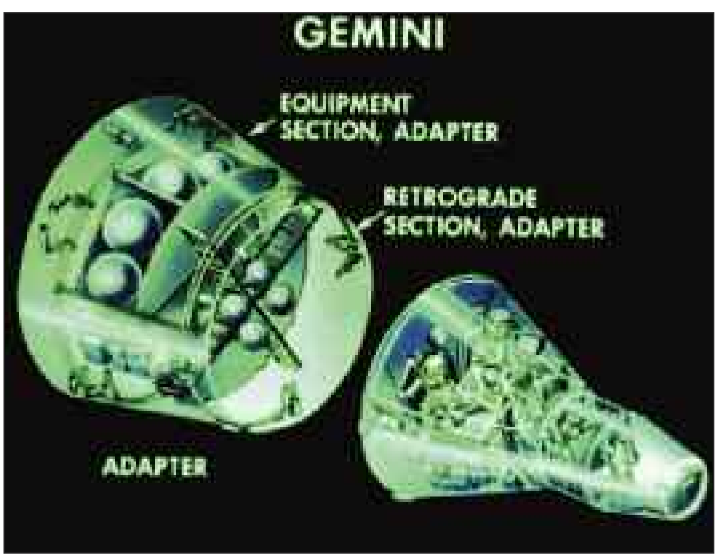
On the final Mercury flight, astronaut Gordon Cooper orbited the Earth 22 times and stayed in space for about 34 hours and 20 minutes. Project Mercury answered the basic questions about survival in space. Project Mercury accomplished its mission.

***Freedom* 7, ready to carry Shepard into space**

John Glenn entering his capsule, *Friendship* 7

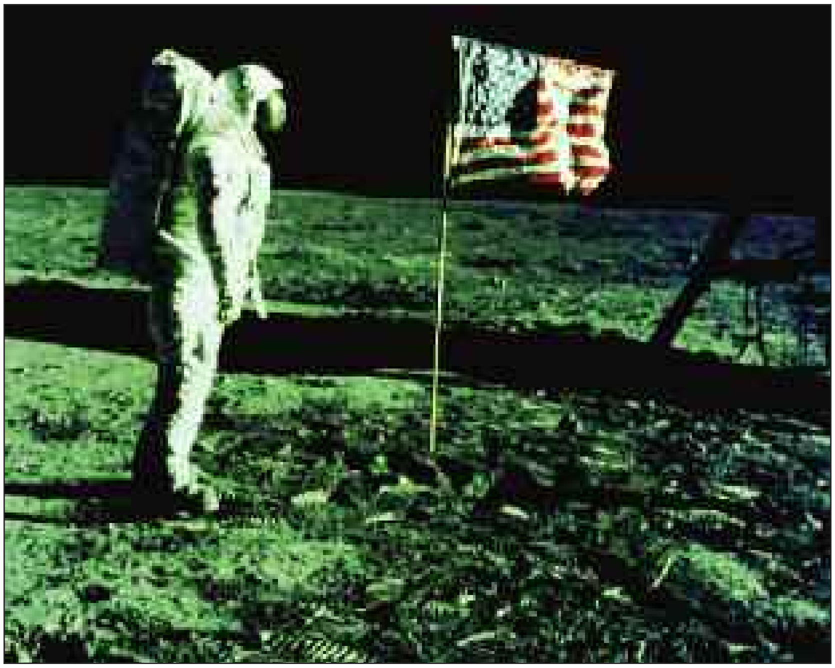
PROJECT GEMINI

The next manned spaceflight project was **Project Gemini**. There were a total of 10 Gemini flights between 1965 and 1966. Gemini was the first two-man capsule, and during one of the missions, astronaut Ed White achieved the first US "space walk." Additionally, Gemini allowed for the first rendezvous and docking of a manned spacecraft with another satellite. The Gemini flights gathered additional information about the effect of spaceflight on the human body. The astronauts studied the effects of weightlessness and were involved in an exercise program. At times, they removed their space suits and relaxed in shirtsleeves. Because the flights lasted for several days, the astronauts were able to establish routines for sleeping and eating. Enough information was gathered to convince scientists that a space flight could safely last for several weeks or even months. These Gemini flights were very valuable in America's plan to place a man on the Moon.



The two-man Gemini capsule

Gemini IV's astronaut Ed White during a 22-minute space walk


Neil Armstrong, the first human to walk on the Moon

PROJECT APOLLO

After the Gemini missions were completed, **Project Apollo** took center stage in America's space program. From the early 1960s, it was known that Apollo's mission would be to put a man on the Moon. So, the Apollo flights were conducted with that overall goal in mind. Several of the early Apollo flights traveled to the Moon, orbited it, and returned to Earth. It was not until *Apollo* 11 that the mission was accomplished. *Apollo* 11 landed on the Moon, and on July 20, 1969, Neil Armstrong was the first man to walk on the Moon.

A few minutes later, Edwin "Buzz" Aldrin also stepped off the ladder of the Lunar Module and joined Armstrong on the Moon. Many have called that landing the greatest scientific and engineering accomplishment in history. After *Apollo* 11, there were six more Apollo flights to the Moon. Five of them resulted in successful Moon landings.

The only flight of the six that didn't land on the Moon was *Apollo* 13. *Apollo* 13 had to be aborted due to an explosion in the spacecraft. However, *Apollo* 13 did make a successful emergency landing back on Earth.


Aldrin joins Armstrong on the Moon


The Apollo 11 astronauts, Edwin E. "Buzz" Aldrin, Michael Collins, and Neil A. Armstrong

PROJECT SKYLAB

Project ***Skylab***, the next spaceflight project, used a lot of leftover equipment from the Apollo missions. *Skylab's* mission was to put a laboratory into space. Scientists had been interested in continuing their studies of the effects of long-duration space flights using a manned orbiting laboratory. This was accomplished when *Skylab* was launched in May 1973.

Skylab

Skylab had about the same amount of room as a three-bedroom house. It also contained all of the food, water, and oxygen needed to support the entire mission.

Three different crews spent time in the lab. The first crew manned *Skylab* for 28 days. The second crew spent 58 days aboard the laboratory. The final crew spent 84 days in space. The main lesson that came from *Skyla*b was that people could live and work in space for at least three months with no ill effects.

PROJECT APOLLO-SOYUZ

After the Apollo flights, the last manned space launch before the Space Shuttle was the ***Apollo-Soyuz* Test Project**. This occurred in July 1975 and involved a linkup in space of American and Soviet manned spacecraft. This was a unique moment in history. These two superpowers that had been involved in a well-publicized space race for 15 years, met and shook hands in space. This was indeed a special moment.

Image of the *Apollo-Soyuz* project

The two crews docked together and spent two days moving between the capsules helping each other with scientific experiments. Among the American crew were former Mercury and Gemini astronauts. Among the Soviet crew was Alexei Leonov, the first man to "walk in space." This joint venture truly was an historic event.

Apollo-Soyuz marked the end of an era. It marked the end of the expendable spacecraft. A new era was being ushered in, the era of the reusable space vehicle, the Space Shuttle.

SPACE SHUTTLE

The United States Space Transportation System (STS), commonly known as the Space Shuttle Program, has served the country well for 30 years. However, as this module is being prepared, plans are to discontinue the program in 2012. Proposed new space programs are in the planning stages to replace the aging system. More about those new programs will be discussed later in this chapter but, first let's discuss the Space Shuttle Program and its accomplishments over the years.

From 1975 until 1981, the US didn't have any astronauts in space, but that changed with the Space Shuttle. In April 1981, the **Space Shuttle** was launched. The Space Shuttle provided a system for transportation into space and a return back to Earth. This has been a major advantage of the shuttle since it can be used again and again.

The Space Shuttle consists of three main parts: the orbiter, the solid rocket boosters, and the external tank. The orbiter looks like an airplane and is about the same size as a *DC*-9 jet. The orbiter carries the crew and the payload. The other two parts are required to launch the shuttle into space. The boosters burn away and the tank separates early into the flight.

When the shuttle was first built it could remain in space for 14 days. That time has increased to 30 days now. When it is time for the shuttle to return to Earth, the astronauts fire the two orbital maneuvering engines, which slow down the shuttle. The shuttle then reenters the Earth's atmosphere.

The first Space Shuttle was actually the *Enterprise*, but it was only used for flight tests. It was not designed for going into space. The other five Space Shuttle spacecraft have all gone into space and have been used for a variety of missions. They are the *Columbia, Challenger, Discovery, Atlantis,* and *Endeavour.*

The first four flights of the *Columbia* were mainly tests. Most of the concern centered around how the *Columbia* would handle reentry into the Earth's atmosphere and how its protective shields would perform. STS-5 was the first real operational flight, and it occurred in November 1982. From orbit, the STS-5 launched two satellites.

Over the years, the Space Shuttle has been used in many ways to further our knowledge of space. The first American woman in space, Dr. Sally Ride, was aboard the *Challenger* for STS-7. STS-9 delivered the first European

The Rollout of the Space Shuttle *Challenger* before it's first launch in 1983

Dr. Sally Ride, first American woman in space, with the crew of the *Challenger* mission STS-7

Two astronauts repairing and servicing the *Hubble Space Telescope*

***Atlantis* launching *Galileo* probe into space**

Space Agency Spacelab into space. STS-13 placed the Long Duration Exposure Facility (LDEF) into space to conduct experiments. A few years later, the LDEF was retrieved and the many experiments analyzed.

On January 28, 1986, less than two minutes after takeoff, the *Challenger* (STS-51L) exploded. The entire crew of seven died. A leak in one of the solid rocket boosters was the cause. After the *Challenger* accident, the shuttle program was suspended for over two years. After design changes were made, and safety procedures and precautions taken, on September 29, 1988 the Space Shuttle flights resumed.

In April 1990, the shuttle *Discovery* deployed the *Hubble Space Telescope*. The *Hubble Telescope* is operating at over 300 miles above the Earth and is free of any atmospheric interference. Therefore, the objects are seen much more clearly than from ground observations. The telescope is expected to operate until at least 2014 due to servicing provided by three separate Space Shuttle missions.

Atlantis, with mission STS-34, placed the *Galileo* probe into space. The *Galileo* probe investigated Jupiter and its moons until 2003. In 1993, STS-55 carried the European developed *Spacelab* into orbit. Many useful experiments were conducted from the *Spacelab*.

In July 1994, Payload Specialist Chiaki Mukai became the first Japanese woman to fly in space. She was part of STS-65 that performed more than 80 experiments that delved into life sciences, space biology, human physiology, and radiation biology. In February 1995, Pilot Eileen Collins became the first female shuttle pilot. Later in 1995, the 100th US human space launch occurred when STS-71 was launched. STS-71 also marked the first US Space Shuttle and Russian Space Station *Mir* docking.

In 1996, five space agencies (NASA/US; European Space Agency/Europe; French Space Agency/France; Canadian Space Agency/Canada; and Italian Space Agency/Italy) and research scientists from 10 countries worked together on the primary payload for STS-78. More than 40 experiments were conducted on microgravity science, human physiology, and space biology. STS-78 was the first to conduct comprehensive sleep studies and task performance in microgravity.

In 1998, the ninth and final Space Shuttle-*Mir* docking took place, and then later in 1998, John Glenn returned to space. John Glenn had been the first American to orbit the Earth in 1962, and after a successful career in the US Senate, he became the oldest human to venture into space when he was part of the crew aboard STS-95. John Glenn was 77 years old when he returned to space. In December 1998, the first International Space Station (ISS) flight occurred with STS-88. This was the first of several missions to construct the ISS. (You can read more about the ISS in later chapters of this module.)

STS-93 was launched in 1999 and commanded by Commander Eileen Collins. This was the first Space Shuttle in history to be commanded by a woman. She was the first woman pilot and eventually the first woman commander in space.

In 2001, as part of STS-102, astronauts Susan Helms and Jim Voss conducted the longest spacewalk in shuttle history. The spacewalk lasted 8 hours and 56 minutes. Then in 2002, Mission Specialist Jerry Ross, aboard STS-110, became the first human to fly in space seven times.

On February, 1, 2003, STS-107 *Columbia* and her seven-member crew were lost during re-entry over Texas. Damage was sustained during launch and this created a hole allowing hot gases to melt the wing structure. The resulting investigation and modifications interrupted shuttle flight operations for more than two years.

In May 2009, the STS-118 crew included Barbara Morgan, and she became the first teacher to visit space. Morgan had been the backup teacher when the 1986 *Challenger* disaster occurred. Also in 2009, STS-125 conducted the final servicing mission for the Hubble Space Telescope. Hubble's lifespan was extended until at least 2014.

As mentioned at the beginning of this section, the STS program is coming to an end. A special Space Shuttle mission scheduled for STS-133 will be piloted by Eric Boe, a former CAP Spaatz cadet and current CAP senior member. This will be Eric Boe's second mission aboard a Space Shuttle. This will mark the 36th shuttle mission to the ISS, the 133rd shuttle flight, and the final flight of the *Discovery* orbiter.

Eileen Collins STS 93 Mission Commander

The Space Shuttle has been the workhorse of America's space program since 1981. The shuttle has carried many astronauts to successful missions and these missions have greatly increased our knowledge of space. (See associated Activity Three at the end of the chapter.)

MANNED SPACEFLIGHT – THE HUMAN VENTURE CONTINUES

The Timeline of Manned Space Flight – 1961-2010*

	Russia / USSR	United States	China	Total
1961–1970	16	25		41
1971–1980	30	8		38
1981–1990	24	37		61
1991–2000	20	63		83
2001–2010	20	31	3	54
Total Missions	110	164	3	277

**As of August 2010*

A CURRENT PICTURE

As has been discussed, and as the chart above indicates, Russia and the United States have been active in spaceflight programs since the 1960s. For many years the two countries have worked side by side achieving major accomplishments in the exploration of space. Many other countries have also been active in space, particularly with the development of the International Space Station (ISS). Countries such as, Canada, Japan, and Brazil and many others have contributed to the development of the ISS. But there is another country that hasn't been part of the ISS, but is now very active in pursuing space, and that country is China.

In 2003, China launched its first manned spacecraft, *ShenZhou* 5, and then followed that with two more manned spacecraft missions in 2005 and 2008. China is also developing a spacecraft docking system that should be ready in 2010 or 2011. Then, China intends to place an astronaut on the Moon. Many observers believe that will happen in the next few years. So, China is aggressively catching up to Russia and the United States.

Meanwhile, Russia's current space priorities include developing new communications, navigation, and remote sensing spacecraft. Russia's current space budget remains unchanged with approximately 50% spent on their manned space program. Russia has indicated that they want to complete their segment of the ISS and also are considering missions to the Moon and Mars. Russia is also working on new rocket launchers to support their missions.

The United States space program is at a crossroads. The current Constellation program is under review and may be cancelled. Its goal of returning to the Moon and then on to Mars may be in jeopardy. The US is currently considering continuing pursuit of Mars and/or concentrating on commercial spaceflights. With the end of the Space Shuttle program, immediate political decisions will determine the direction and extent of America's future space involvement. Trips to the ISS are still a distinct possibility, but American astronauts may be traveling on Russian rockets. On the other hand, the *Ares* I crew launch vehicle and the *Orion* capsule may still carry American astronauts to the ISS. As of the preparation of this module, these difficult decisions had not been made. (See associated Activity Four at the end of the chapter.)

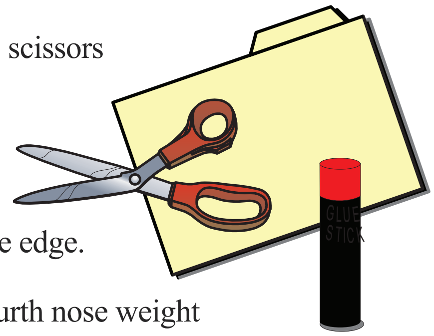
China Astronaut

ACTIVITY 2 SECTION

Activity Three - The Space Shuttle Glider

Purpose: This activity creates a model of the Space Shuttle glider (orbiter) and allows experimentation with how the shuttle glides in for a landing.

Materials: old file folders (1 makes 2 gliders), glue sticks or hot glue, scissors

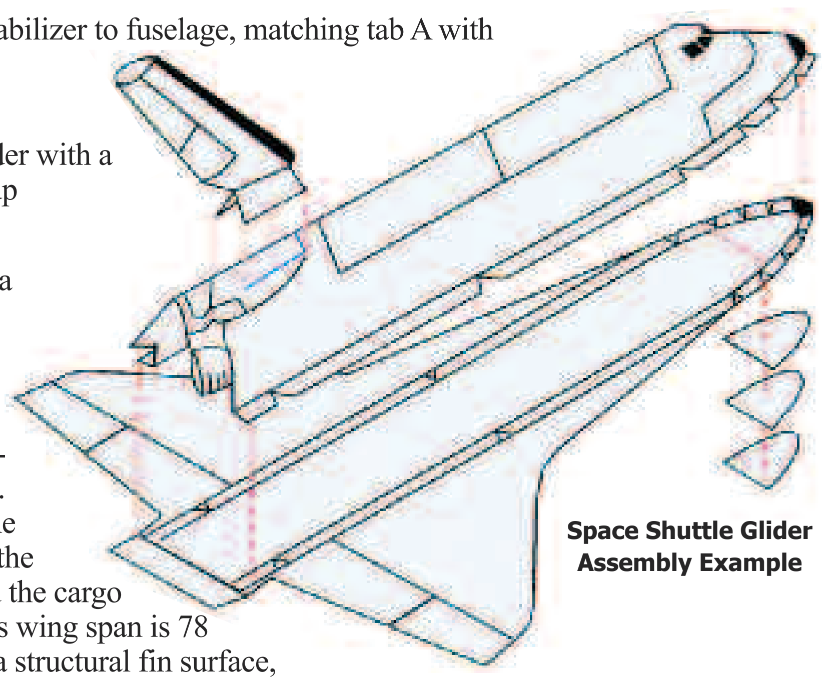


Procedure:

1. Copy the templates shown on following pages on color copier.
2. Glue the templates to heavy paper or file folders.
3. Using scissors, neatly cut out all parts.
4. Cut 13 V-shaped notches in the fuselage to create tabs along outside edge.
5. Fold tabs out.
6. Glue or tape three nose weights to underside of your glider. Use fourth nose weight provided, if needed for extra trim after assembly.
7. Fold fuselage along middle line.
8. Starting at the nose, glue or tape fuselage to deck and wing assembly. Match tabs on fuselage exactly to the ones printed on the deck and wing assembly.
9. To close the nose, glue or tape the two halves together using tabs provided.
10. Fold vertical stabilizer assembly.
11. Fold out tabs A and B. Except for tabs A and B, glue or tape vertical stabilizer assembly to make one solid piece.
12. Attach, with glue or tape, vertical stabilizer to fuselage, matching tab A with point A and tab B with point B.

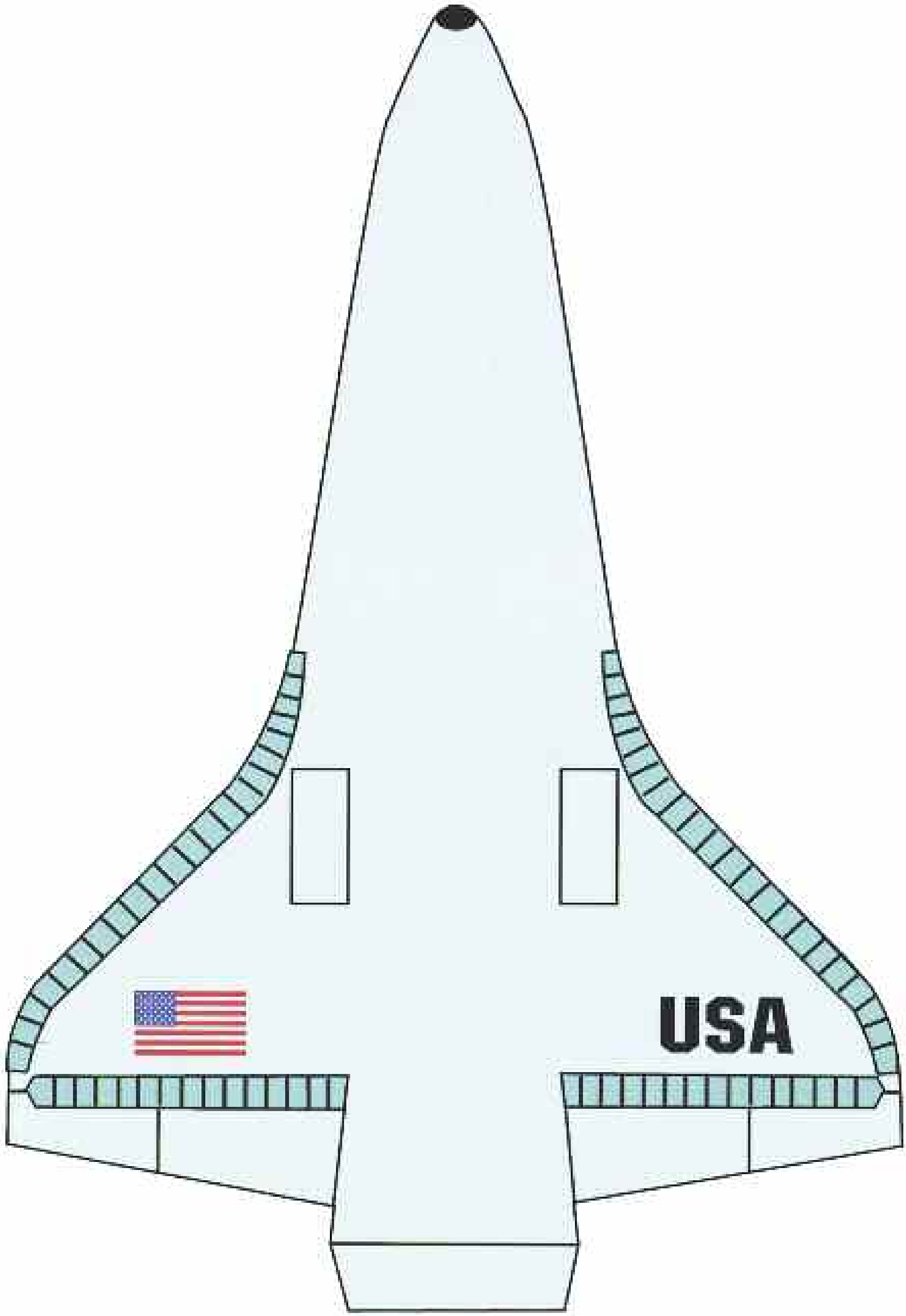
Preflight Instructions:

For best results, launch your shuttle glider with a gentle, level toss. Bend the Body Flap up slightly for greater lift.

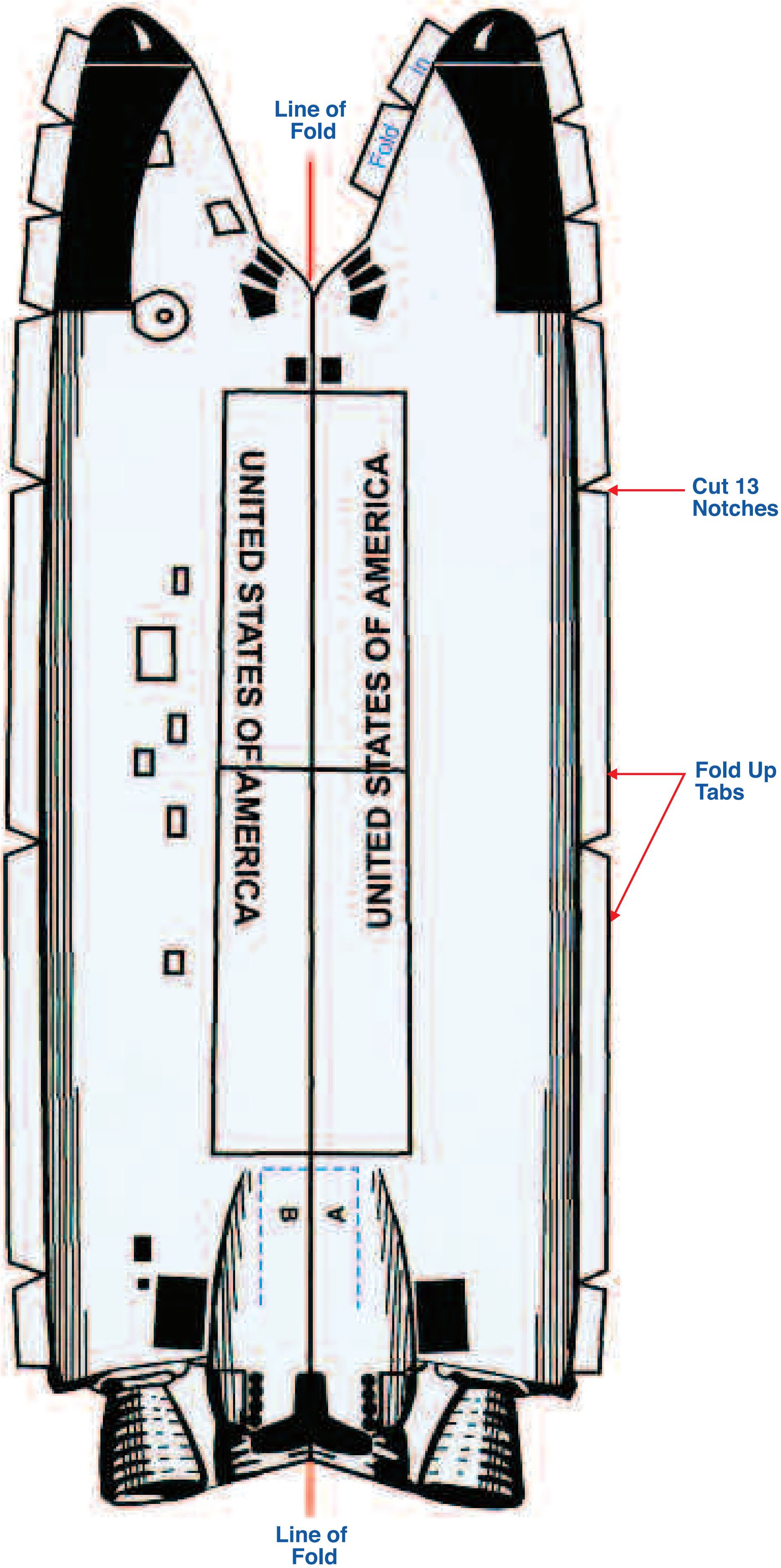


Space Shuttle Glider Assembly Example

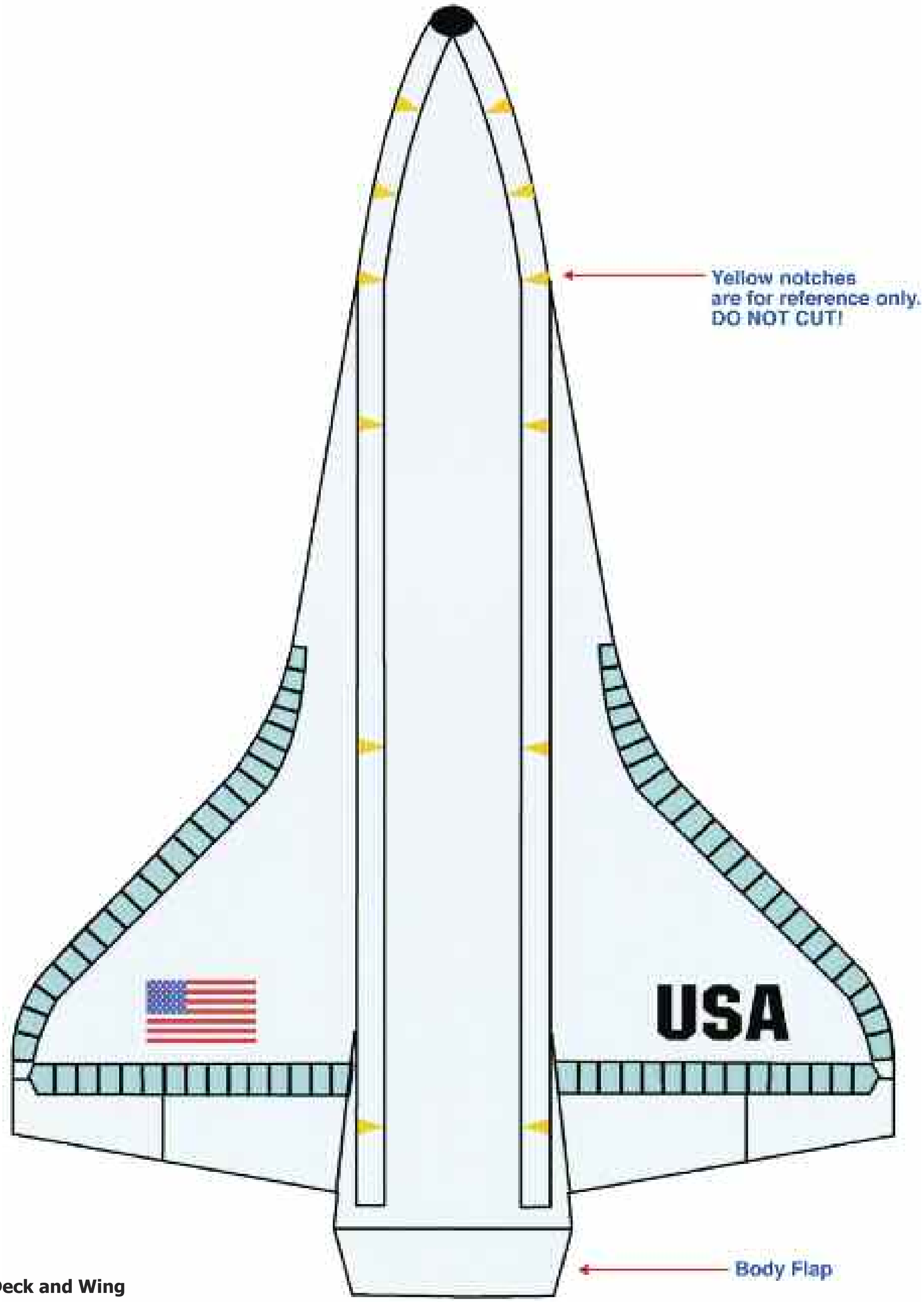
Summary: The Space Shuttle glider is a scale model of the actual Space Shuttle orbiter in the Space Transportation System (STS). As the glider is put together, discussion can revolve around such terms as fuselage, tail and wing assembly, and vertical stabilizer assembly. These terms can be compared to airplane parts. The fuselage is the main body of the aircraft that holds crew, passengers, and the cargo (called the payload). The actual shuttle's wing span is 78 ft. The shuttle's vertical tail consists of a structural fin surface, the rudder/speed brake surface, a tip, and a lower trailing edge. The rudder splits into two halves to serve as a speed brake. Like the fin of an aircraft, the vertical stabilizer keeps the shuttle on course in the Earth's atmosphere, and helps it to steer.



Space Shuttle Glider Bottom

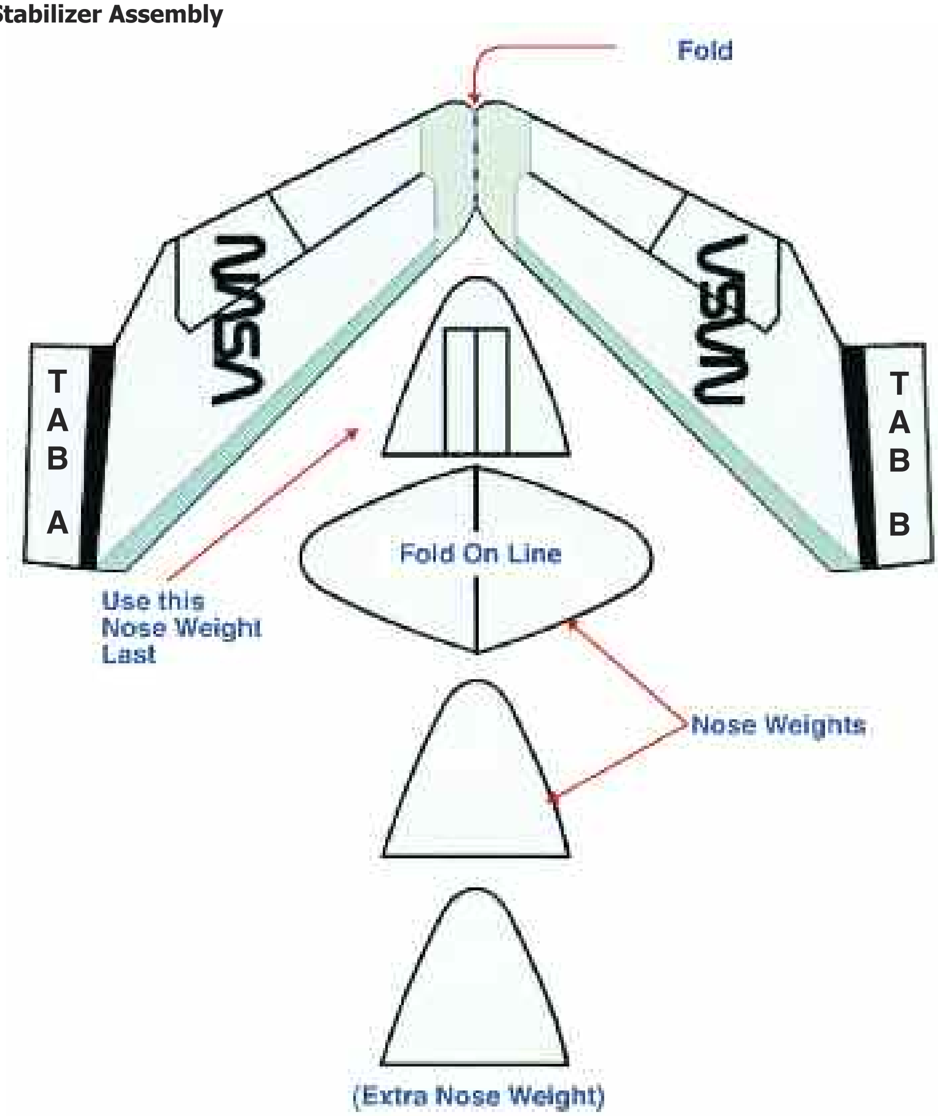


Space Shuttle Glider Fuselage Assembly



Deck and Wing Assembly

Vertical Stabilizer Assembly



Glider kit designed for NASA by
Kentron Hawaii, Ltd.
Artist: Roland O. Powell

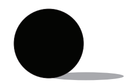
Activity Four - See How the Earth Looks to an Astronaut

Purpose: This activity will help you understand the perspective of an astronaut as he/she views Earth from space.

Materials: 16" Earth globe and a 4" Moon globe

Procedure:

1. Using the summary information below, calculate the distance between the Earth and the Moon using a model where the Earth is 16 inches in diameter and the Moon is 4 inches in diameter. (The Earth is 30 Earth diameters from the Moon, or about 40 feet.)
2. Measure the distance from your calculation. Inflate a 16-inch Earth from Space globe.
3. Have one person hold the Earth globe at the beginning point of the distance measurement you made.



4. Have another person hold the Moon globe at the ending point of the distance measurement you made.
5. Standing with the person holding the Moon globe, you can "look back" at Earth and have an idea of the view of our planet from space.

Summary: The distance from the Earth to the moon is 240,000 miles on average, because the Moon is in an elliptical orbit around Earth (due to the gravitational pull of the Sun). So, sometimes, it is closer to the Earth than other times. The circumference of the Earth is 25,000 miles. Considering the size of the Earth, the Moon is about 9.5 Earth circumferences away from the Moon. In relation to the scaled Earth and Moon in this activity, that means if the circumference of the 16" diameter Earth globe is 50.24" ($C=\pi d$), then the distance from the Earth globe to the Moon globe should be 9.5 x 50.24" = 477.28" or 39.77 ft (about 40 ft).

3 LIVING AND WORKING IN SPACE

Learning Outcomes

- Describe *Space Station Alpha*.
- Explain the differences between *Mir* and *Skylab*.
- Define *Spacelab*.
- Describe the significance of *Salyut* 1.
- Describe the living and working conditions in space.
- Describe the different space suits.
- Define and give examples of spinoffs from the space program.
- Describe possible future space endeavors.

Important Terms

Mir - Russia's space station of the 1980s and 1990s
Salyut - Russia's first space station
Skylab - first space station of the US
Spacelab - European Space Agency's first space station

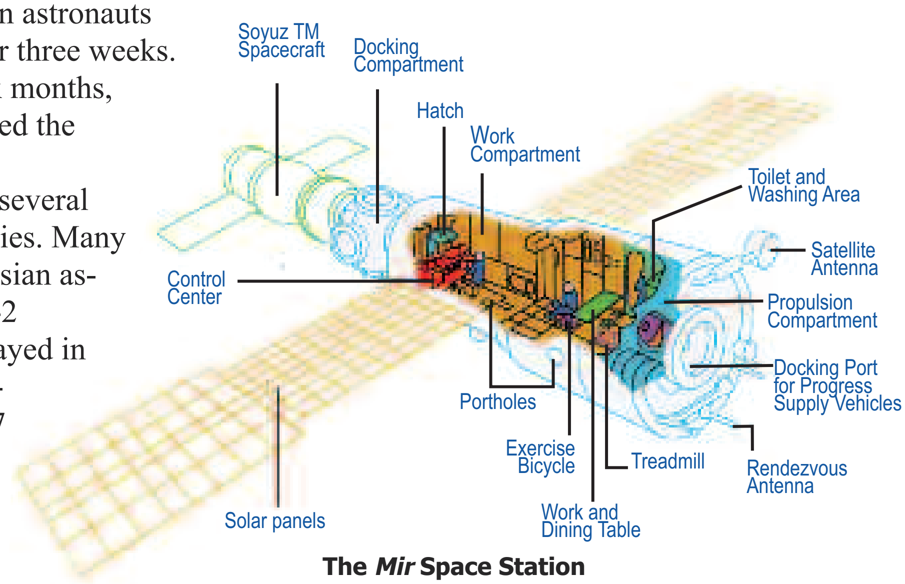
SPACE STATIONS

The idea of a permanent space station has been with us since the beginning of the space race. The benefit of having a way station en route to the Moon or the planets has been recognized for some time. For scientific, research, and even military reasons, a permanent space station has been considered a necessity.

Russia launched the first space station, *Salyut* 1, in April 1971. Russian astronauts docked and stayed on board for three weeks. *Salyut* 1 stayed in space for six months, then burned up when it reentered the Earth's atmosphere.

Russia continued to launch several space stations in the ***Salyut*** series. Many of the missions resulted in Russian astronauts staying in space for 1-2 months. *Salyut* 6 and 7 both stayed in space about four years. The astronauts stayed aboard *Salyut* 7 for a record 234 days.

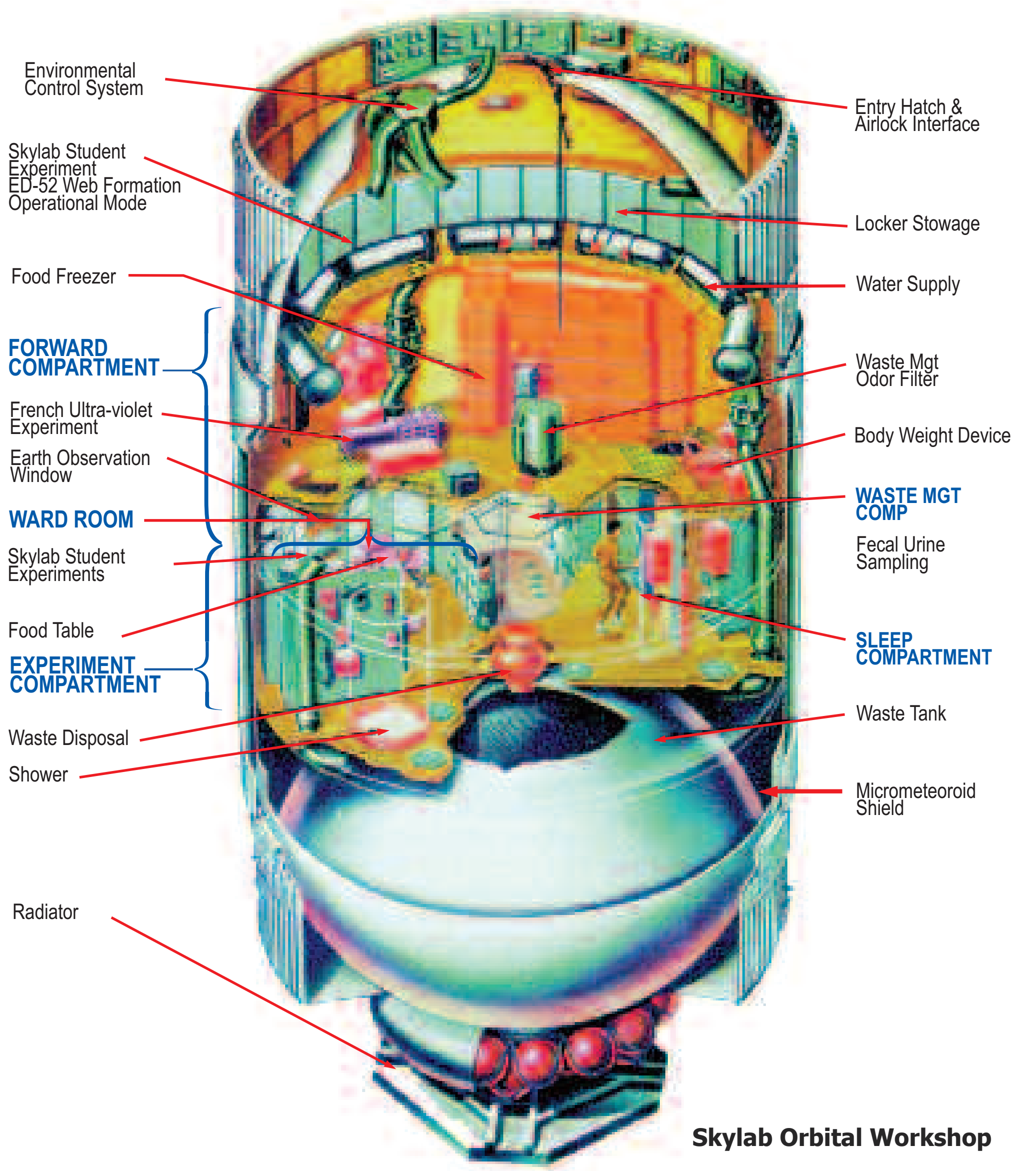
The success of the *Salyut* series brought on the next model of Russian space sta-



The *Mir* Space Station

tion, the ***Mir***. *Mir* was launched in February 1986 and was about the same size as *Salyut.* However, *Mi*r didn't carry as much scientific equipment, so it had more privacy, comfort, and space for the astronauts.

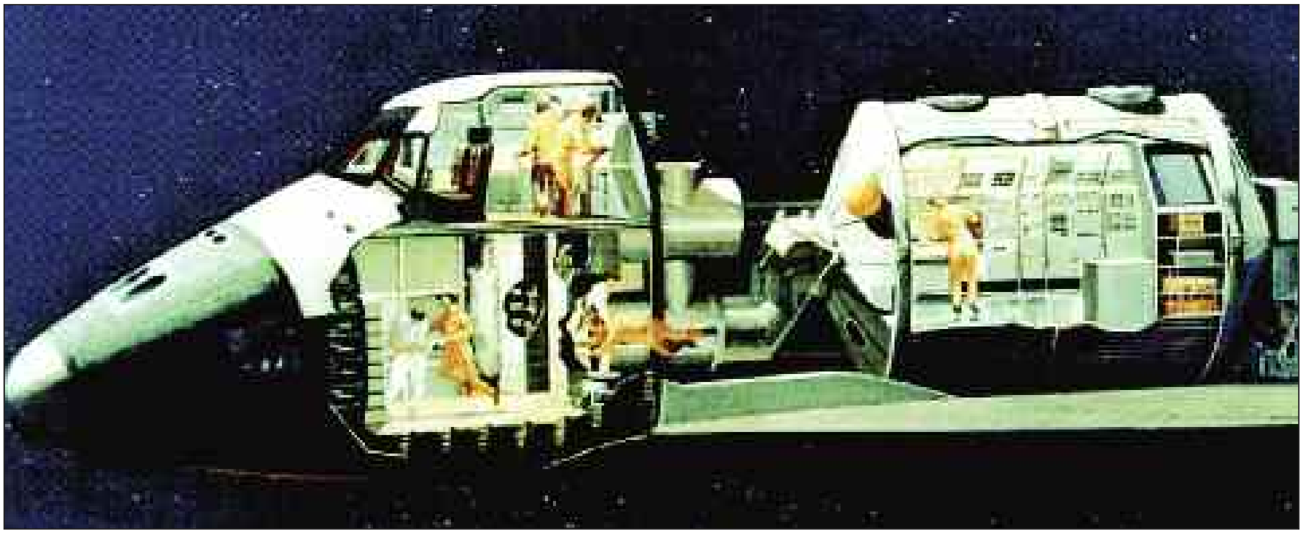
In 1998, *Mir* was frequently in the news. This was due to several malfunctions that were occurring. The United States sent the Space Shuttle to *Mir* several times to help with repairs. In fact, American astronauts spent over two years aboard *Mir* on different missions. *Mir* was scheduled to fall back to Earth in 1999. However, The Russians boosted *Mir* to stay in space longer. So, despite early problems *Mir* remained in space until 2001.



Skylab Orbital Workshop

The first US space station was ***Skylab***. As mentioned earlier, it was launched in May 1973 two years after *Salyut*. Three different crews lived in the *Skylab*. The last crew stayed for 84 days, which was the longest of the crews. During their stays, the crews conducted many experiments. They demonstrated that people could live and work in space. No other crews visited *Skyla*b, but it remained in space for six years before reentering Earth's atmosphere and falling back to Earth. Most of *Skylab* burned up on reentry, but some pieces landed in the Indian Ocean and were recovered.

The European Space Agency developed a "short-term" space station called ***Spacelab***, which was a reusable laboratory used inside the payload bay of a Space Shuttle. ***Spacelab*** was used on over 20 Space Shuttle missions between 1983 and 1998, providing an environment dedicated to scientific research and hands-on experiments.



Spacelab on board the Space Shuttle Columbia

INTERNATIONAL SPACE STATION (ISS)

The ISS is an internationally developed research facility being assembled in low Earth orbit. After several years of planning and preparation, the first mission to assemble the ISS took place in November 1998. The ISS is scheduled for completion in 2011. It is the largest international scientific project in history with sixteen countries contributing to this massive undertaking. The countries involved are: USA, Russia, Japan, Canada, Brazil, and 11 European countries.

The International Space Station on orbit

The purpose of the ISS is to achieve long-term exploration of space and to provide benefits to the people of Earth. Since November 2000, a continual human presence has existed on the ISS. Astronauts began by staying a few days on the ISS and some have now extended that stay to a few months. During this time, hundreds of scientific experiments have been conducted on the ISS. Human research, microgravity, life sciences, physical sciences, and astronomy are a few of the primary fields that have been studied.

The ISS is the largest satellite in space and can be seen from Earth with the naked eye. It orbits the Earth at an altitude that varies from 173 miles (278 km) to 286 miles (460 km) at a speed of

17,227 miles per hour. The ISS constantly loses altitude due to atmospheric drag but is boosted several times a year to regain its higher altitudes. It completes 15.7 orbits in a 24-hour period. You can track the ISS to determine when you can view it as it flies overhead. Go to http://www.spaceflight.nasa.gov/realdata/sightings/ for sighting opportunities.

LIVING AND WORKING ON SPACE STATIONS

What is it like inside a space station? Well, first of all, microgravity or near weightlessness exists inside the ISS. We have probably all seen pictures of astronauts floating around inside of space stations. This is not really a problem. Astronauts have learned how to cope with near weightlessness. They can hold on to the walls, or they can wear special cleats, or they can even strap themselves in if they want.

The air inside the ISS is a mixture of oxygen and nitrogen. This works better than breathing pure oxygen. Also, the temperature is regulated so that the astronauts are comfortable in t-shirts and shorts or sport shirts and pants.

On the *Skylab*, the crews had a dining room, a toilet area, and bedrooms. The astronauts could eat either hot or cold food. They would place their feet and legs in restraints and could actually sit and eat. As for sleeping, the astronauts had sleeping bags placed vertically on the walls. They could fasten themselves in and go to sleep.

Foot restraints

Living on the International Space Station (ISS) is similar to the previous space stations, but also different. First of all, the food has gotten better. Astronauts pick their menus months ahead of time knowing how important their diet is in space. The ISS has a microwave and a refrigerator, so even though dehydrated food is still used, so is frozen food. Drinks and soups are still sipped through plastic bags and straws. Solid food is eaten with a knife and fork on trays with magnets to prevent them from floating away.

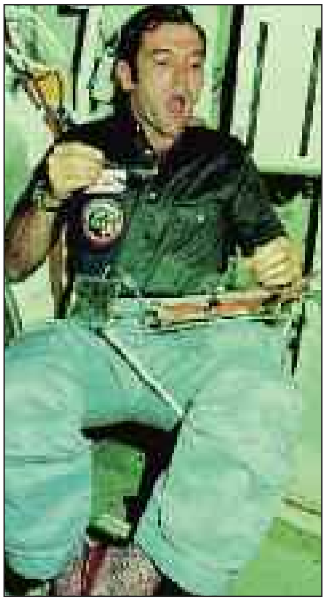
Working is also a part of life inside a space station. Astronauts have their housekeeping chores to perform. Plus, they have their research and experiments to conduct. Sometimes they have satellites to deploy or retrieve, or maybe they have to repair a satellite. Physical activities are a normal daily occurrence on the flights. So, there is plenty to keep the astronauts busy.

Near weightless in space

Near weightlessness causes loss of bone and muscle mass, so exercise is very important to astronauts. To prevent this muscle loss, astronauts exercise daily. The ISS is equipped with two treadmills and a stationary bicycle. Astronauts must strap themselves to the equipment to keep from floating away. The negative effects of near weightlessness reverse quickly once astronauts return to Earth.

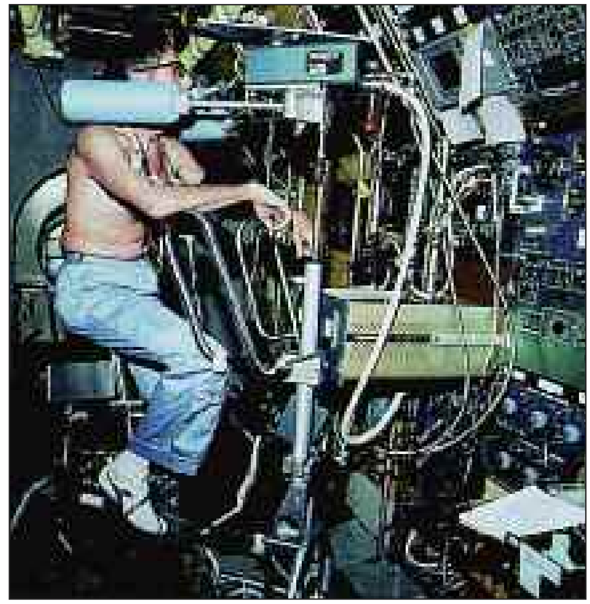
Sleeping in the ISS is similar to earlier space stations. Astronauts still sleep in wall-mounted sleeping bags that zip them into the bag. They also have arm restraints to keep their arms from floating above their head while they sleep.

Astronauts spend most of their waking moments conducting scientific experiments and observations. They are also involved in maintaining the ISS and repairing equipment, as necessary. Generally, the astronauts work for 10 hours during the weekdays and 5 hours on Saturday. The rest of the time they either relax or do catch-up activites. The ISS doesn't have a shower, so the astronauts take sponge baths or clean themselves with washcloths and wet towels. Each astronaut has a personal hygiene kit with toothbrush, toothpaste and shampoo. (See associated Activities Five and Six at the end of the chapter.)



Eating with food strapped to lap

Eating with food strapped to cabin ceiling



Exercising muscles to keep them from wasting away in microgravity

A nice warm shower

A shave

Sally Ride in a sleep restraint

EXTRAVEHICULAR ACTIVITIES (EVA)

These last few paragraphs have discussed life inside a space station. Now, let's spend a little time discussing life outside the space station. Many times a Space Shuttle mission would include repairing a satellite. This involved going outside of the shuttle. The general term used for going outside of the shuttle is Extravehicular Activity.

Russian Alexei Leonov accomplished the first EVA or "space walk" in March 1965. He was outside of his spacecraft for about 20 minutes. Less than three months later, Ed White was the first American to "walk" in space. This occurred in June 1965. White was outside the spacecraft for 22 minutes traveling at 18,000 miles per hour. Since 1965, there have been many EVAs in space.

One recent EVA involved the *Hubble Space Telescope*. Astronauts made repairs to the *Hubble Telescope* during an EVA. These successful repairs will allow the telescope to stay in space longer.

"Spacewalks" have become a very routine part of most of the ISS missions. There have been well over 250 "spacewalks." The longest one occurred in 2001 when the "space walk" of astronauts Susan Helms and Jim Voss lasted for 8 hours and 56 minutes. They were part of the STS-102 *Discovery* crew and despite the numerous "spacewalks" that have occurred since 2001, this record still stands.

SPACE SUITS

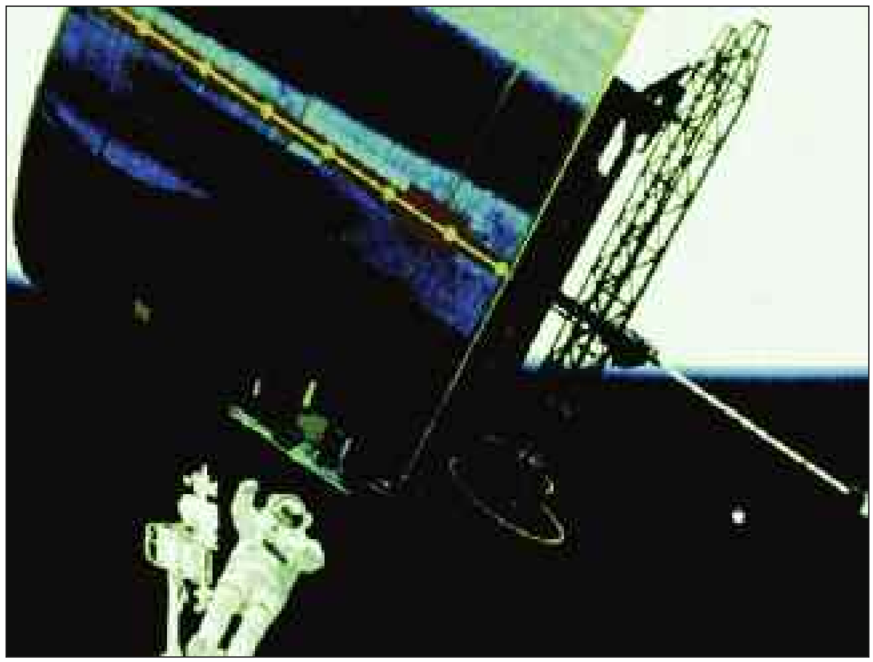
Obviously, a subject that comes to mind when talking about space walks is space suits. Space suits have changed a lot over the years. Let's take a look at the evolution of the space suit. Space suit design began in the 1930s with high-altitude flyers. These suits were really pressure suits. Over the next 30 years, the technology improved. However, the early astronauts of Project Mercury still wore pressure suits.

During the Gemini flights, a lightweight, easily-removable space suit was developed. It was during Gemini 7 that space suits were taken off inside of the spacecraft for the first time. Prior to that, astronauts left them on during the entire flight.

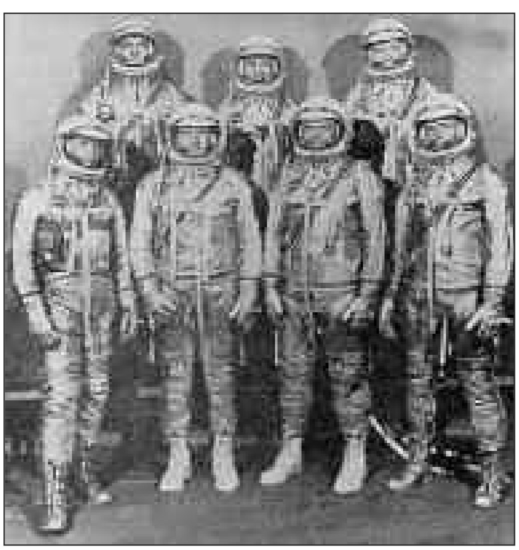
Initially, the space suits were very immobile. It was hard for the astronauts to move around. However, as the space flights progressed and more was expected of the astronauts,

An EVA near *Skylab*

An Atlantis EVA



Taking a look at the Hubble Space Telescope



Pressure suits worn by the seven Mercury astronauts

Lightweight space suits wore by Gemini astronauts

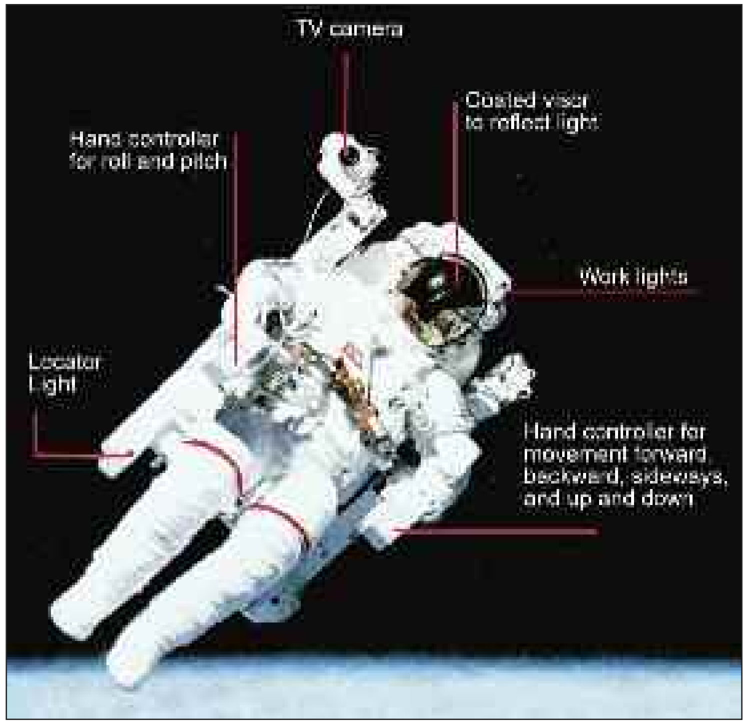
A more advanced suit for moon walking for the Apollo astronauts

the space suits got better. Comfort and mobility became higher priorities.

The Apollo moon suit was more advanced than previous suits. The astronauts carried their oxygen on their backs and could communicate, as well. The suit also had a supply of drinking water and a collection point for going to the bathroom.

All of these space suits consisted of several layers of material. This protected the astronauts during EVAs. For instance, the Apollo suit protected the astronaut in temperatures of over 250° F, while also protecting against harmful radiation.

All of these space suits were made specifically for the individual astronaut. That changed with the Space Shuttle. The shuttle suit was much easier to put on. The astronauts dressed one layer at a time. The shuttle suit was made of several parts that could accommodate a man or a woman. It was also reusable and expected to last for 15 years.



The Manned Maneuvering Unit

In 1984, the astronauts used the Manned Maneuvering Unit (MMU) for the first time. This unit fit on the back of the astronaut's space suit and allowed him or her to move around without being tied to the spacecraft. The MMU was used on three missions, all of which occurred in 1984. After the ***Challenger*** tragedy in 1986, the use of the MMU was discontinued due to safety concerns. An improved version of the MMU, the Simplified Aid for EVA Rescue (SAFER), was first flight-tested during STS-64 in 1994. It was developed for use in case a tethered astronaut performing as EVA became untethered.

As you can see, space suits have come a long way. The improvements in the suits have allowed the astronauts to do much more in space, and do it more efficiently. To see NASA ideas for future spacesuits, "Google" future spacesuits on the internet. You will be amazed at the future technology planned to protect mankind in space. (See associated Activities Seven and Eight at the end of the chapter.)

THE FUTURE IN SPACE

Due to our enduring fascination with space, indications are that space travel will continue into the unforeseeable future. We have come a long way since Russia launched *Sputnik* in 1957, and with each additional mission we seem to learn more and more. In many people's minds, this increased knowledge justifies a persistent, progressive space program.

For almost the last 30 years, the United States' Space Transportation System (STS), has been the primary mode of space transportation. The Space Shuttle is scheduled to retire in 2011. What will replace it? As of the preparation of this module the answer is unclear. Indications are that the International Space Station (ISS) will remain in space until at least 2020. So, it's easy to assume trips will be made to the ISS. Russia and the United States are seeking more cooperation in space travel, and using a Russian space shuttle to take American astronauts to the ISS is being considered.

In 1999, the *X*-37 Orbital Test Vehicle began as a NASA project and was transferred to the US Department of Defense in 2004. The *X-37's* first test flight was in 2006 at Edwards Air Force Base, California, and then its first orbital flight was in April 2010 using an Atlas V rocket. Its successful return to earth resulted in two more missions, one in 2011 and another in 2012.

In 2006, the US Air Force announced it would develop its own version of the *X-37.* They called it the *X-37B* Orbital Test Vehicle (OTV), and it was designed to remain in orbit for up to 270 days at a time. The OTV-1 was launched in 2010 and placed in low Earth orbit for testing. It circled the Earth every 90 minutes on an orbit of from 249 to 262 miles above Earth. In December 2010, the OTV-1 landed at Vandenberg AFB, CA, after 224 days in space, becoming America's first autonomous orbital landing onto a runway. OTV-2 and OTV-3 missions have continued with efforts to test new space technologies. The missions have been classified.


Credit: NASA/Marshall

The X-37 in the clouds

NASA has looked beyond 2020 and has envisioned something like the *Spaceliner*. This vehicle would take off like a plane, most likely on a rail system, and be powered by air-breathing rockets and ramjets. The Spaceliner is being designed to take about 50 passangers to 47-50 miles above Earth and then glide back to Earth at hypersonic speeds of more than 15,000 mph. This would enable passengers to fly from Europe to Australia in 90 minutes. The Spaceliner is aiming to fly passengers by 2050. This is one idea, but the technological challenges are daunting and funding must be available. Regardless, if space travel continues, it is the goal to make it cheaper, safer, and more reliable.

Another distinct possibility is commercial space travel. Virgin Galactic and Scaled Composites are working together to make commercial space travel a reality. Scaled Composites is the company that in 2004 won the $10 million X-Prize for flying at a altitude of 62 miles or 100 kilometers, returning safely to Earth, and then repeating the flight within two weeks. The spacecraft was called *SpaceShipOne*. Now, the two companies are building a spacecraft called *SpaceShipTwo* that will take passengers into space. Initially, tickets can be purchased for $200,000. The spacecraft is designed to seat six passengers and two pilots and fly to about 68 miles, or 110 kilometers. The passengers will experience a 2 ½ hour flight with several minutes of near weightlessness. Already, countries are placing orders for the *SpaceShipTwo*. After about 50-100 test flights, *SpaceShipTwo* is expected to take passengers in 2014.

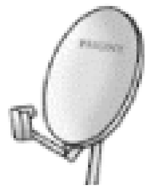
Regardless of the direction it takes, the United States will probably stay heavily involved in space for many years. Additionally, Russia has announced a renewed interest in space, and China is coming on strong and wants to increase its involvement. China has even expressed interest in placing a person on the Moon. So, with these and other countries involved, the exploration of space should remain an important issue for the world for many years.

Future Transatmospheric Aircraft

SPINOFFS FROM THE SPACE PROGRAM –
Putting Space Technology To Work Back On Earth

Our day-to-day lives have been touched by many space technologies. It has been recorded that since the mid-seventies, over 1,600 documented NASA inventions have benefitted our quality of life and has provided Americans with a large number of jobs.

Many have heard that Tang, Velcro, and microcomputers were all spinoffs of space technology. Actually, this is not the case; however, there have been some achievements that are very commonplace in our daily lives. A few examples, put into an easy-to-understand form are:

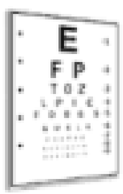


TV Satellite Dish

NASA developed ways to correct errors in the signals coming from satellites. This technology is used to reduce noise (that is, interference to picture or sound) in TV signals coming from satellites.

Medical Imaging

NASA developed ways to process signals from spacecraft to produce clearer images. (See more on digital information and how spacecraft send images from space on the internet.) This technology also makes possible these photo-like images of the inside of the human body.



Vision Screening System

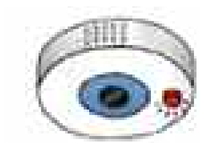
This uses techniques developed for processing space pictures to examine eyes of children and find out quickly if they have any vision problems. The child doesn't have to say a word!

Ear Thermometer

Instead of measuring temperature using a column of mercury (which expands as it heats up), this thermometer has a lens-like a camera and detects infrared energy, which we feel as heat. The warmer something is (like your body), the more infrared energy it puts out. This technology was originally developed to detect the birth of stars.

Fire Fighter Equipment

Fire fighters wear suits made of fire-resistant fabric developed for use in space suits.



Smoke Detector

This was first used in the Earth orbiting space station called *Skylab* (launched back in 1973) to help detect any toxic vapors. It is now used in most homes and other buildings to warn people of fire.

Sun Tiger Glasses

This comes from research done on materials to protect the eyes of welders working on spacecraft. Protective lenses were developed that block almost all the wavelengths of radiation that might harm the eyes, while letting through all the useful wavelengths that let us see.

Automobile Design Tools

This is a computer program developed by NASA to analyze a spacecraft or airplane design and predict how parts will perform. It is now used to help design automobiles. This kind of software can save car makers a lot of money by letting them see how well a design will work even before they build a prototype.

Cordless Tools

Portable, self-contained power tools were originally developed to help Apollo astronauts drill for moon samples. This technology has led to the development of such tools as the cordless vacuum cleaner, power drill, shrub trimmers, and grass shears.

Aerodynamic Bicycle Wheel

A special bike wheel uses NASA research in airfoils (wings) and design software developed for the space program. The three spokes on the wheel act like wings, making the bicycle very efficient for racing. Surprisingly, this technology has also helped in the design of more aerodynamic bicycle helmets.

Thermal Gloves and Boots

These gloves and boots have heating elements that run on rechargeable batteries worn on the inside wrist of the gloves or embedded in the sole of the ski boot. This technology was adapted from a spacesuit designed for the Apollo astronauts.

Space Pens

The Fisher Space Pen was developed for use in space. Most pens depend on gravity to make the ink flow into the ball point. For this space pen, the ink cartridge contains pressured gas to push the ink toward the ball point. That means you can lie in bed and write upside down with this pen. Also, it uses a special ink that works in very hot and very cold environments.

The Most Famous Spinoff

Football helmets use a padding of Temper Foam, a shock absorbing material, that was first developed for use in aircraft seats. It is the most recognized and widely-used NASA spinoff. Temper Foam, whose origin dates back to 1966, was developed to absorb shock and offer improved protection and comfort in NASA's airplane seats. It has paid its dividends to Earth repeatedly, and in many different ways. It has padded the helmets of the Dallas Cowboys throughout the 1970s and 1980s, protected bedridden patients from bedsores, and comforted the feet of thousands wearing stylish shoes that incorporate the cushioning material in their insoles.

Four decades later, the world has come to realize that there are no bounds to Temper Foam's benefits. Though the rights to the technology have been shared amongst various manufacturers, the original product maker is still going strong, pushing Temper Foam into new arenas, including automotives, amusement parks, prosthetics, sleep items, and modern art.

Ski Boots

These ski boots use accordion-like folds, similar to the design of space suits, to allow the boot to flex without distortion, yet still give support and control for precision skiing.

Failsafe Flashlight

This flashlight uses NASA's concept of system redundancy, which means always having a backup for the parts of the spacecraft with the most important jobs. This flashlight has an extra-bright primary bulb and an independent backup system that has its own separate lithium battery (also a NASA developed technology) and its own bulb.

Invisible Braces

These teeth-straightening braces use brackets that are made of a nearly invisible translucent (almost clear) ceramic material. This material is a spin-off of NASA's advanced ceramic research to develop new, tougher materials for spacecraft and aircraft.

Edible Toothpaste

This is a special foamless toothpaste developed for the astronauts to use in space (where spitting is not a very good idea).

Joystick Controllers

Joystick controllers are used for lots of things now, including computer games and vehicles for people with disabilities. These devices evolved from research to develop a controller for the Apollo Lunar Rover, and from other NASA research into how humans actually operate (called "human factors").

Advanced Plastics

Spacecraft and other electronics need very special, low-cost materials as the base for printed circuits (like those inside your computer). Some of these "liquid crystal polymers" have turned out to be very good, low-cost materials for making containers for foods and beverages.

Spinoff technology has had a large impact within the field of medicine. Thousands of lives have been saved with the development of procedures and machines such as:

1. A NASA-developed chemical process was responsible for the development of kidney dialysis machines.
2. The need to find imperfections in aerospace structures and components, such as castings, rocket motors, and nozzles, led to the development of a medical CAT scanner which searches the human body for tumors or other abnormalities. CAT stands for Computer Tomography Scan.
3. It is well known that the near weightlessness experienced while living in space can lead to physical deterioration, cardiovascular problems, and muscle atrophy. A space exercise machine led to the development of a physical therapy and athletic development machine used by football teams, sports clinics, and medical rehabilitation centers.
4. A hospital food service system employs a cook/chill concept for serving food. The system allows staff to prepare food well in advance, maintain heat, visual appeal, and nutritional value, while reducing operating costs.

Because of budget changes and the amount of funding available to space exploration, it is difficult to predict what the future will be in aerospace technology. However, we, as Americans, can say that our space adventure over the past 50 years has been of great benefit to all mankind.

3 ACTIVITY SECTION

Activity Five - Investigating Near Weightlessness

Purpose: This activity will use the scientific method and inquiry to experiment with the concept of near weightlessness.

Materials: ping-pong ball, golf ball, plastic Dixie cup, round wooden bead or a metal nut, and a piece of string

Procedure:

1. Cut the string into two pieces, one long and one short.
2. Attach the longer piece to the rim of the plastic cup like a pail handle.
3. Attach the wooden bead or metal nut to one end of the shorter piece by tying a knot at the end to hold the bead on the string.
4. Start with the ping-pong ball and the golf ball. Hold one ball in each hand. From the same height and at the same time, drop the two balls. Observe the results.
5. Set the plastic cup on a table.
6. Hold the string with the bead at the end over the cup. Let go of the string and observe. What happens?
7. Now carefully stand on a chair or stool. Hold the string handle of the cup. Hold the end of the bead string in the same hand, with the string in the middle of the handle so the bead hangs over the cup.
8. Hold the cup and the ball high and drop them together. What happens this time?
9. Discuss as a group what was expected to happen and what actually happened for each action.

Summary: Galileo (1564-1642) was a scientist who achieved many accomplishments in the fields of astronomy and physics. Galileo was the person who discovered that all objects fall at a constant rate of speed on Earth, no matter what their size or weight. Due to Galileo's experiments, today we have an accurate picture of how the near "weightlessness" in space works. Near weightlessness occurs when two objects (the bead and the cup) are free-falling in gravity. But what keeps the Space Shuttle from free falling to the Earth like the cup and the bead? A spacecraft can maintain its free fall for a very long period of time by traveling fast enough -- about 7.5 kilometers (4.7 miles) per second — horizontally, so that even though it is being pulled toward the center of the earth, its free-fall path is parallel to the earth's curvature. In other words, the spacecraft continually falls all the way around the earth. This microgravity or sensation of weightlessness refers to an environment in which the local effects of gravity have virtually been eliminated by free-fall.

Activity Six - How Does Motion Cause Disorientation?

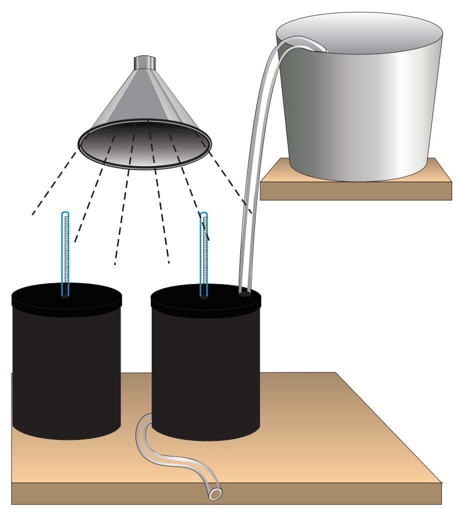
Purpose: This activity will demonstrate how our senses help orient us in space and how motion causes disorientation.

Materials: swivel chair, blindfold, pencil, and a friend

Procedure:
1. Ask a friend to sit in a swivel chair and put on a blindfold. The friend places arms out in front of the body, holding a pencil in an upright position.
2. Ask your friend to point the pencil in the direction of rotation as you turn the chair. Slowly stop the chair. Then turn the chair in the opposite direction. Watch the pencil.
3. Stop the chair. Watch the pencil. In what direction did your friend point the pencil after the first rotation? When the chair was stopped? After the second rotation? Discuss how our senses help orient us in space.

Summary: The results of this activity are that motion causes disorientation and sight is one of our senses that help us stay oriented. In space, there is a disorientation resulting from the conflict between the signals coming from the vestibular system (consisting of the semicircular canals and the special organs of the inner ear), which no longer correspond with the visual and other sensory information sent to the brain and the new spatial reality. The normal concepts of "up" and "down" no longer apply. This same disorientation is demonstrated in the activity because of the blindfold and the spinning of the chair.

Activity Seven - Keeping Cool



Purpose: This activity will demonstrate how a spacesuit liquid cooling system works to moderate body heat.

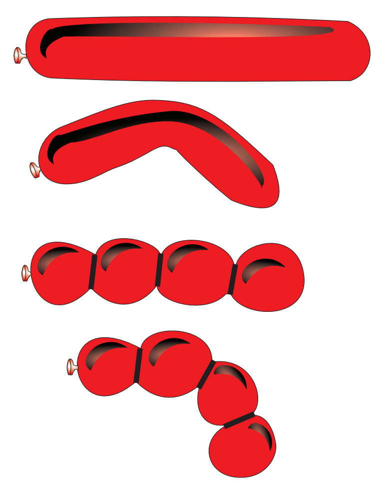
Materials: 2 empty coffee cans with plastic snap-on lids, 2 thermometers (must be able to read a full range of temperatures from freezing to boiling), black spray paint, floodlight and light fixture, plastic aquarium tubing (6 meters), masking tape, 2 buckets, ice, water, stopwatch or watch with a second hand, graph paper, and metal punch or drill

Procedure:
1. Spray paint the outside of both cans black and permit them to dry.
2. Punch a hole in the center of each lid and insert a thermometer.
3. Punch a second hole in one of the lids large enough to admit the aquarium tubing. Also punch a hole in the side of that can near its base.
4. Form a spiral coil with the plastic tubing along the inside wall of the can with the hole punched in its side. Be sure that the coil doesn't touch the thermometer directly. Do not pinch the tube. Extend the tube's ends out of the can, one through the hole in the can and the other through the hole in the lid. The upper end of tube should reach into the elevated water bucket and the other should hang down from the side of the can toward the lower bucket.

5. Set up the floodlight so that it will shine on the sides of the two cans. Make sure the light is equidistant from the two cans.
6. Fill one bucket with ice and water. Make sure there is enough ice to chill the water thoroughly.
7. Elevate the ice water bucket on a box or some books next to the can with the tubing.
8. Insert the long end of the aquarium tubing into the bottom of the ice water bucket. Using your mouth, suck air from the other end of the tube to start a siphoning action. Permit the water to drain through the tubing that runs through the black can into a second bucket on the floor.
9. Immediately turn on the floodlight so that both cans are equally heated.
10. Begin recording temperatures, starting with an initial reading of each thermometer just before the light is turned on and every 30 seconds thereafter until the water runs out.
11. Plot the temperature data on graph paper, using a solid line for the can that held the ice water and a dashed line for the other can. Construct the graph so that the temperature data are along the Y (vertical) axis and the time data along the X (horizontal) axis.
12. Compare the slope of the plots for the two cans.

Summary: In spacesuit design, one of the challenges is to maintain a comfortable temperature inside the suit when the temperatures in space are so extreme. This activity demonstrates how chilled water can keep a metal can from heating up even when exposed to the strong light of a floodlight. An astronaut's body heat, released from exertion during extravehicular activities, can quickly build up inside a space suit, leading to heat exhaustion. Body heat is controlled by a liquid cooling garment made from stretchable spandex fabric and laced with small diameter plastic tubes that carry chilled water. The water is circulated around the body. Excess body heat is absorbed into the water and carried away to the suit's backpack, where it runs along a porous metal plate that permits some of it to escape into outer space. The water instantly freezes on the outside of the plate and seals the pores. More water circulates along the back of the plate. Heat in the water is conducted through the metal to melt the ice directly into water vapor. During the process, the circulating water is chilled.

Activity Eight - Bending Under Pressure



Purpose: This activity simulates the mobility of a spacesuit arm.

Materials: 2 long balloons, 3 plastic bracelets or thick rubber bands

Procedure:
1. Inflate one balloon fully and tie it.
2. Inflate the second balloon, but while it is inflating, slide the bracelets or bands over the balloon so that the balloon looks like sausage links.
3. Compare the "bendability" of the two balloons.

Summary: Maintaining proper pressure inside a spacesuit is essential for survival. However, pressure produces problems. An inflated spacesuit is hard to bend. Designers have learned to strategically place breaking points at appropriate places to make the suit bend more. In this activity, the rings serve as the breaking points. These rings create joints. Further spacesuit research has shown that built-in ribs, like a clothes dryer or vacuum cleaner hose, promote easier bending.