Chapter 26 UNMANNED EXPLORATION

At the end of World War II, the team of German V-2 rocket experts (led by Dr. Wernher von Braun) surrendered to American troops to avoid being captured by Russian troops. The United States seized a V-2 assembly plant and 100 partially assembled V-2 rockets. These events formed the nucleus of US rocket research during the late 1940s and early 1950s, and marked the beginning of the "space race" between the United States and the Soviet Union.

Objectives

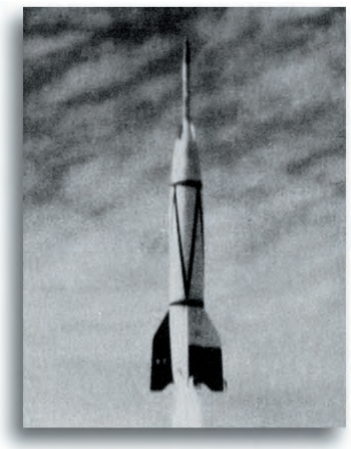
Discuss America's early space efforts.
Discuss the Soviet Union's early space efforts.
Describe America's reaction to the Soviet launch of *Sputnik* 1 in October 1957.
State one of the biggest reasons for the space race between the United States and the Soviet Union.
Discuss the establishment of the National Aeronautics and Space Administration.
Describe the sources of space law.
Describe the significance of *Sputnik* to space law.
Describe the three principles of space law.
Identify two significant provisions of the 1967 Outer Space Treaty.
Explain the significance of the 1972 Anti-Ballistic Missile Treaty of space operations.
Explain the significance of the National Aeronautics and Space Act.
Explain the significance of the Commercial Space Launch Act.
Explain the significance of the Land Remote Sensing Commercialization Act.
Describe the function of the International Telecommunications Union.
Describe the 1976 Bogota Declaration.
Describe the International Space Station Agreement.
Identify three issues addressed by the International Space Station Agreement.
Define a satellite.
Identify four categories of satellites.
Identify uses of communications satellites.
Define an active communications satellite.
Define a passive communications satellite.
Describe the purpose of the Global Positioning System (GPS).
Describe the elements required for global positioning.
Identify GPS uses.
Identify three types of observation satellites.
Match examples of data to the satellite type most likely to observe and record it.
Identify examples of weather satellites.
Identify examples of multi-spectrum imaging satellites.

Objectives *(continued)*

Identify four types of reconnaissance satellites.
Identify two purposes of scientific satellites.
Describe the *Explorer* Satellite Program.
Identify the contributions of the *Orbiting Astronomical Observatory* and the *High-Energy Observatory.*
Explain the missions of the *Dynamic Explorers* and the *Solar Mesosphere Explorers*.
Explain the purpose of the *Infrared Astronomy Satellite*.
Explain the purpose of *X-ray Timing Explorer.*
Describe the *Hubble Space Telescope* Program.
Define a probe.
Identify examples of fly-by and landing-type probes.
Describe the purpose of the *Ranger* probes.
Explain how the *Surveyor* probes helped the *Apollo* Program.
Identify the planet that the *Mariner*, *Pioneer*, *Viking* and *Voyager* probes investigated.
Describe the *Mars Pathfinder* and *Mars Surveyor* missions.
Rovers, Spirit and opportunity launch

The Space Race Begins

The US Army assembled a team of scientists and engineers at the White Sands Proving Ground, New Mexico, in 1946 for the purpose of conducting scientific research on the upper atmosphere. This effort was a joint program involving the Army, Naval Research Laboratory, Air Force, General Electric Company, and several universities and scientific institutions. Beginning in 1949, a second-stage rocket named the WAC Corporal was added to the V-2.



WAC Corporal Rocket Atop a V-2 Rocket

Beginning in the 1950s, the different branches of the military began going their separate ways in rocket research. The Naval Research Laboratory contracted with the Martin Company to build an improved V-2 called the Viking. They also contracted with Johns Hopkins University to build a research rocket called the Aerobee. In 1951, both were launched successfully. The Viking reached an altitude of 136 miles, and the Aerobee flew to 80 miles altitude.

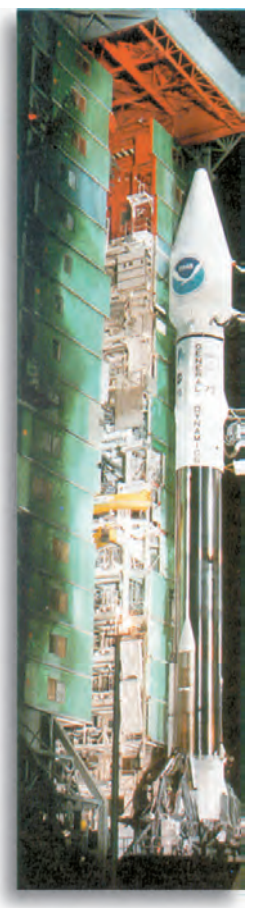
The Army moved Dr. von Braun's team to Redstone Arsenal in Huntsville, Alabama, in 1950. The Army viewed rockets as an extension of its artillery, so they gave the von Braun team the job of developing a liquid-fuel, battlefield missile based on the *V*-2. The result

was the Redstone missile, which was first flown in August of 1953. The Redstone had a 200-mile range and reached a speed of 3,300 mph.

Werner von Braun

In 1946, the Air Force began research on the first intercontinental ballistic missile (ICBM). The project had to be canceled in 1947 due to a lack of money. From 1947 to 1951, the Air Force did not have an active ICBM Program. Shortly thereafter, two major occurences changed the national priorities and money became available to restart the Air Force ICBM Program.

The Redstone Missile



The Atlas

First, in 1949, the Soviet Union exploded its first atom bomb, and the United States lost its nuclear monopoly. Second, in 1950, the Korean War started. In 1951, the Air Force gave a new contract to Convair to build an ICBM. They called the missile the Atlas.

In 1953, scientists developed a way to build nuclear warheads small enough to be mounted on missiles. In 1954, based on studies from the Rand Corporation and the Air Force Strategic Missile Evaluation Committee, the Atlas Missile Program was the Air Force's highest priority. The missile became operational on September 1, 1959.

By 1955, the Navy perfected the Viking and the Aerobee, the Army had a successful Redstone, and the Air Force was beginning production of the Atlas. In August 1955, President Dwight D. Eisenhower announced that the United States would place several small satellites into orbit during the International Geophysical Year (IGY), which started on July 1, 1957. This project was called Vanguard.

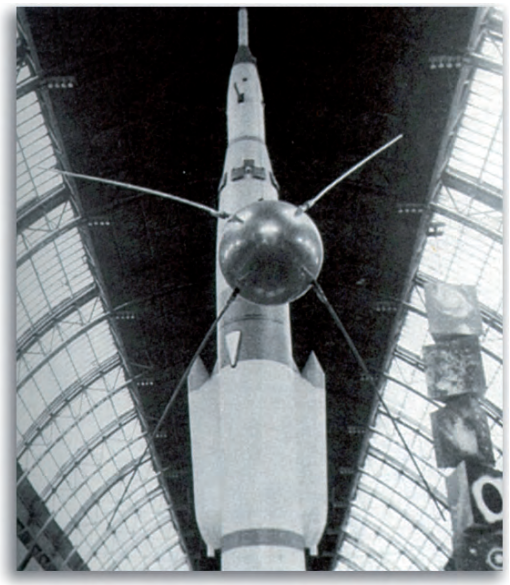
At this time, the United States had two vehicles able to put a satellite into orbit. One was the Navy Viking (with an Aerobee second stage and a solid-fuel third stage) and the other was the Army's Redstone (with an upper stage). The Navy's entry was selected in 1955 to launch the Vanguard satellite.

Soviet Union Efforts

As for the Soviets, they also had captured partially built German V-2 rockets at the end of the war. However, as mentioned earlier, von Braun and his team had escaped to the United States. The Soviet

Union captured only a handful of German engineers and hundreds of technicians. The Soviets also got a list of the manufacturers who supplied the parts for the V-2 and, from these manufacturers, the Soviets obtained enough parts to build a few of the rockets.

The Soviet Union also began upper atmosphere research using captured V-2s. Because they had so few, they had to begin building their own much sooner than the United States. In 1949, the Soviets developed an improved V-2 called the T-1 and in 1954, they started working on a large multistage rocket.

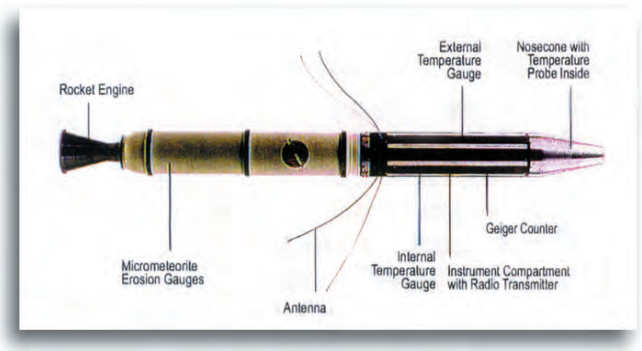


The *Sputnik* 1 Suspended in a Soviet Museum.

In a 1956 speech, Premier Nikita Khrushchev stated the Soviet Union had developed an ICBM and would soon have missiles with nuclear warheads. In August 1957, the Soviet Union successfully test-launched its ICBM and on October 4, 1957, using the same rocket, they launched *Sputnik* 1, the world's first artificial satellite. On November 3, they launched Sputnik 2, which carried a dog named Laika. The Soviets were winning the race into space.

American Reaction

The reaction in the United States was immediate. The Senate began an investigation, and the White House announced that the Navy was preparing for the *Vanguard* 1 launch at Cape Canaveral. In reality, the Navy was preparing for a test launch of the Viking/Aerobee rocket and was not ready to launch *Vanguard* 1. On December 6, 1957, when the Navy made its test launch, the *Vanguard's* first stage exploded, and the whole world saw America's disasterous entry into the space age via television.



Explorer 1

In November 1957, the Secretary of Defense revised the Army's Redstone proposal and advised Dr. von Braun to prepare to launch as soon as possible. The Army had a Redstone with a solid-fuel upper stage, which it had been working on as a test rocket (renamed Jupiter C) to study some of the problems of reentry heating. The Army placed the satellite developed for Vanguard atop this Jupiter C and successfully launched *Explorer* 1. This was America's first satellite. The date was January 31, 1958.

The Space Age

The Soviet Union entered the space race first because it had developed a rocket large enough and powerful enough to place very heavy objects into orbit. For example, *Explorer* 1 weighed 31 pounds

while the Soviet's *Sputnik* 2 weighed 2,926 pounds. Eventually, the large rockets would prove to be the Soviets undoing, because they were not forced to develop the miniature electronics and other lightweight materials that the United States was forced to produce. When America finally caught up with the Soviet Union in large rockets, the United States was far ahead in the amount of equipment that could be taken to the moon or into space with a single rocket.

This space race was occuring during the Cold War between the United States and the Soviets. One of the biggest reasons for the space race was international prestige. The ability to put satellites into space was impressive, but even better was manned space flight.

NASA Established

As mentioned earlier, the Soviet Union launched *Sputnik* 2 on November 3, 1957, with a dog aboard. This was a clear indication that the Soviet Union's goal was to place people into space. The launch of *Sputnik* 3, 6 months later, demon-strated they had the booster power to do it.

This knowledge prompted a reevaluation of America's national priorities in the area of scientific research and lead-ers in the United States began looking for an agency to head up a space exploration program.

The military services had different ideas about what the priorities should be in space research. Their primary responsibility was the defense of the United States. This led to a final decision that a space exploration program be headed by a new civilian agency.

On July 29, 1958, President Eisenhower signed the National Aeronautics and Space Act into law, creating the National Aeronautics and Space Administration (NASA). NASA was established as the agency to lead America's civilian space program, while the Department of Defense retained responsibility for space projects necessary for national security. The 8,000 employees of the National Advisory Committee for Aeronautics became employees of NASA on October 1, 1958.

Space Law

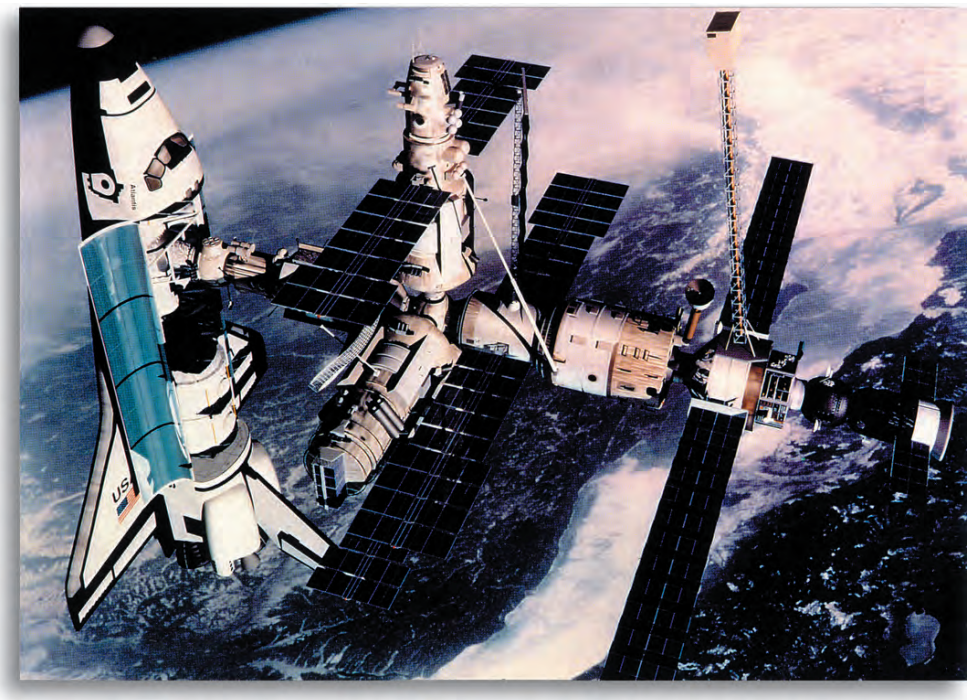
Space by its very nature is an international concern. Virtually all nations have an interest in space. However, only a few nations have the technological means to exploit space. What protects the interest of those that do not? How are conflicts resolved between those that do? International law provides broad guidelines for dealing with these conflicts. International law is drawn from several sources. Some of those are more powerful than others.

The most powerful source of international law is treaties. These are written agreements that are legally binding on those who sign them. Penalties for breaking them are often spelled out in detail. They may be bilateral or multinational. Bilateral means the agreement is between two nations. Multinational treaties are generally more powerful because they involve many nations. Most space treaties are multinational.

When disputes arise between nations they often refer them to an international court, such as the International Court of Justice. Unfortunately, there is no effective enforcement of these decisions. They are only binding if the nations involved agree to abide by the court's findings. Nevertheless, these decisions made by international courts are a second, important source of international law.

Along the same lines as international courts, the legal opinions of noted scholars and respected authorities are another source of international law. These opinions, called opinio juris, may be based on previous court cases. When there is no related case law, the opinio juris is simply the consensus opinion of the experts in the field. As with international court decisions, there is no method of enforcement. Because opinio juris lacks the formality of a court, it is a less powerful source of international law.

The least powerful source of international law is sometimes the most effective. This source is customs. Customs are those practices accepted by nations as the right way to act. They are rarely written down. They are also rarely violated. Sometimes they are based on tradition or long-standing practice. Sometimes they are simply based on common sense. Customs can slowly occur over time or they can occur quickly.



Space Shuttle Docking with Russian *Mir Space Station*

The launch of the first Russian satellite, *Sputnik*, is an example. *Sputnik's* first orbit established a very important new custom. It established the right of satellites to fly over countries without permission. This right to freely fly over nations is reflected in the first principle of space law.

There are three principles of space law that appear in both national and international space laws. Sometimes the principles are spelled out exactly. Sometimes they are only implied. The first of these principles is freedom of use. It is the idea that all nations should have access to space. Thus, no nation should be allowed to prevent another from gaining access.

The second principle concerns ownership. It is called non-appropriation. The idea is that no one owns any part of space. Appropriation of space by anyone would preclude freedom of use by all.

The third principle is that of common interests. It concerns the use of space. Since space belongs to all mankind, all nations should share its benefits. This vague notion is found in many United Nations (UN) resolutions. In reality all nations do benefit from the many common uses of space. Examples include navigational aids, communications, geological data and weather information.

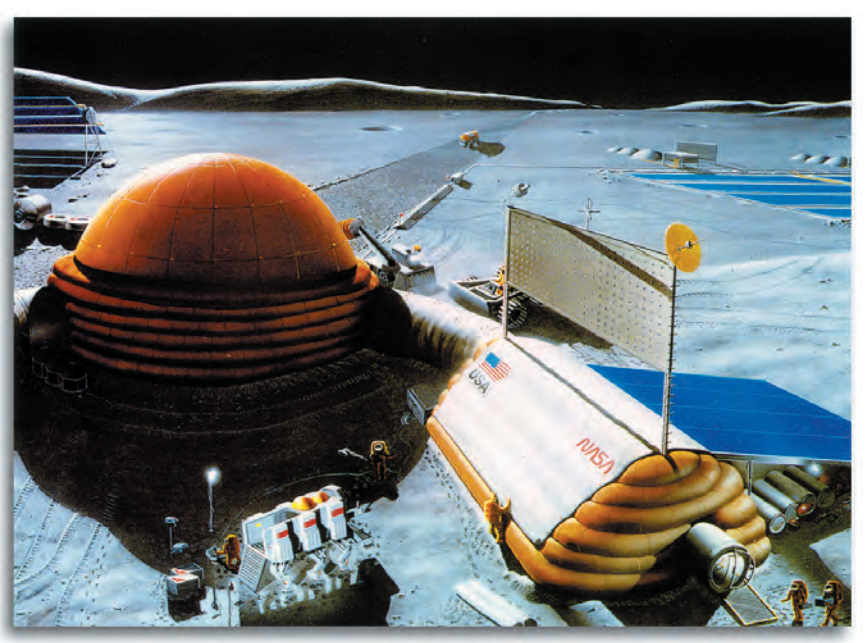
Treaties

As we just discussed, treaties are an important source of space law. Over the past several decades, space operations have grown enormously. In the early years, basically, only two nations, the United States and Russia, were involved. Today, virtually the entire world is involved in space activities. As the activities in space increased, the need for regulations to avoid conflicts increased. Many treaties were made to meet this need. We'll look at the ones that continue to have a major impact on space activities. Some of these are between parties that no longer exist. For example, bilateral arms control agreements between the United States and the former USSR remain in force.

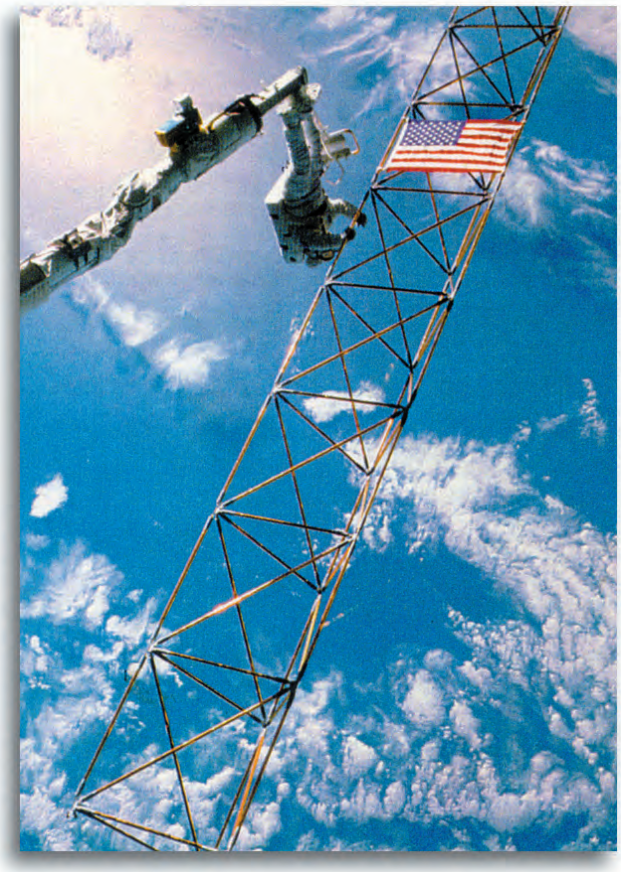
Outer Space Treaty

The first treaty we'll look at is one of the most significant; called simply the 1967 Outer Space Treaty. Its full title is " The Treaty on the Principles of the Activity of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies." In the midst of the space race between the United States and the Soviet Union, both countries sought a politically acceptable way to regulate space activities. The treaty grew out of a series of conferences on space activities and UN resolutions. The UN General Assembly approved it in 1966. It went into force in 1967. Approval was unanimous. Over ninety nations agreed to abide by it.

Many important issues were addressed in the Outer Space Treaty. It established the principle of freedom of use and called space the "province of all mankind." It also stated that exploration of space should benefit all countries.



Proposed Lunar Outpost



Astronaut acknowledging that the United States of America has been there.

Other issues it addressed were emergencies and accidents. It referred to astronauts as "envoys of mankind." It further stated those landing in foreign territories were to be treated as such and returned to their home nation. Nations, and not the organizations, that launched objects were held responsible for damage from accidents and returning objects. It stated that space would be used "exclusively for peaceful purposes," but allowed military personnel to conduct scientific research.

While many of the provisions in the Outer Space Treaty remain important, two merit special emphasis. First, the treaty documents the three principles of space law in written form. Secondly, it legitimizes a military presence in space.

ABM Treaty

The Outer Space Treaty provided for only peaceful use of space. Intercontinental Ballistic Missiles (ICBMs) threatened to breach this provision. Systems for destroying missiles before they reached their targets were proposed. It was thought these systems might make nuclear war more likely. As long as everyone knew both sides would be destroyed in a war, no one would attack. Anti-Ballistic Missile (ABM) systems offered a potential defense against attack.

The treaty on the limitation of Anti-Ballistic Missile systems was signed on May 26, 1972. Both the US and the USSR agreed not to develop or test ABM systems. This included space-based systems. However, the ABM Treaty is not significant to space operations because of what it prohibited. Military systems were already prohibited. It is important because it specifies monitoring treaty compliance from space. It sanctioned monitoring other countries from space. Thus, while *Sputnik* established the right to fly over a country without permission, the ABM Treaty establishes the right to gather treaty compliance information while doing it.

National Space Law

In addition to international law, space operations must also comply with national laws. United States' space law is only binding on US nationals and US organizations. It addresses many issues such as safety and liability. However, much of it is concerned with easing commercial entry into space. This is where we'll focus our attention now.

National Aeronautics and Space Act (NASA Act)

The NASA Act was the first effort to regulate space in the United States. It was signed into law in 1958. Best known for founding the National Aeronautics and Space Administration, it is the legal basis for military and civil space activities. It defines civil and military responsibilities, and provides a process for coordination between the two.

Commercial Space Launch Act (CSLA)

The purpose of the CSLA was to promote private sector activity and investment in space. It sought to create a single agency to regulate commercial space. NASA was not considered because they were in direct competition with commercial interests. The Department of Transportation (DOT) was designated the lead agency. The Office of Commercial Space Transportation was created within DOT to manage the effort.

Under CSLA, any US citizen or organization must be licensed to conduct space operations. The payload launch vehicle, and launch facility must all be licensed. The license is required even if the launch occurs in another country. During the process, the mission and safety are reviewed. The mission review ensures the payload and purpose are consistent with national policy. Applicants must also show proof of insurance before a license is granted.

The most important part of the act concerns the use of military launch facilities. CSLA authorizes the military to provide facilities and support for commercial launches. The launch company must only pay for the cost of the service. The military pays for maintaining the facilities. It saves commercial interests from having to build and maintain their own launch facilities.

Land Remote Sensing Commercialization Act (LANDSAT Act)

This act was designed to commercialize the government *LANDSAT* Program. *LANDSAT* is an earth observation satellite that produces special digital images. The images are valuable for monitoring crop growth, pollution and deforestation. *LANDSAT* didn't have many customers because it was less competitive than foreign systems. Whether or not the act succeeded in its design is not important. Its rules on remote sensing are what is important. It allowed the sale of government data. It also set limits on the level of quality that could be sold without harming national security. Finally, it prohibited selling to the

***LANDSAT* Image of the Gulf Coast of Southern Louisiana and Mississippi**

highest bidder or to preferred customers. It directed that data be provided to all customers at the same cost.

International Space Issues

Space is a very big place. However, the orbital space around earth has limits. Some orbits are more useful than others and, thus, are in great demand. Earlier, we looked at types of orbits. We learned that a geostationary orbit allows a satellite to remain over the same point on the earth's surface. This is extremely valuable for communication uses. Transmitters and receivers can lock onto the satellite and never lose contact. Many, many users compete for the limited number of geostationary orbital positions. Therefore, some method of assigning positions is necessary. Radio frequencies used by geostationary satellites must also be regulated. Otherwise, satellites would be jamming each other's signals.

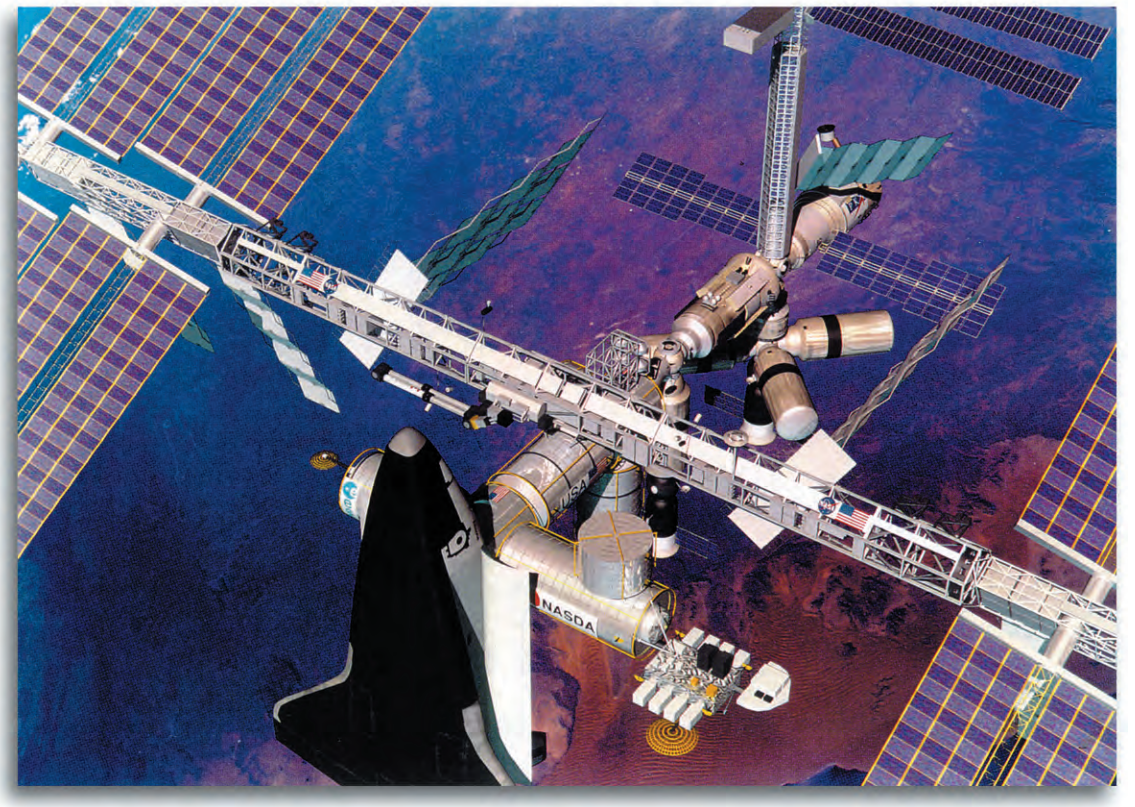
The International Telecommunications Union (ITU) is a United Nations organization that regulates international communications. The ITU was originally created to regulate radio frequencies and to set common standards. The ITU began regulating geostationary orbits in the 1960s. They assigned orbits and frequencies on a "first-come, first-served basis." Not everyone recognized the authority of the ITU to allocate orbital position. The "first-come" policy conflicted with the "equal access for all" principle of space law. Those with the means to access space would gobble up all the choice orbits. Also, because geostationary orbits remain fixed over a single point, some of the countries below claimed ownership, conflicting with the principle of non-appropriation.

These spacecraft are only 210 feet apart. (NASA)

Eight equatorial nations issued the Bogata Declaration in 1976. In it, they claimed sovereignty over the geostationary orbits above their territories. They argued that these unique orbits depended on the gravity of the earth below. In other words, each unique position was tied to the land below. They insisted that all countries needed their permission to place a fixed satellite above their land. No major space powers recognized their territorial claims.

However, the conflict focused attention on the problems of uncontrolled growth in satellite communications. Countries without space capability realized they could be squeezed out of this limited resource. They feared there would no longer be room when they were ready to launch their own satellites. As a result, they demanded "equitable access" provisions in ITU policy.

The ITU held two World Administrative Radio Conferences to address the problem and they came up with a solution. First, developing nations were guaranteed orbital slots. Current satellite operators were granted access rights for at least 20 years. No nation was guaranteed a specific slot, but they were assured access to a suitable segment of the orbital arc.



International Space Station *(NASA)*

The ITU also recognized that other useful orbits may eventually become overcrowded. Military, civil and commercial systems all vie for a limited spectrum of radio frequencies. And new orbits are being used. Communication systems are being designed for low earth orbits. The Iridium system consists of 77 satellites in low earth orbit. These factors led the ITU to consider allocations in low earth orbit.

Space as a limited natural resource is not the only issue that plagues nations. The cost of exploring and exploiting space is another. Some projects are simply too large for a single nation. The *International Space Station* is a prime example of such a combined effort. Proposed in 1984, the first International Space Station Agreement was signed in 1988. The United States provides overall management of the program.

The United States also provides the infrastructure and operating subsystems. Subsystems consist of life support, power, laboratory and habitation modules. Japan, European Space Agency (ESA) and Canada were to be other participants. Each was to provide elements of the station. Russia joined the team in 1993 and, in 1998, a new agreement was signed. The new agreement includes Russian participation and provides for more international involvement. It also reflects design changes made to reduce costs.

The Space Station Project is the largest and most complex international science and engineering program ever. A multitude of issues needed to be settled. Most of them concerned how the members would work together. They detailed who would do what and who would bear the costs. These were fairly

straightforward issues. Issues concerning the use of the station are another matter.

The first issue was managing the use of the station. All countries agreed to do this through consensus. If consensus cannot be reached, the dispute is forwarded to a Multilateral Coordination Board for a decision. The United States chairs this board.

The second issue of use refers to ownership of intellectual property. Who owns inventions and discoveries made on the station? Under the terms of the agreement, each state retains jurisdiction over its own station elements. A state's patent rights and copyrights apply to creations its nationals make while in their own modules. Ownership is determined on a terrirorial basis. Whose laws apply when a multinational team makes a discovery is unresolved.

The third issue on use concerns military involvement. Initially, the partners were very reluctant to have US Department of Defense involved. They preferred a purely scientific, non-military platform. However, many of the most experienced astronauts are military members. To restrict them from the station would hurt the effort. A compromise was worked out. The owner of each module decides whether activities occuring within that module are for peaceful purposes. The compromise did not completely relieve the concerns, but it did provide a workable solution.

Satellites- Unmanned Spacecraft

A satellite is a natural or artificial object that orbits around the earth. An example of a natural object in space is the moon. In fact, it is the earth's only natural satellite. Artificial means man-made, and as we know, *Sputnik* was the first man-made satellite in space. Astronomers and other scientists still refer to either a natural or man-made object in space that orbits the earth as a satellite.

Thousands of satellites now occupy various orbits. There are so many old satellites that concern has been expressed for the survival of new satellites being placed into certain orbits. The fear is that collisions could occur between the new craft and those now considered "space junk."

Many of the older satellites have continued to function well beyond their intended lifetimes. Some of these craft have had to be silenced because no funds were available to continue processing the data they returned. We'll take a look at some of these old satellites and their contributions to the space program. We'll also look at some current satellite systems. But first, let's see what purposes satellites serve.

The first satellites were experiments. They were designed simply to tell us how to make better satellites. Today, satellites serve a huge variety of purposes. Very few are experimental systems. Satellite technology has become very sophisticated. Virtually, all satellites gather, relay or provide information for our use. Some analyze cosmic radiation. Some look at earth's cloud cover. Others allow us to exchange ideas all over the world. Still others tell us where we are and what time it is.

All of these purposes can be divided into four broad categories. The first is communication. These satellites relay and amplify signals. The second category is navigation. These satellites send positional data and timing to special receivers, which can then calculate their own position. The third category is observation. These satellites look at the earth, collect information and relay it to ground stations. The last category is scientific. These satellites collect information about the universe.

Communications Satellites

The Communications Satellite (SATCOM) System began in 1958 when taped messages were broadcast from orbit. The *Score* satellite operated for only 13 days. But its messages excited the people of our nation. Since then the system has grown extremely complex.

Echo 1 was a very large reflective balloon placed in orbit in 1960. It extended the range of line-of-sight signals by bouncing them back to earth. It was an example of a passive communications satellite. Its function was nothing more than to reflect radio and television signals. Active satellites amplified the relayed signals. Because the satellite was in low earth orbit, it could only be used for a short time as it flew over broadcasting and receiving stations.

The *Courier* 1*B* also orbited in 1960. This active early communications satellite was the first of the repeater types. It received signals from ground stations, amplified them, then rebroadcast the signals to receiving stations on earth.

Telstar 1 was the first test of the commercial value of comunications satellites. In 1962, *Telstar* 1 was placed into orbit for Bell Telephone. It was an active satellite that amplified and retransmitted as many as 60 two-way telephone conversations at one time. *Telstar* 1 obtained the electrical power it needed to receive and transmit signals from banks of solar cells mounted on panels attached to the satellite. Ground stations were established in the United States, England and France.

A few months later, *Relay* 1 was launched for the RCA Corporation of America. It added Italy and Brazil to the growing list of countries receiving broadcasts from satellites in outer space. *Telstar* 3*D* was deployed from the *Discovery* orbiter in 1985.

Today, the large SATCOM business continues to grow as national and international corporations provide financing for growth. They construct, launch and operate several types of SATCOMs. The uses of communications satellites are also growing. They are still used for media transmission such as radio and television, as well as for pure data transmission such as the internet. Another use is for personal comunication systems such as cellular phones. And finally, a fourth important use is to provide links to other spacecraft. Examples of these uses are described below.

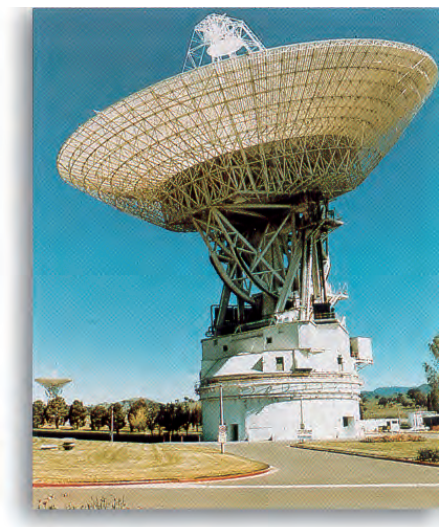
INTELSAT **IV rescued to be repaired and returned to space.**

INTELSAT

INTELSAT is both a series of satellites and an organization. Standing for the

International Telecommunications Satellite Organization, INTELSAT has more than 140-member nations and over 40 investing entitities worldwide. It operates as a commercial cooperative, linking the world's telecommunications networks together via a global satellite system of geostationary satellites. It has been in business since 1964 and now brings global access to over 200 countries and territories around the world.

Early satellites had the capability of relaying the output of two television channels. They could also relay 12,000 simultaneous telephone conversations. In 1978, INTELSAT provided coverage of World Cup football matches obtaining a record-setting global viewing audience estimated at 1 billion people in 42 countries. Both the organization and the system have continued to grow, launching a new generation of high-powered satellites in 1995. Today they have 17 advanced satellites in orbit and with orders placed for several new ones, they continue to be a leading wholesaler of satellite communications.



Deep Space Network Antenna (TDRSS)

Galaxy Series

The Galaxy series of satellites relays video, voice, data, and facsimile information worldwide. *Galaxy* 1 was dedicated to distributing cable television programming. The fleet has since grown to include many variations with names other than *Galaxy,* all relaying telecommunications. In 2006, Galaxy successfully launched Galaxy 16. This was the 43 communication satellite since Galaxy 1 and broadcasts the clearest cable network signal yet.

The Tracking and Data Relay Satellite System (TDRSS) consists of three satellites and a ground station. *TDRSS-East* and *TDRSS-West* are active satellites. The third is an on-orbit spare.

The ground segment is at White Sands, New Mexico. The system is designed to provide simultaneous full-time coverage for the Space Shuttle and up to 25 other NASA low-earth-orbiting spacecraft. The system relays data and communications to and from the shuttle orbiter during flights.

At 5,000 lbs. (2,260 KG), the TDRSS satellites are some of the largest, most complex communications satellites ever built. Each measures more than 50 feet (15 meters) from one tip of its solar array to the other.

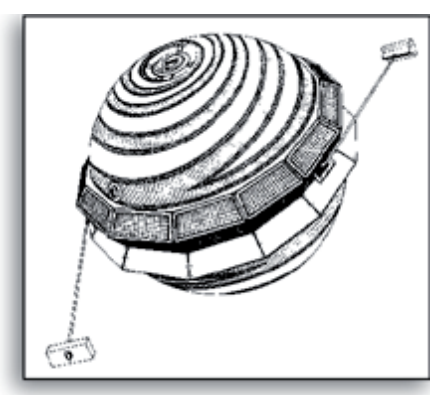
The Tracking and Data Relay Satellite System (TDRSS) Communications Satellite

The TDRSS antenna is designed only to point at spacecraft up to 7,500 miles high. Providing communications to spacecraft above this level requires help. The system, which assists in NASA's Deep Space Network (DSN), consists of three deep space communication complexes. They are located at Goldstone, California; Madrid, Spain; and Canberra, Australia. The complexes provide continuous links for planetary spacecraft as the earth rotates.

The DSN has supported all the deep space probes since its beginning in 1959. It also supported all of the Apollo lunar missions. When the *Voyager* 2 spacecraft flew by Uranus, the DSN antennas received the signals. They provided 29,000 bits of information per second, equivalent to a color picture every 5 minutes. The result was hundreds of color pictures during the brief encounter. The Australian station viewed the spacecraft longer than either the Goldstone or Madrid stations, since Uranus was in the southern part of the sky in 1986.

The military also operates a variety of communications satellites. These satellites are exclusive to military missions. The Defense Satellite Communication System (DSCS) is a continuous long distance message service. It provides exclusive communications services to the highest levels of the US government. Transmissions can be voice, teletype, video or digital data. The Ultra High Frequency Follow-On (UHF F/O) satellites provide the Department of Defense with continuous worldwide communications. They link aircraft, ships, submarines, and ground stations to military commanders and the National Command Authority. *MILSTAR* combines many communications services in one family of satellites. *MILSTAR* satellites provide command and control of military forces at all levels of activity. They are designed to survive nuclear war.

Navigation Satellites



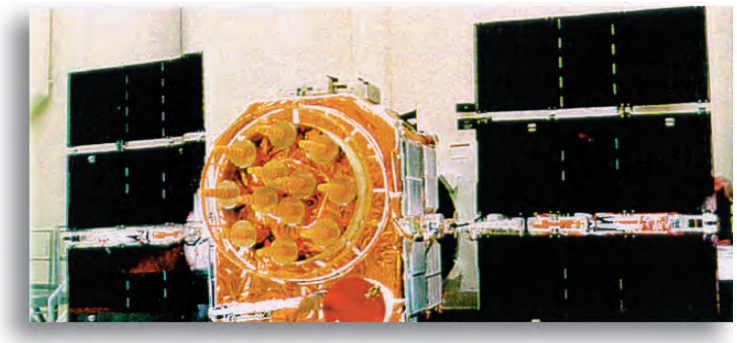
In the early 1960s, the Air Force and Navy actively pursued the idea of using radio signals from satellites for navigation and positioning. They envisioned a continuously operating space-based system that could also serve as an all-weather global system. Believing this could be a highly accurate system, the Navy sponsored both TRANSIT and TIMATION, two early programs designed to meet that vision.

Johns Hopkins University developed TRANSIT. It was designed to update the inertial navigation system on Polaris submarines. It became operational in 1964. In 1967 it was made available to non-military users. It is still working today, providing intermittent navigation information to ballistic missile submarines and surface ships.

TIMATION was a two-dimensional navigation system. It used high stability oscillators and time transfer capabilities to determine longitude and latitude. The Air Force was conducting its own research at the same time. Their project was called System 621B. System 621B was designed to identify longitude, latitude, and altitude. It was a three-dimensional system with a design that allowed it to run continuously.

In 1974, the Air Force was directed to oversee the creation of a new global navigation system. It would combine the best features of the previous programs. The new system was called NAVSTAR Global Positioning System. All the military services would participate in the program, assisted by the Defense Mapping Agency. The first NAVSTAR launched in 1978.

The NAVSTAR Global Positioning System (GPS) is a space-based radio-positioning system managed by the NAVSTAR GPS Joint Program Office at the Space and Missile Systems Center, Los Angeles Air Force Base, California. It provides navigation and timing information to both civilian and military users worldwide. Position, velocity and time can be precisely determined by GPS users. GPS satellites emit continuous navigation signals as they orbit earth every 12 hours. The GPS system provides positioning accuracy for military users to 16 meters nominally, while accuracy for civilian users is nominally 100 meters.

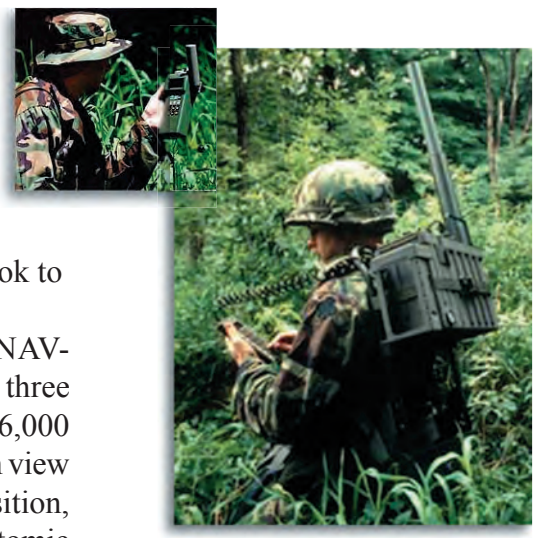


NAVSTAR Global Positioning System Satellite (GPS)

The system consists of a constelation of 24 orbiting satellites, a worldwide satellite control network and GPS receiver units that pick up signals from these satellites and translate them into position information. The satellites act as precise reference points and continuously broadcast position and time data. These satellites are spaced in orbit so that a minimum of six will be in view at any one time.

The control network is made up of ground stations operated by the US Air Force; the master control station is in Colorado. Five monitoring stations and three ground antennas located throughout the world all work together to track the satellites and send the data to the master control station. This data is used to adjust the satellite positions if that should be necessary.

Every user of the system has a receiver, each one of which uses the broadcast signals to calculate its position. The entire system is based on ranging the satellite, a process of determining how far away it is. The satellite broadcasts its location and the time that the signal was sent. The receiver then measures how long it took to receive the signal, thus determining relative distance.



Backpack and Hand-held GPS Receivers

Highly accurate atomic clocks are the key to the NAVSTAR GPS satellite system. On board each satellite are three of these clocks, which lose or gain only one second in 36,000 years. Any receiver with a minimum of three GPS satellites in view and an atomic clock can calculate a three-dimensional position, which is given in latitude, longitude and altitude. If no atomic clock is available, a fourth satellite must be in view in order to

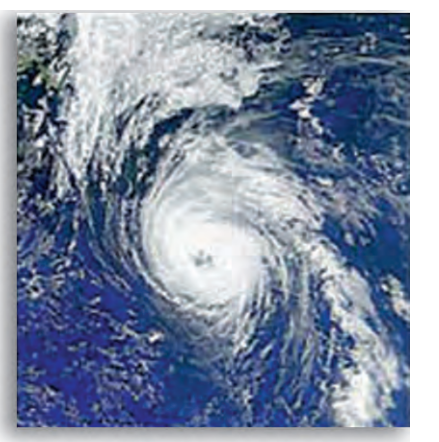
calculate the three-dimensional position. Since atomic clocks are expensive, most GPS receivers rely on getting signals from four or more satellites.

GPS is rapidly replacing all other navigational means. Virtually all ships and airlines rely on it. Trucking fleets and law enforcement agencies use it. It is an all-weather location system that has become critical for search and rescue. US military forces rely on it to locate enemy positions as well as their own. Farmers use it to lay out their fields. Many fishermen, hunters and hikers favor it over a compass.

Observation Satellites

Satellites orbiting the earth in space have a great view of earth. Military "spy satellites" have been keeping an "eye in the sky" on potential adversaries for decades. But, there is a lot more to look at and learn. Today, these remote observers serve many other purposes. For convenience, we'll divide observation satellites into three broad types.

Weather Satellites



The first type is the weather satellite. Most of us are very familiar with the satellite images shown on the evening news. But, these observation satellites look at a great deal more. Weather satellites measure temperatures at the surface and in the atmosphere. They also measure cloud cover and moisture levels. Some even measure lightning strikes.

The United States launched its first weather satellite, *Tiros* 1, in 1960. Ten Tiros satellites were launched. Their cameras provided the first large-scale weather photographs of earth. An improved type of weather satellite, *Nimbus* 1, was launched in 1964. *Nimbus* 6 was launched in 1975. It measures radiation in the earth's atmosphere. This data is used to determine climatic changes.

The National Oceanic and Atmospheric Administration (NOAA) series of weather satellites are advanced *TIROS N* craft. They also carry special search and rescue instrumentation. The TIROS program is a cooperative effort of NASA, NOAA, the United Kingdom and France.

NOAA's on-board sensors measure earth's cloud cover, surface temperature, atmospheric temperature, moisture and electric particle flux. A data system collects environmental information from sensors on land, at sea and in the air. In 1986, an *Atlas E* booster carried the NOAA 10 weather satellite into pilar orbit. This satellite is equipped with an L-band search and rescue payload that pinpoints distress signals from ships and aircraft.

The information gained from NOAA satellites can be used in several areas. For example, data has been used to help fire fighters control forest fires and to provide analyses of ice conditions at sea to the US Coast Guard. The NOAA satellites have detected volcanic eruptions in remote areas.

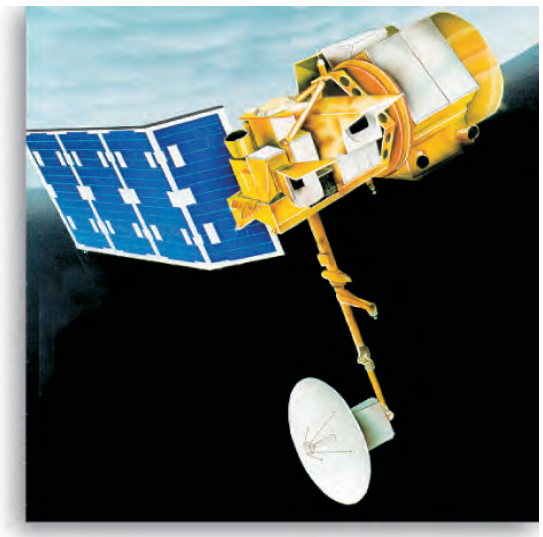
The pictures you often see on television of the earth's surface and cloud cover are transmitted from the GOES system. GOES stands for Geostationary Operational Environmental Satellites. Aboard the GOES spacecraft are instruments that provide cloud-cover pictures. Pictures in visible light and in infrared are possible. The infrared pictures are very useful in determining the intensity of storm systems. An instrument known as VAS collects data on the water vapor content. It also measures the temperature of the atmosphere. It provides data at various altitudes in the atmosphere. Meteorologists need this type of information for weather forecasting.

The US military has weather satellites as well. The Defense Meteorological Satellite Program (DMSP) provides weather data exclusively to the military. DMSP satellites use an optical system to gather data. They provide visual and infrared cloud data, as well as solar and oceanographic data.

Multi-spectrum-imaging Satellites

The second type of observation satellites is called multi-spectrum-imaging satellites. That's a long name for a satellite that observes radiant energy. This can be energy that is reflected from the surface of the earth. It can also be energy generated by objects on the earth. Either way, they give us some very useful data including information about crops, ocean currents and natural resources. Farmers and resource managers use the data extensively. Map makers also find satellite imagery much faster and cheaper than land surveys.

One of the best-known satellite systems of this type is the *LANDSAT* series of satellites. *LANDSAT*s locate natural resources and monitor other conditions on the earth's surface. New mineral resources have been, and continue to be, discovered by *LANDSAT* imagery. Placed into polar orbit, one *LANDSAT* can examine conditions on earth's total surface every 98.9 minutes.



***LANDSAT* 4 is a Natural Resources Satellite**

Agricultural conditions are monitored by *LANDSATs* and, thus, provide very important data to farmers, researchers and governments. Information relayed back to earth can show the rate of crop growth and allow accurate predictions of crop yield.

Healthy crops radiate at a known wavelength and produce a certain pictorial image. Any change in this image signals disease or damage, and corrective measures can be taken early. Similarly, grasslands for cattle can be monitored for overgrazing or to locate grazing areas, which could provide more nutritious food for cattle. Worldwide soil conditions can and have been evaluated. Thus, better use of available soil is made possible.

Land-use information is important to governments at all levels. For example, the study of *LANDSAT* imagery can point out the best areas for the future development of cities or the expansion of existing cities. Urban planners can use land areas that are the least suitable for crops. Laws can be passed that forbid construction of new homes or businesses on land that would be more valuable for some other use.

Federal and state governments find *LANDSAT* imagery particularly useful in the management of coastal resources. Effects of the tides, the status of industrial and waste pollution entering coastal waters and many other conditions are readily monitored. This allows corrective actions to be taken at proper times.

Fresh water is essential to life, and the availability of fresh water has diminished over the years. The problem lies in the fact that the demand for fresh water increases yearly with a higher standard of living and an increasing population. *LANDSATs* have been used to discover new sources and amounts of water. Its pictures of snowfall amounts provide specialists a measure of the fresh water that will result when the snow melts. In turn, very accurate estimates can be made of how much water will be in reservoirs before the dry seasons begin, how much will be available for growing crops, and so forth. This allows planners to prepare for any water shortages that may develop in certain areas of the country.

Another well-known series of multi-spectrum imaging satellites is France's SPOT system. *SPOT* 1 was the first in the series. It was very advanced for its time. This Earth resources mapping satellite was launched in 1986 atop *Arianne* 1. It carried visible and infrared sensors capable of much finer resolution than the comparable *LANDSATs.* This spurred better *LANDSATs.* The competition between them has resulted inexceptionally good imaging products. The more images they produce, the more uses are found for them.

A single scene from the Thematic Mapper of *LANDSAT 4* contains six times more data than a similar-sized area from the first *LANDSATs.* This image is of the Washington DC/ Baltimore, Maryland area.

Reconnaissance Satellites

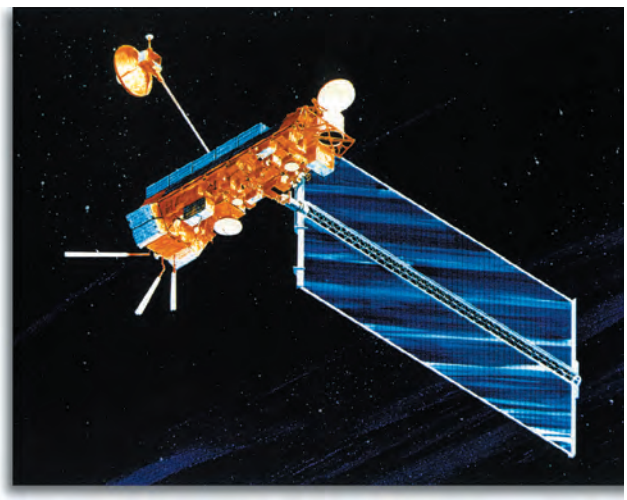
The third type of observation satellite is the reconnaissance satellite. This satellite monitors the activities of people on the surface of the earth. Generally, they serve military purposes. There are four major purposes: providing early warning by detecting enemy missile launches, detecting nuclear explosions, electronic reconnaissance and photo-surveillance.

These satellites monitor radio and radar transmission from the countries they pass over. Satellites that do photo-surveillance can be either high or low-resolution pictures. Satellites designed for high resolution are called close-look satellites. Expert analysts can distinguish minute details, using these pictures, such as different models of aircraft on the ground. Those designed for low resolution are called area-survey satellites. These pictures are generally used to provide general terrain information.

The names and details of most surveillance satellites are not released to the public. The existence of early warning satellites may be an exception. Publicizing these satellites lets adversaries know their launches can be detected. They also are used for treaty compliance. One example is the Defense Support Program (DSP) satellite system. The details of this system were declassified in 1974. Many believe the reason for this was to let the Soviet Union know United States' capabilities. The purpose of DSP is to monitor ballistic missile and space launches. However, it is also capable of detecting nuclear detonations.

Scientific Satellites

Scientific satellites orbit for the sole purpose of gaining information. Scientists in several fields then use the information gained in an effort to better understand the total aerospace environment. There have been many scientific satellites orbited since the capability to do so was developed. Each series or individual satellite has had more or less a specific job. The growth of technology now allows satellites to conduct multiple missions from one spacecraft. All of these missions can be divided into two broad categories. The first is orbital astronomy. Examples include *Explorer, Orbiting Solar Observatory (OSO), Orbiting Astronomical Observatory (OAO), High-Energy Observatory (HEAO), Rossi X-ray Timing Explorer (RXTE),* and the *Hubble Space Telescope*. The second type is environmental analysis. Examples include *Solar Mesosphere Explorer (SME)* and *Earth Radiation Budget Satellite (ERBS)*.



An Artist's Concept of the Scientific Satellite *NASA Polar Orbiting Platform* (NPOP-1)

The Explorers

The first of this series of satellites was orbited in 1958. *Explorer* 1 discovered the Van Allen radiation belts. The *Explorer* 3, also orbited in 1958, provided more information about radiation in space. It also investigated micrometeoroids in its flight path. In 1959, *Explorer* 6 gave us the first photograph of earth from space. Other Explorer satellites have looked at conditions from earth's atmosphere to thousands of miles into space. They have looked at radiation and solar flares of the sun. The Explorers were particularly essential to understanding the space environment prior to sending astronauts into orbit and to the moon.

Orbiting Solar Observatory (OSO)

The sun has been, and continues to be, studied by different types of scientific satellites. One early group was called *Orbiting Solar Observatory (OSO)*. The *OSO* 1 was launched in May of 1962. For over one year, it transmitted data on 75 solar flares that occurred during its lifetime. Later, orbital flights of the *OSO* series made further studies of the sun's production of x-rays, gamma rays and other radiation. The *OSO* 4 gave us the first pictures of the sun in the extreme ultraviolet wavelength.

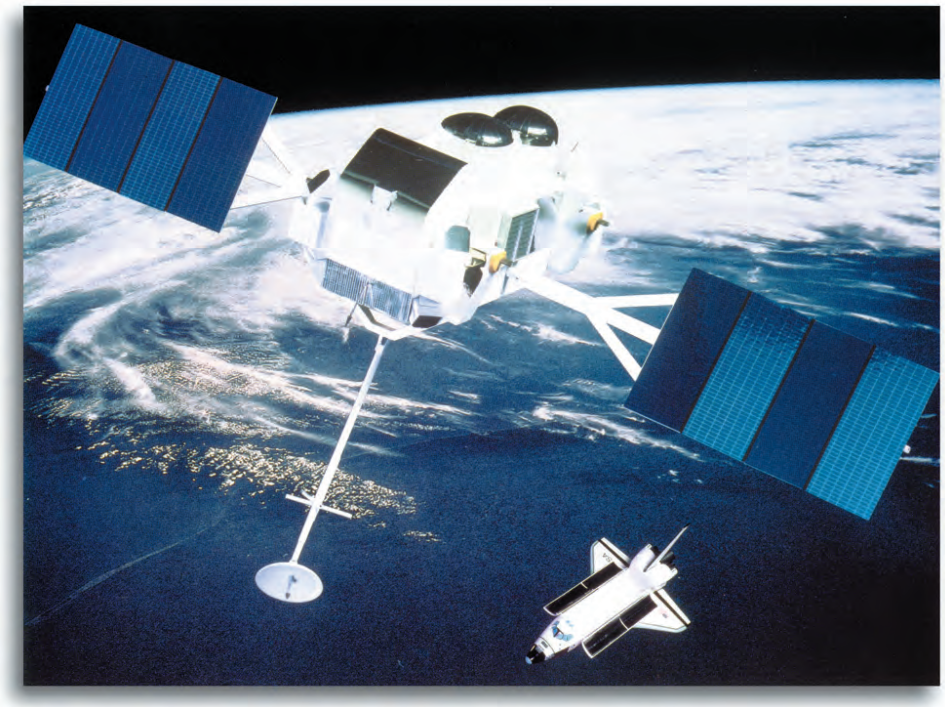
Orbiting Astronomical Observatory (OAO)

The *Orbiting Astronomical Observatory (OAO)* broadened scientists' understanding of the universe. The first of the series was orbited in 1968. It studied the stars in the ultraviolet, infrared, gamma, and x-ray wavelengths. The OAOs were able to extend scientists' knowledge of interstellar gases. *OAO* 2 discovered the existence of huge hydrogen clouds around comets. Astronomers had predicted such clouds. They could not confirm this and many other theories until the flights of the OAOs.

High-Energy Astronomy Observatory (HEAO)

Named for their special missions, the *High-Energy Astronomy Observatory (HEAO)* was orbited to investigate the sources and intensities of high-energy radiation that are at the very far end of the electromagnetic spectrum. Among the many discoveries of this satellite family were the bursts of gamma rays and jets of the x-rays coming from the galaxy Centaurus A. From within our own galaxy, sources of gamma ray bursts were discovered. Pictures of a pulsar, or rotating neuron star, were made from the x-rays generated by the star.

The why and how of the data received from each *HEAO* satellite may keep astronomers busy for years. Each question answered through study of the data invariably generates more questions. For this reason, other satellites with *HEAO* capabilities have been and will continue to be sent into space.



***Gamma Ray Observatory (GRO)* is equipped with four detectors to study gamma rays, the atomic messengers that tell the story of cataclysmic events in our universe.**

Rossi X-ray Timing Explorer (RXTE)

The *Rossi X-ray Timing Explorer (RXTE)* satellite is an explorer-class spacecraft. It's a continuation of the great strides already made in x-ray astronomy through the use of satellites. Astronomers are particularly interested in x-ray emissions coming from galaxies. They believe that the study of such x-ray emissions from groups of galaxies will help them understand how giant systems of galaxies form.

RXTE was launched into a low earth orbit in 1995 and its mission continues today. The spacecraft carries three science instruments including high-energy x-ray timing equipment, an all-sky monitor and a Proportional Counter Array. It is able to detect x-ray sources that are 50 to 100 times weaker than those sources detected by earlier searches. The *RXTE* is studying a variety of x-ray sources including white dwarfs, accreting neutron stars, black holes, and active galactic nuclei.

The Hubble Space Telescope

Earth's atmosphere limits the usefulness of our best astronomical telescopes. The atmosphere interferes with light rays by scattering, bending or blocking some of them out before they reach a telescope lens. Another problem is light pollution. Light pollution results from the interaction of the atmosphere and man-made lights. Light pollution can be experienced when you look for the stars in the sky at night while in a city. Only the brighter stars can be seen.

The *Hubble Space Telescope* is built to work similar to a ground observatory. It operates from an altitude of about 310 miles above the earth. At this altitude, it is free of the atmospheric interference. Astronomers are able to detect faint objects that are 50 times better than those seen from earth-based

The *Hubble Space Telescope*

Astronauts F. Story Musgrave and Jeffrey A. Hoffman teamed up to perform final servicing tasks on the *Hubble Space Telescope*.

observatories. The astronomers are also able to see objects much more clearly. The clarity is about seven times better than ground observations.

Initally the Hubble Space Telescope was scheduled to operate for 15 years, but it has been such a valuable tool that its time has been extended. Astronauts have made four service calls on the Hubble and are scheduled to do one final stop in 2008. That final servicing mission will keep Hubble operational until at least 2013.

Solar Mesosphere Explorer (SME)

SME is an example of an environmental analysis satellite. The mission of this satellite was to study the reactions between sunlight and earth's atmosphere. Of particular interest to scientists were reactions between sunlight and the ozone layer of the atmosphere and other chemicals.

Earth Radiation Budget Satellite (ERBS)

ERBS is a scientific satellite designed to study earth radiation and the interaction of the earth with radiation energy received from the sun. It was deployed by the *Challenger's* manipulator arm in 1984. The satellite's own hydrazine thrusters burned for long periods to boost it into its operational flight path. A pair of solar panels provides power.

Earth Observing System (EOS)

In 1991, NASA initiated a program to study the earth as a complete environmental system. This program was called Earth Science Enterprise. NASA has been studying the earth since 1958. They believe the key to understanding the global environment is exploring how the earth's systems of air, land, water and life interact. The program has three parts: a series of observations satellites, and advanced data system and teams of scientists. Some of the data will be collected from existing satellites and the Space Shuttle. Specialized *Earth Observing System (EOS)* satellites will also gather data. *EOS* is the first system to provide integrated measurements of earth systems.

Probes

There have been many spacecraft sent to investigate the moon and various planets within the solar system. Some have even been sent beyond our solar system. We refer to all of these satellites or spacecraft that either fly by, orbit or land on a celestial body, other than earth, as probes. Each flight deserves a full explanation, but only a brief summary can be provided here. Similar to the families of satellites discussed earlier, the probes are grouped by name.

The Rangers

This was an early series of probes intended to investigate the moon by taking pictures of the moon as the spacecraft approached on a direct impact course. An instrument packaged aboard each spacecraft was planned to withstand impact and send data back to earth. Several of the craft failed, but three of them provided the first close-up pictures ever seen of the moon's surface.

The Surveyors

Attention to the moon became more concentrated when the series of Surveyor probes landed on its surface during the period 1964 to 1968. These were soft-landers in that they carried retro-rockets that slowed them sufficiently to land undamaged. Of the seven launched, five landed as intended on different areas of the moon's surface. The probes sent hundreds of pictures back to earth. They also sampled the lunar soil for its chemistry and other characteristics.

Planners of the Apollo landings depended very heavily on the information gathered by the Surveyors. The had to know what the lunar excursion module would encounter upon its descent to the moon's surface.

Lunar Orbiters

In approximately one year, 1966 to 1967, five orbiter-type probes were launched to the moon. All of the probes were successful, and they did their job of providing high-quality photographs of the moon's entire surface. From these photographs, maps of the moon were made.

This effort, like those of the Ranger and Surveyor programs, was in preparation for the Apollo landings. To make certain there would be no danger of collision with the Apollo vehicles near the moon, each of the orbiters was sent crashing into the moon's surface after it completed its mission.

The Mariners

This family of probes was used to investigate the inner planets. *Mariner* 2 made a flyby of Venus in 1962, confirming that Venus had a very hot atmosphere near its surface and that it had neither radiation belts nor a magnetic field. In 1967, *Mariner* 5 provided confirmation of the first flyby findings and provided more information about the planet's atmosphere. *Mariner* 10 flew by Venus and Mercury in 1973 and this gave us the first pictures of the circulation pattern of the Venusian cloud cover and the cratered surface of Mercury.

***Mariner* 10 Mars Observer**

An Artist's Concept of *Pioneer* Leaving the Solar System (NASA)

The Pioneers

The Pioneers have probed both the outer and inner planets. *Pioneer* 10 gave us the first close-up pictures of Jupiter in 1973. The craft continued past Jupiter on its journey out of the solar system.

Pioneer 11 was the second probe of Jupiter. It flew past the Jovian system in 1974 and began a trajectory to Saturn. The first pictures and data from Saturn were received on Earth in 1979.

The Vikings

In 1975, NASA launched two space probes, the *Viking* 1 and *Viking* 2, to explore the environment of Mars. Each probe consisted of an orbiter and a lander.

Objectives for the Viking mission included analyzing the Martian atmosphere and photographing the planet's surface. But, the primary emphasis was the search for life. Each of the landers took samples of the Martian soil and submitted the samples to various tests for evidence of life processes within the soil. The experiments were not conclusive.

Although life was not found, scientists did obtain enough information to make several conclusions about the status of Mars, such as the fact that the polar ice caps are largely made of water ice. Thousands of photographs were taken of the Martian landscape from orbit and from landers' positions on the surface. In appearance and in content, the surface was found to be somewhat like desert soils on earth.

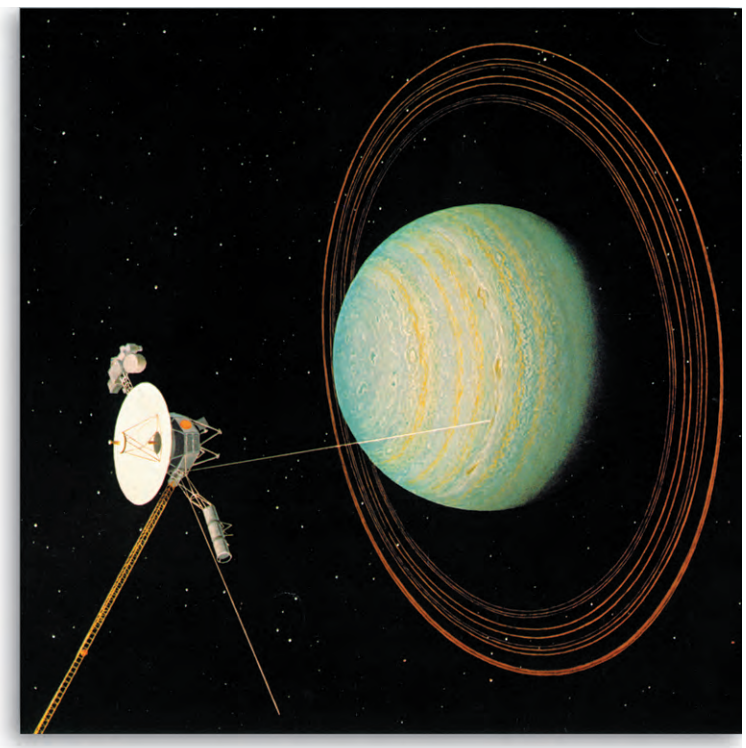
Voyagers 1 and 2

The Pioneers opened the way to outer-planet investigations, but the Voyagers gave us greatly improved pictures and data. Both craft were launched in 1977, and both encountered Jupiter and Saturn. The *Voyager* 1 was launched after the *Voyager* 2 because it placed on a faster trajectory to Jupiter.

The *Voyager* 1 reached Jupiter in March 1979 and flew on to Saturn, arriving there in November 1980. *Voyager* 1 completed its planetary encounters and is traveling toward interstellar space on a path away from the ecliptic plane. We can look forward to further investigations by the *Voyager* 2. *Voyager* 2 flew by Jupiter in 1979 and Saturn in 1981. It flew within 63,000 miles of Saturn and headed toward an encounter with two other planets.

The *Voyager* 2 spacecraft flew by Uranus in January 1986. The spacecraft's closest approach was 107,000 km from the planet. The *Voyager* 2 flew in and out of the Uranium system in a matter of hours. A planned 1987 firing of *Voyager's* onboard thrusters was adjusted to retarget its August 1989 flyby of Neptune from a miss of 1,280 km to 4,800 km to avoid possible ring debris and radiation belts.

Both Voyagers are continuing on out of the solar system. They will continue to send information as long as power supplies last. We expect to learn a great deal about the edge of the solar system as they pass into interstellar space. Scientists are very interested in the area where the interstellar wind is equal to the solar wind. This area is called the Heliopause Boundary. They want to study the magnetic interactions of solar wind plasma and interstellar wind particles.



This painting shows *Voyager's* encounter with Uranus. (NASA)

Giotto

In 1985, the European Space Agency launched *Giotto* on an Ariane launch vehicle. It was sent to explore Halley's Comet. It streaked within 450 km of Halley's nucleus. Bombarded 100 times a second with particles weighing up to .001 gram, *Giotto* was, by encounter's end, coated with 26 kg of dust.

The Soviet Union launched *Vegas* 1 and *Vegas* 2 that flew past the comet and provided final targeting data for *Giotto*. They also suffered severe dust erosion of solar arrays. Japan launched the *Suisei* and *Sakigake* probes. *Sakigake* provided images from 7.1 million km (4.4 million miles).

The closest and most hazardous approach was made by *Giotto*, which was targeted to fly through the tail of Halley's Comet and behind the nucleus in order to obtain images with the highest possible resolution. The scientific instruments aboard measured neutrons, ions and dust particles, and recorded dust impacts. An on-board camera took color pictures of the nucleus from about 1,000 km. The probe sent back more than 2,000 images.

Mars Global Surveyor

Mars Global Surveyor (MGS) was launched in November 1996. It was the first of NASA's several low-cost planetary Discovery missions. It was designed to orbit Mars for a two-year period. Its purpose was to map and collect information about the surface of Mars. It also collects data on Martian atmosphere, gravity and magnetic fields. The data will be used to investigate such things as Martian geology, resources, climate and weather.

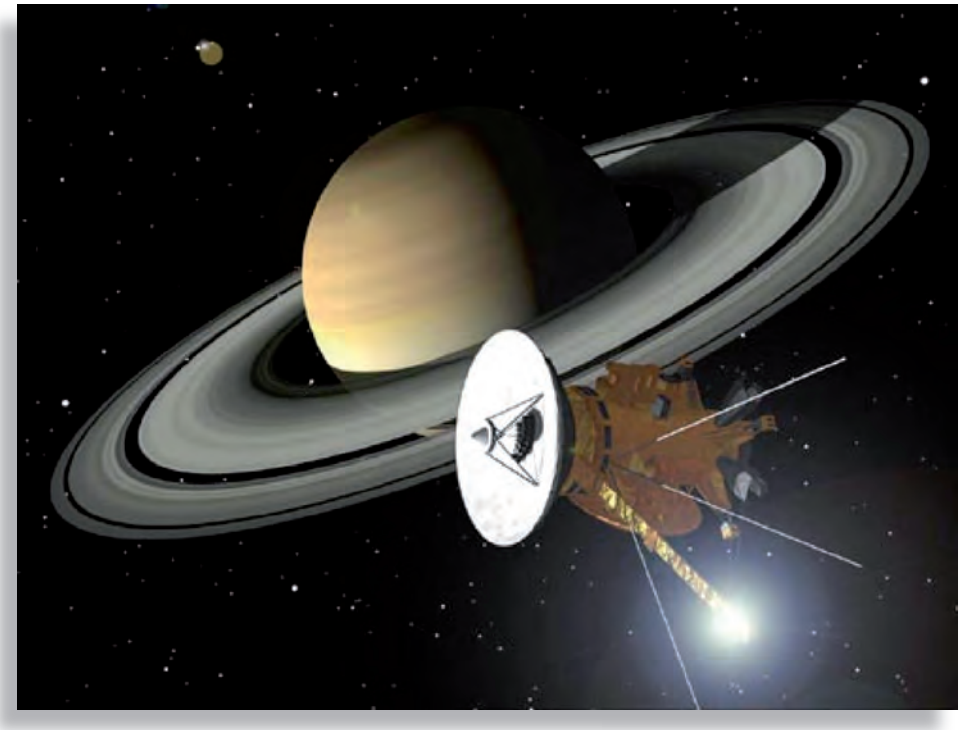
Mars Pathfinder

Mars *Pathfinder* was the second of NASA's low-cost planetary Discovery missions. It consists of a stationary lander and a surface rover. The primary objective is proving the feasibility of low-cost landings on and exploration of the Martian surface. It has provided atmospheric entry data, long-range and close-up surface images. It has also done rock and soil composition experiments.

Mars *Pathfinder* proved low-cost landings could be accomplished. During the landing, the craft was surrounded by four air bags that formed a protective ball. Once on the surface, the bags were deflated. After some maneuvers to clear an airbag out of the way, ramps were deployed and the rover rolled out onto the surface. The mission continued to send images and results from experiments until September 1997, when communications were lost for unknown reasons.

Galileo

Named for the discoverer of Jupiter's inner moons, the *Galileo* spacecraft was launched by NASA in 1989. After a 6-year journey, it entered orbit around Jupiter in 1995.

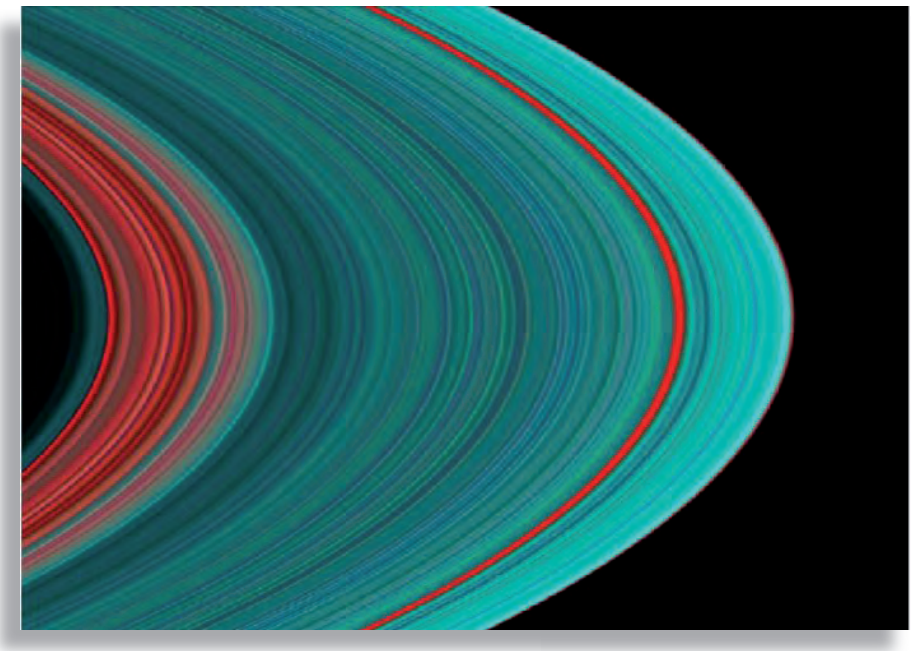


Artist's Illustration of the *Space Probe Cassini* Passing Saturn *(Courtesy of NASA)*

The mission was the first to take direct measurements from within Jupiter's atmosphere. When it arrived, it injected a probe into Jupiter's atmosphere. The probe measured cloud temperatures, chemistry and electrical activity. Atmospheric pressure was also a part of the measurement taken. The orbiter continued to send a steady stream of images and scientific data for two years. This was its primary mission. It then began a secondary mission to explore two of Jupiter's moons.

Cassini

In 1997, this two-story robotic spacecraft began a journey for Saturn. *Cassini* is an international project involving NASA, the European Space Agency and several European academic and industrial partners. It went into orbit around Saturn in July of 2004 and will observe the planet and its moons for at least four years.



An actual image returned from *Cassini* taken of the rings of Saturn
(Courtesy of NASA)

Chandra

On July 1999, *Chandra* was launched as NASA's

***Chandra* – An artist's illustration of a space probe that is proving that truth is more exciting the fiction. It has been giving science data that is more dramatic than anything Hollywood could produce.** *(NASA illustration)*

new x-ray observatory. This probe was named after Subrahmanyan Chandrasekhar, one of the most prominent astrophysicists of the 20th Century. *Chandra* is solar powered and has only three major parts. The x-ray telescope contains eight mirrors that focus x-rays emitted by space objects. The scientific instruments on board the satellite include a high-resolution camera that records x-ray images and a spectrometer that determines the energy level of the x-rays. The spacecraft itself provides a safe environment for the telescope and the instruments. It is operated by the Chandra Flight Operations Center at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts. *Chandra* records observations of the universe in the high energy end of the electromagnetic spectrum. The x-ray images that *Chandra* records are 25 times sharper than previous x-ray images taken by other telescopes. *Chandra's* extraordinary capabilities make it possible for scientists to study high energy objects such as supernovae and black holes in much greater detail.

Phoenix

In August of 2007, NASA launched a spacecraft, known as the *Phoenix Mars Lander.* This probe is designed to claw down into the icy soil of the red planet's northern plains. The robot will investigate whether frozen water near the Martian surface night periodically melt enough to sustain a livable environment for microbes. To accomplish that and other key goals, *Phoenix* will carry a set of advanced research tools never before used on Mars.

"Our 'follow-the-water' strategy for exploring Mars has yielded a string of dramatic discoveries in recent years about the history of water on a planet where similarities with Earth were much greater in the past than they are today," said Doug McCuistion, director of the Mars Exploration Program at NASA Headquarters, Washington, D.C. *"Phoenix* will complement the strategic exploration of Mars by being our first attempt to actually touch and analyze Martian water—water in the form of

buried ice."

NASA's *Mars Odyssey* orbiter found evidence in 2002 to support theories that large areas of Mars, including the arctic plains, have water ice within an arm's reach of the surface. *"Phoenix* has been designed to examine the history of ice by measuring how liquid water has modified the chemistry and mineralogy of the soil," said Peter Smith , the Phoenix principal investigator at the University of Arizona, Tucson.

"Phoenix can assess whether this polar environment is a habitable zone for primitive microbes. This is just another step toward our efforts to see if life ever existed on our sister-planet," said Jean Cesarone, aerospace educator, about the importance of this mission in our never-ending effort to find life beyond planet earth.

Phoenix Mars Lander *(Illustration by Corby Waste, NASA)*

Key Terms and Concepts

- scientific approach
- application spacecraft
- satellites
- probes
- manned spacecraft
- National Aeronautics and Space Administration (NASA)
- international treaties
- international laws
- international courts
- international customs
- United Nations resolutions
- 1967 Outer Space Treaty
- ABM Treaty
- NASA Act
- Commercial Space Launch Act (CSLA)
- Land Remote Sensing Commercialization Act (LANDSAT Act)
- geostationary orbit (GEO)
- International Telecommunications Union (ITU)
- Bogata Declaration of 1976
- International Space Station Agreement
- European Space Agency (ESA)
- active vs. passive communications satellites
- International Telecommunications Satellite (INTELSAT)
- Tracking and Data Relay Satellite System (TDRSS)
- Defense Satellite Communication System (DSCS)
- Global Positioning System (GPS)
- National Oceanic and Atmospheric Administration (NOAA)
- Defense Meteorological Satellite Program (DMSP)
- multi-spectral imaging
- Defense Support Program (DSP)
- *Orbiting Solar Observatory (OSO)*
- *Orbiting Astronomical Observatory (OAO)*
- *High-Energy Astronomy Observatory (HEAO)*
- *Rossi X-ray Timing Explorer (RXTE)*
- *Solar Mesosphere Explorer (SME)*
- *Earth Radiation Budget Satellite (ERBS)*
- *Earth Observing System (EOS)*
- *Mars Global Surveyor (MGS)*

? Test Your Knowledge ?

SELECT THE CORRECT ANSWER

1. *The* **(1967 Outer Space Treaty / Anti-Ballistic Missile Treaty of 1972)** *stated that space would be used "exclusively for peaceful purposes."*
2. *The* **(GPS / DSP)** *permits users to instantly determine their position, provides their velocity and time, and is more accurate than any radio system.*

MATCHING

3.

a. Earth Observatory System	**1) Discovered the Van Allen Radiation Belts**
b. Earth Radiation Budget Satellite	**2) Studied the sun's protection of x-rays and gamma rays**
c. Explorers	**3) Improved knowledge of interstellar gases**
d. High Energy Astronomy Observatory	**4) Discovered burst of gamma rays from Galaxy Centaurus A**
e. Hubble Space Telescope	**5) From LEO, studies white dwarfs, black holes, active galactic nuclei**
f. Orbiting Astronomical Observatory	**6) Solved the problems of light pollution and atmospheric interference**
g. Orbiting Solar Observatory	**7) Studied the reaction between sunlight and earth's ozone layer**
h. Solar Mesosphere Explorer	**8) Studies interaction of earth and radiation energy from the sun**
i. X-ray Timing Explorer	**9) Studies how air, land, water and life interact on earth**

MATCHING

4. **Match the probe type with its contributions:**

a. Cassini	**(1) Provided the first close-up pictures of the moon**
b. Galileo	**(2) Information gathered helped Apollo planners know what to expect**
c. Giotto	
d. Lunar Orbiters	**(3) Flyby missions investigated Mercury and Venus**
e. Mariners	**(4) Launched in 1966-1967, five probes provided high-quality photographs of the moon's entire surface**
f. Mars Global Surveyor	
g . Pathfinders	**(5) Provided the first close-up pictures of Jupiter and Saturn**
h. Pioneers	**(6) Investigated Mars using an orbiter and a lander; tested soil samples**
i. Rangers	
j. Surveyors	**(7) Flew past Jupiter, Saturn, Neptune, Uranus, now headed for interstellar space**
k. Vikings	
l. Voyagers	**(8) Launched by ESA to investigate Halley's Comet**
	(9) Launched in 1996 to investigate Martian geology, resources, climate and weather
	(10) Put the first rover on another planet to perform rock and soil composition experiments
	(11) Launched to take direct measurements of Jupiter's atmosphere and explore its moons
	(12) International robotic probe sent to Saturn to study rings, atmosphere, magnetosphere

FILL IN THE BLANKS

5. _____ *are unmanned exploratory spacecraft traveling beyond earth's orbit;* _____ *are unmanned spacecraft that orbit the earth.*
6. _____, *the first Soviet satellite, established the right satellites to* _____.
7. _____ *communications satellites reflect the radio or television signals while* _____ *communications satellites amplify the signals before return.*
8. _____ _____ *in the GPS has built, in error, factors to protect US security and is available to civilian users;* _____ _____ _____ *has more accurate data and is available only to military users with the appropriate codes.*
9. *Identify the satellite type with its function (**weather, multi-spectrum imaging, reconnaissance**):*
   a. DMSP _____
   b. DSP _____
   c. GOES _____
   d. LANDSAT _____
   e. NIMBUS _____
   f. SPOT _____
   g. TIROS _____
10. *The International Telecommunications Union Policy of "first come, first served" in assigning* _____ *conflicted with the* _____ *principle of space law.*
11. *Eight equatorial nations responded to the ITU Policy with the* _____, *in which they claimed sovereignty over the* _____ *above their territories.*
12. *The acronym DMSP stands for* _____, *which provides* _____ _____ *data exclusively to the* _____, *using an/a* _____ *system to provide* _____ *and* _____ _____ *data.*
13. *The two purposes of scientific satellites are* _____ *and* _____.
14. *Identified as L4 and L5, these points in space where a body will be in equilibrium are the most likely potential place for* _____.

MULTIPLE CHOICE

15. *Which of these spacecraft launch agencies has only recently been acknowledged to exist?*
    a. Commercial
    b. Military
    c. Civilian
    d. National security

16. *Which of the following is* ***not*** *a source of space law?*
    a. *Customs*
    b. *Treaties*
    c. *UN decrees*
    d. *International courts*
17. *The Land Remote Sensing Commercialization Act did which of the following?*
    a. *Allowed the sale of government data*
    b. *Set limits on the quality of the data that could be sold*
    c. *Directed that data be provided to all customers at the same costs*
    d. *All of the above*
18. *Which member of the 1998 International Space Station Agreement started participating in 1993 and signed the new 1998 agreement?*
    a. *Japan*
    b. *Russia*
    c. *Canada*
    d. *European Space Agency (ESA)*

TRUE OR FALSE

19. *Scientific application satellites gather information that may or may not have immediate use.*
20. Telstar *1 was the first telecommunications satellite.*
21. *TRANSIT and TIMATION were precursors to the Global Positioning System.*
22. *Taking photos and infrared observations are the only activities of reconnaissance satellites.*

SHORT ANSWER

23. *Describe the three basic principles of space law.*
24. *What were the two most significant provisions of the Outer Space Treaty of 1967?*
25. *Briefly describe the situation that led to the ABM Treaty and explain why it is significant to space operations.*
26. *How did the National Aeronautics and Space Act help space exploration in the United States?*
27. *How did the Commercial Space Launch Act aid the development of commercial space activities?*
28. *What three issues were at least partially resolved by the International Space Station Agreement?*
29. *Name the four categories of satellites.*
30. *Name the four uses of communications satellites.*
31. *List the three segments of GPS and their functions.*
32. *What are the three types of observation satellites?*
33. *What are the four purposes of reconnaissance satellites?*
34. *What are some of the potential reasons to construct space colonies?*