LESSON 3

Space in Your Daily Life

Quick Write

Read the vignette about AFJROTC cadets' real-life experiences with the Lunar Crater Observation and Sensing Satellite (LCROSS). Consider the ways you might put to use your experiences in the JROTC program. What areas of aerospace science are you most interested in pursuing?

Learn About

- history of satellites
- how satellites are used every day
- space technology in everyday use

Combine your knowledge and understanding of science, technology, engineering, math (STEM), and now aerospace science, and you just might find yourself above the clouds. Or perhaps, you will land yourself on the moon!

Air Force JROTC cadets at the Lewis Center for Educational Research's Academy of Academic Excellence (AAE) in Apple Valley, CA have also put their aerospace knowledge and skills to use. For 110 days, cadets tracked NASA's Lunar Crater Observation and Sensing Satellite (LCROSS). LCROSS's mission was to study ice water on the south pole of the moon. LCROSS impacted the moon to create a dust cloud that could be studied.

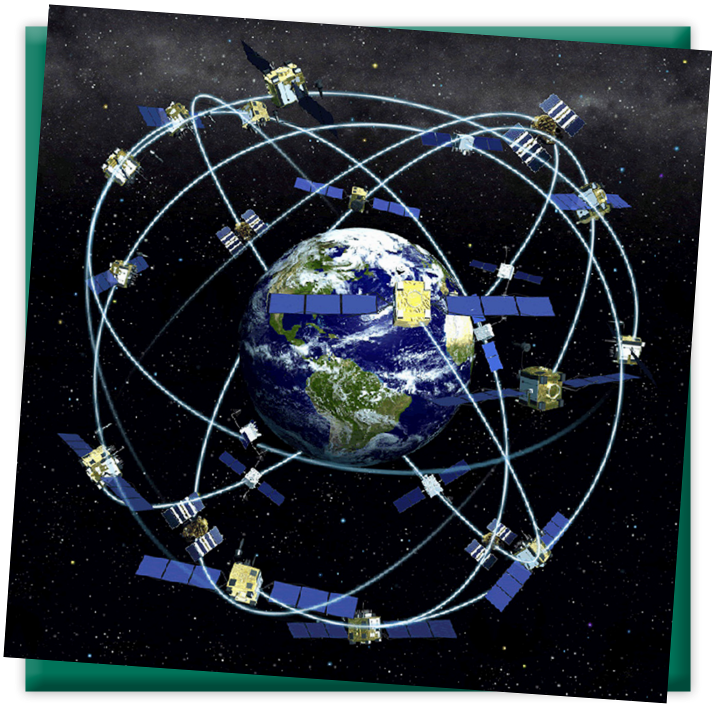
LCROSS was commanded from the Goldstone Apple Valley Radio Telescope (GAVRT) in the Mojave Desert, CA. The cadets photographed the satellite's impact with the moon and sent the first viewed images to NASA.

This was an exercise in commitment and dedication for the cadets. While NASA controlled the spacecraft for only a few of the 110 days, the cadets controlled and gathered data from the spacecraft for 97% of the mission!

As you read on to learn more about the development of satellites and the growing interest in private commercial satellite launches, consider how we use satellites every day and the possibility of soaring beyond the clouds yourself!

More than 400 AAE students, faculty, and family members gathered in classrooms October 9, 2009, to watch the live viewing of the impact.

Courtesy of Air Force



Over 30 navigation satellites are orbiting Earth. These satellites, along with ground stations and receivers, tell us our location at any given time.
Courtesy of NOAA

Vocabulary

- satellite
- geosynchronous orbit
- transponder
- uplink
- downlink
- geostationary orbit
- constellation satellites
- bus
- radiometers
- polar-orbiting satellites
- cellular communications
- satellite cellular phones
- trilateration
- reconnaissance
- spinoffs

History of Satellites

Today, thousands of satellites are orbiting the Earth. By definition, a satellite is *an object that orbits around a bigger object*. Planet Earth itself is a satellite because it orbits around a larger object, the Sun. The Earth and the Moon are natural satellites. In this lesson, our focus is artificial or man-made satellites.

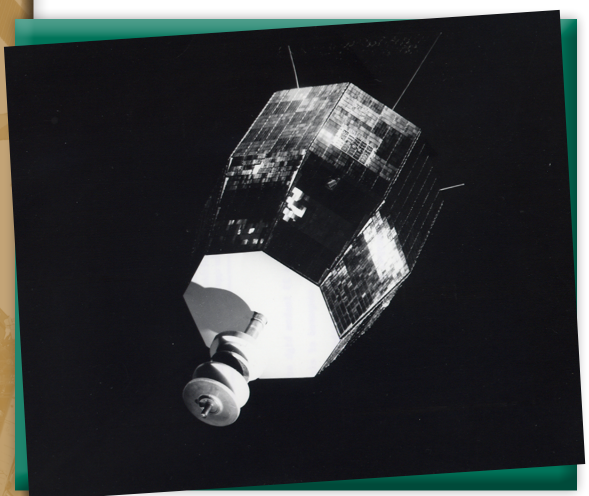
Many of the thousands of artificial satellites orbiting Earth today are fully operational. Fully operational satellites provide us with television signals, communication abilities, GPS, and so much more! With the many current uses and emerging applications, the trend of satellite development and launch is here to stay.

Let's take a look back at the evolution of satellite development.

Satellite Development

NASA has worked with private companies since the 1950s and 1960s to develop satellites for communications and for advancements in meteorology. Companies like Radio Corporation of America (RCA), American Telephone and Telegraph Company (AT&T), and Hughes Aircraft Company partnered with NASA in these efforts over the years.

In 1961, NASA partnered with RCA on a satellite relay program to test across-ocean communications. Think of a satellite relay like a relay race in track and field. A runner goes a certain distance and then passes a baton to the next runner on his or her team. The baton is passed from runner to runner until the finish line. With a satellite relay, data passes from satellite to satellite until it reaches the ground on Earth. For NASA and RCA, a satellite relay was used to measure radiation in space for the purpose of determining the damage that radiation might do to the satellites.



This 1964 image shows the 172-pound Relay satellite.
Courtesy of NASA

Relay satellites were launched beginning in 1963. Each satellite in the RCA program was designed with two sets of circuits. If the first circuit became damaged, the second one would provide backup. With the launch of Relay 1 in 1963, the first circuit did fail, but the second circuit functioned properly. Relay 2 was launched in 1964 using improvements gained from the first flight, and the second circuit was not used. Because of advanced planning and design changes, a planned Relay 3 flight was not needed!

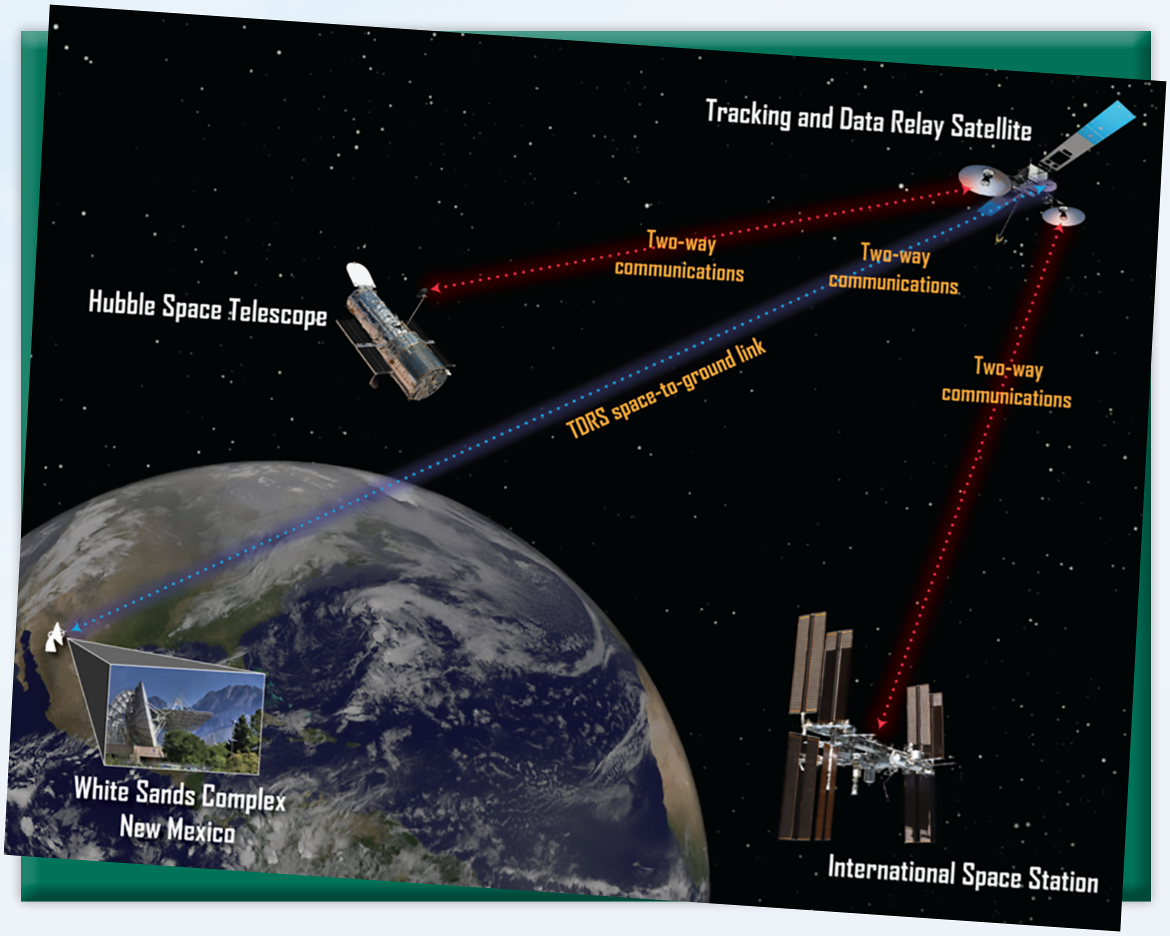
About the same time as the RCA program, AT&T developed its own satellite as part of the Telstar program. AT&T paid NASA $3 million to launch it. Telstar I was the first privately sponsored communications satellite. It was launched into orbit on July 10, 1962. The Telstar I satellite continued to operate successfully into the early part of 1963. On the Telstar I project, the world's first transatlantic television signal was broadcast and the first phone call was transmitted by satellite through space.

The first phone call transmitted through space went something like this:

> *"Good evening Mr. Vice President, this is Fred Kappel calling from the Earth Station at Andover, Maine. The call is being relayed through our Telstar satellite as I'm sure you know. How do you hear me?"*
>
> *"You're coming through nicely Mr. Kappel," said Vice President Lyndon Johnson.*
>
> (Colin Schultz/Smithsonian, 2012)

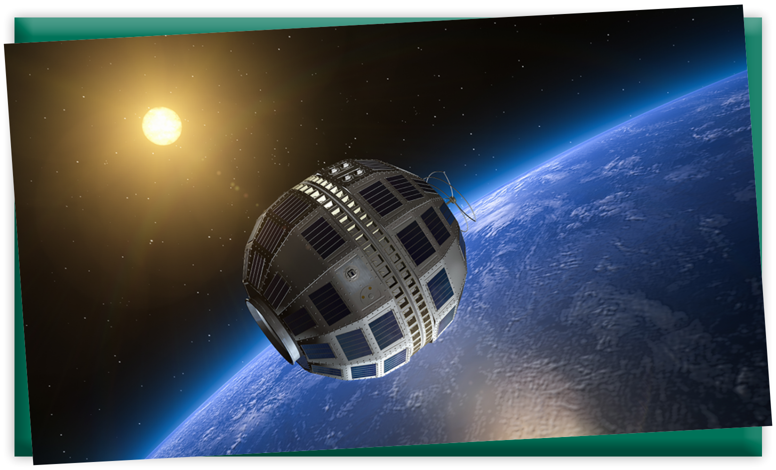
The Right Stuff

Today, there are 10 Tracking and Data Relay Satellites (TDRs) located about 22,000 miles above Earth, receiving information from the ground telling the satellites what to do (take a picture, turn a sensor on or off, send stored data back, or change its orbit). TDRs allow NASA to have global coverage of all the satellites, all day every day, without having to build additional ground stations on Earth.



The Tracking and Data Relay Satellites (TDRs) sit about 22,000 miles above the Earth and pass data from a satellite until it reaches a ground station in view..

Courtesy of NASA



The broadcast satellite, Telstar 1, launched into Earth's orbit in 1962. It was 34.5 inches long and weighed 170 pounds.
Courtesy of gfdunt/Shutterstock

The RCA and AT&T projects had something in common: . . . they were expensive! They required large, rotating antennas on the ground to track the orbits of the satellites around Earth. To lower costs, NASA contracted with Hughes Aircraft Company for alternatives. Hughes built a 24-hour communications satellite, called Syncom, that would operate in geosynchronous orbit. Geosynchronous orbit is *an orbit that puts the satellite in the same place in the sky over a specific point on the surface each day*. It looks like it hovers in the same spot, but it actually travels at the same speed as the Earth's rotation.

The Synchronous Communications (SYNCOM) satellite program was in use for several years. Syncom helped receiving dishes on the ground retrieve information from a satellite by pointing at just one point in the sky. Thanks to Syncom, folks in the United States were able to watch live coverage of the 1964 Olympic Games from Tokyo, Japan. Syncom also provided useful Department of Defense communications during the Vietnam War.

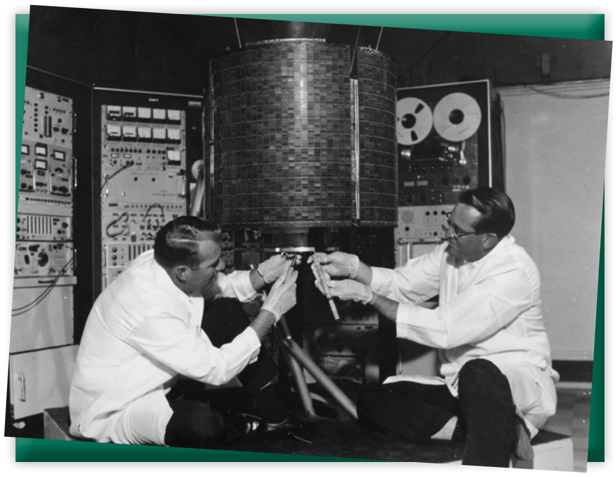
NASA also launched several weather satellites during the period from 1960 through 1966. They were called TIROS (Television Infrared Observation Satellites). These satellites contributed to weather and climate studies and predictions.

Commercial Communications Satellites

In 1964, the International Telecommunications Satellite Organization (INTELSAT) was formed to develop a global network and improve access to communications in developing nations. The greatest achievement of INTELSAT at the time, was the management of the first commercial communications satellite. Intelsat I, also known as Early Bird, was the result of a partnership between Hughes and the private company Communications Satellite Corporation (COMSAT). Early Bird was developed to send back the first transmissions from space from over 20,000 miles above Earth. This included telephone and television signals. Expected to work for about a year and a half, it continued to operate for four years.

Did You Know?

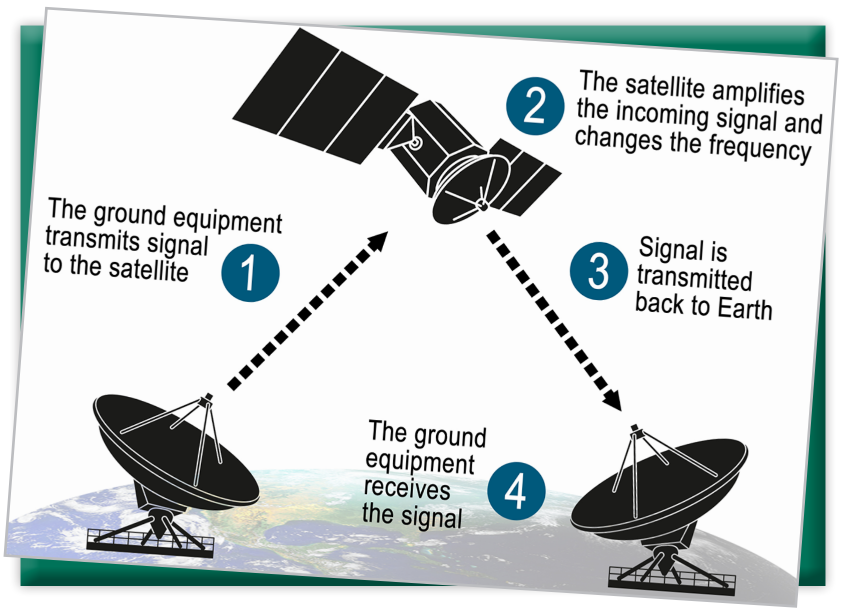
Early Bird's name came from the popular saying "the early bird catches the worm."



Early Bird was the first commercial communications satellite placed in a geosynchronous orbit.
Courtesy of NASA

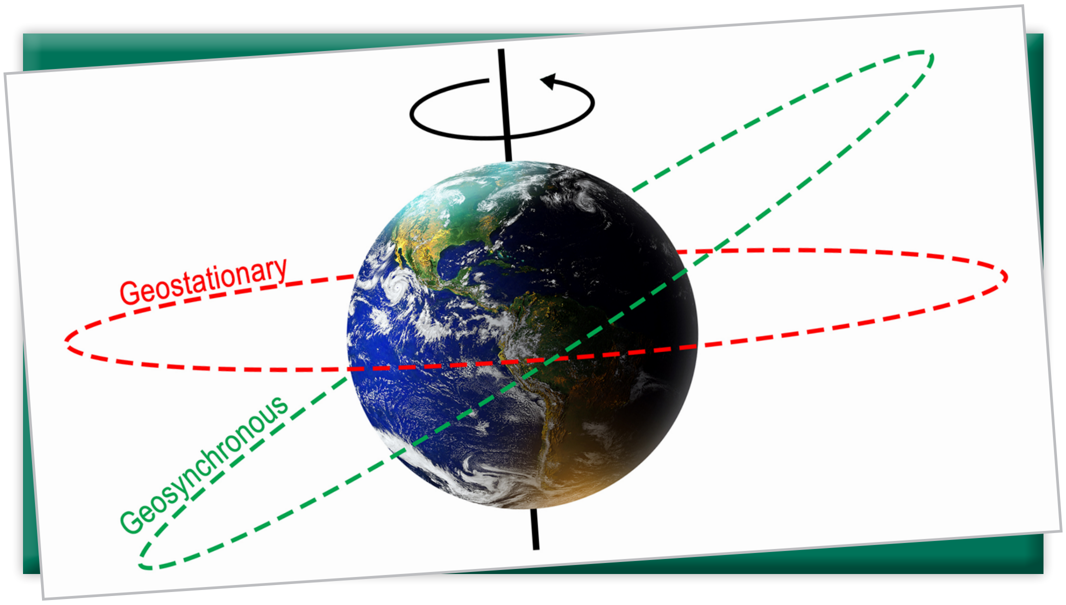
By the end of 1965, the Intelsat II system delivered circuits for the NASA Communications Network (NASCOM). By 1969, the Intelsat III system completed its global network with a satellite over the Indian Ocean. This happened just days before Apollo 11 landed on the moon. The INTELSAT satellites made it possible for millions around the world to watch this important moment in history!

Satellites at the time were used mainly to communicate voice, video, and data from one large antenna to another distant satellite. The distant satellite would then relay communication to land-based networks. These communications satellites receive signals from TV or radio. Then, they amplify the signals via a transponder. The transponder *receives a radio signal and immediately transmits a different signal. The signal transmitted from Earth* is known as an uplink. *The signal transmitted from the satellite to Earth* is the downlink.



Satellite communications involve four steps as shown here.

In 1972, TELESAT Canada launched Anik, the first domestic communications satellite. It was the first system established to improve the telecommunications and broadcasting services within a specific country. This made Canada the first country with a domestic communications satellite system using a satellite in a geostationary orbit. Unlike a geosynchronous orbit, which can have any inclination, a geostationary orbit *puts the satellite in the same plane as the equator*.



Difference between geosynchronous and geostationary orbits.

RCA leased the use of transponders on Anik until launching its own satellite, Satcom 1, in 1974. Meanwhile, Western Union launched the first US domestic communications satellite in 1974. Westar I was used for voice, video, and fax transmissions throughout the US. These satellites were used primarily for voice and data communications. The distribution of video would soon follow.

Did You Know?

Satcom 1 was one of the first satellites used by networks ABC, NBC, and CBS, as well as cable TV channels, (such as TBS and CNN).

As the US launched its first domestic communications satellites, another type of satellite was preparing for liftoff. In February of 1976, COMSAT launched Maristat, our first mobile communications satellite for telephone service and for traffic monitoring by the US Navy and commercial shipping.

In 1979, the International Maritime Satellite Organization (INMARSAT) was created. It would serve the same purpose as INTELSAT but for sea support communications instead of land. It was hailed as an important milestone in preventing the dangers of collision, loss of life, and pollution.

Satellites were our primary means of communication during the 1980s. With the first fiber-optic cable put in place across the Atlantic in the late 1980s, we established another means for communication. The norm today is to use clusters of *smaller satellites working together*, also known as constellation satellites.

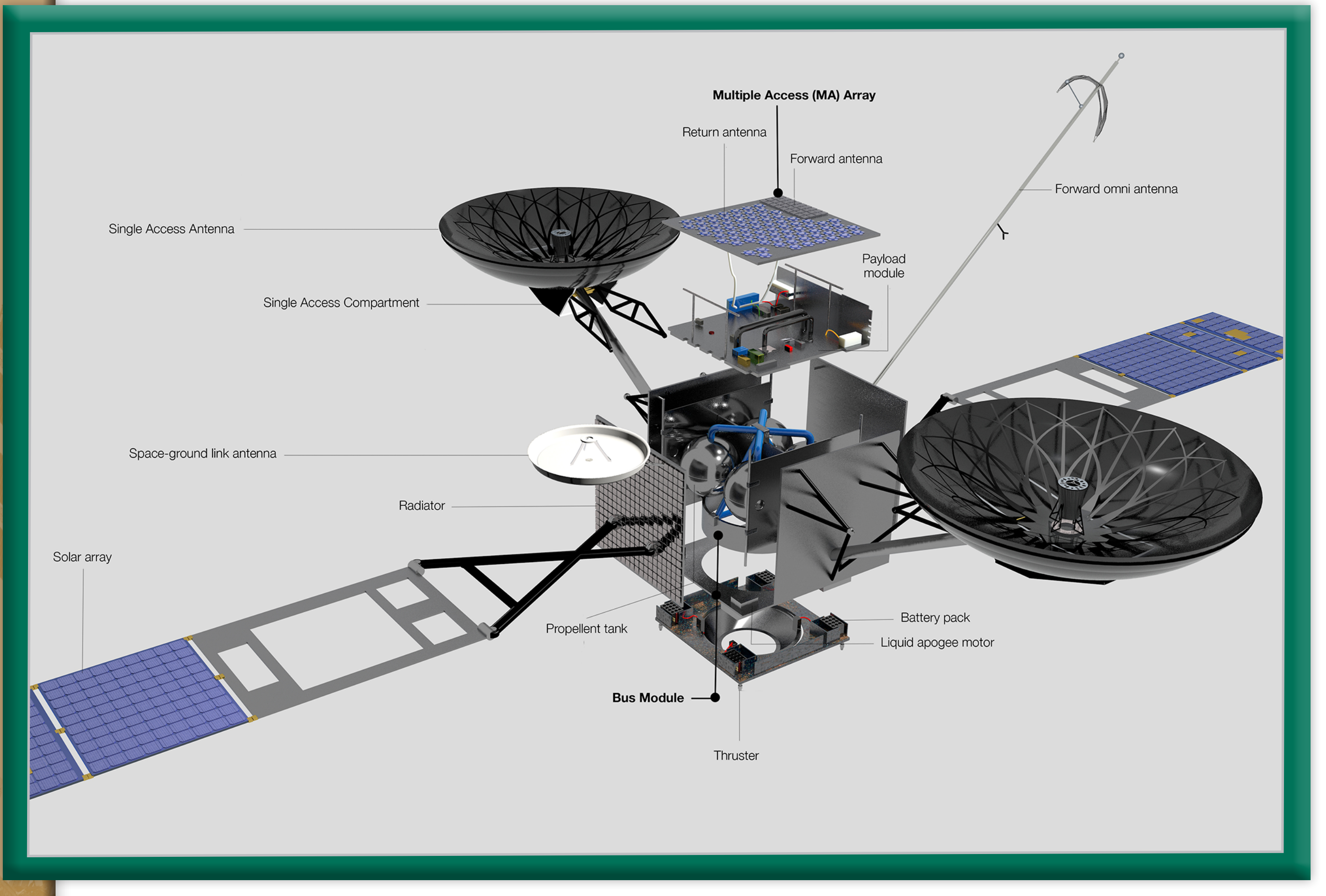
Technology and satellite design continue to improve and advance. Equipment becomes smaller, lighter, and more affordable for launching low Earth orbit (LEO) satellites. LEO satellites orbit the Earth at lower altitudes (about 99 to 1,200 miles) above the Earth's surface, and they take a longitudinal orbit path. They provide faster transmission and coverage of data.

The Right Stuff

The Components of a Satellite

Although satellites perform different functions, they all have common components.

- The bus is *the metal or composite frame and body of a satellite*. The bus must hold all components of the satellite safely inside the frame. In addition, it must be strong enough to survive launch.
- All satellites have a power source. The typical power source for satellites is solar cells with rechargeable batteries.
- All satellites have onboard computers to monitor their systems.
- A radio system and antenna are common to all satellites. This allows ground-control to request information from the satellite or reprogram the satellite.
- All satellites also have altitude control systems. These systems maintain the direction of the satellite.



TDRS (Tracking and Data Relay) satellite with the vision of internal parts. 3D rendering - Illustration.
Courtesy of Robysot/Shutterstock

Commercial Launches

In the early 1980s, NASA was the only provider and operator of launch vehicles for the US. The number of launches was more than NASA could manage with limited federal funding. We then saw the commercial development and private operation of space launch vehicles take off. The first private rocket launch took place on September 9, 1982. The Conestoga was the prototype for the Space Services Inc. of America (SSIA).

Federal legislation further propelled the private sector into space exploration. President Ronald Reagan signed the Commercial Space Launch Act of 1984. He approved other legislation that encouraged the development of commercial expendable launch vehicles, orbital satellites, and operation of private launch services.

Through the 1980s and early 1990s, more policies were put in place. They required NASA and other government agencies to buy launch services from commercial companies. Through the 1990s and early into 2000, commercial launches surpassed the number of NASA launches.

Today, the private sector has successfully launched several small satellites without the assistance of any governmental agencies. This shift represents a new era in space exploration and a new version of the space race among private companies.

How Satellites are Used Every Day

Without us knowing it, satellites impact our lives almost every minute of every day. We use them for communications, weather, navigation, computing and more. There are a variety of satellites currently in orbit:

- Weather satellites
- Communications satellites
- Broadcast satellites
- Scientific satellites
- Navigation satellites
- Rescue satellites
- Earth observation satellites
- Military satellites

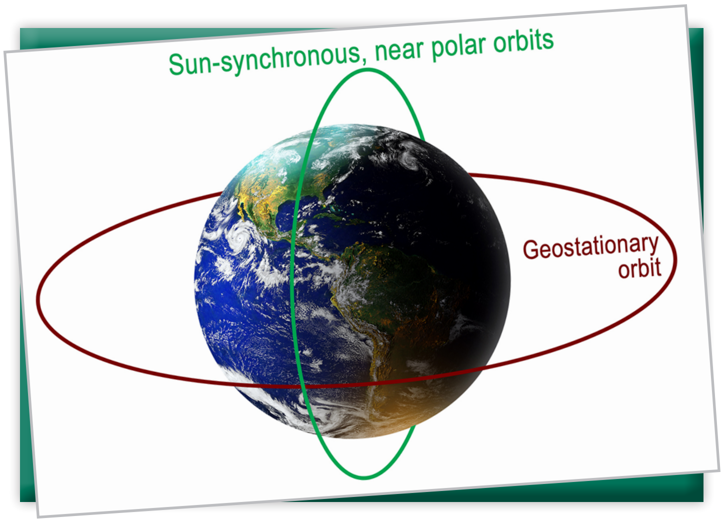
Weather Satellites

If you check the weather before heading out, you rely on satellites. From hundreds—sometimes thousands—of miles above Earth, these satellites use special tools and sensors to gather information about our weather.

Weather satellites collect data on temperature, precipitation, clouds, and wind. They also help us monitor pollution, smoke, snow, ice, and other environmental data. Weather satellites use radiometers to scan the Earth. Radiometers are *instruments for detecting or measuring the intensity or force of radiation*. Radiometers record the visible, infrared, or microwave radiation in the form of electrical voltages. The satellites convert the electrical voltages to digital images, which are then sent to weather forecast centers.

We use two types of weather satellites to collect data and interpret the weather: geostationary operational environmental satellites (GOES) and polar operational environmental satellites (POES). Remember, geostationary-orbiting satellites are located over the equator. The GOES typically orbit at a very high altitude (22,500 miles) and are used for most of the satellite weather images you see. However, there are disadvantages to GOES. The high altitude requires elaborate telescopes with detailed imaging capabilities to capture Earth at high resolution. Another disadvantage is that GOES only monitors a portion of the Earth. For example, GOES-East and GOES-West cover most of the western hemisphere, but the ESA's Meteosat satellite provides coverage of Europe and Africa.

Polar-orbiting satellites are *satellites that orbit across the Earth's poles*. Polar-orbiting satellites are often called sun-synchronous orbits as well. The POES complements the GOES system and orbits the North and South poles approximately every 100 minutes. The POES allows for complete coverage of the Earth at a closer altitude (520 miles). The disadvantage of the POES is that it only allows imaging of a location every 12 hours.



Difference between geostationary and Sun-synchronous orbits.

There are currently two POES in Sun-synchronous orbit so that images are updated every six hours. Because POES provides a full view of the weather on Earth, we often use these images to forecast the weather.

After weather satellites are launched in the US, the National Oceanic and Atmospheric Administration (NOAA) controls them. With the satellites' transmission of data, NOAA analyzes the information to forecast and predict our weather.

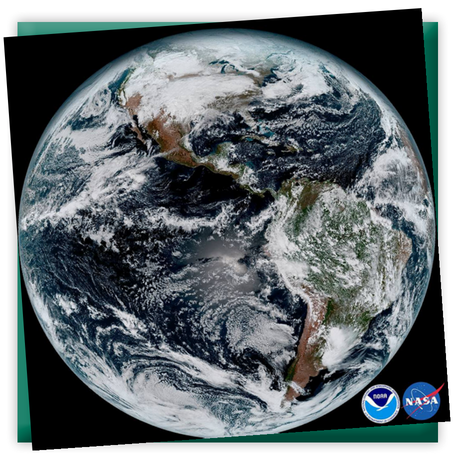


Image taken from NOAA's GOES-16 weather satellite. The image shows North and South America and the surrounding oceans.

Courtesy of NOAA/NASA

Did You Know?

The National Weather Service (NWS) uses satellite data to identify quickly cooling cloud tops. These events suggest the presence of snow squalls, or sudden bursts of heavy snowfall that result in near-zero visibilities and gusty winds. With the use of satellite data, forecasters can make life-saving warning decisions.

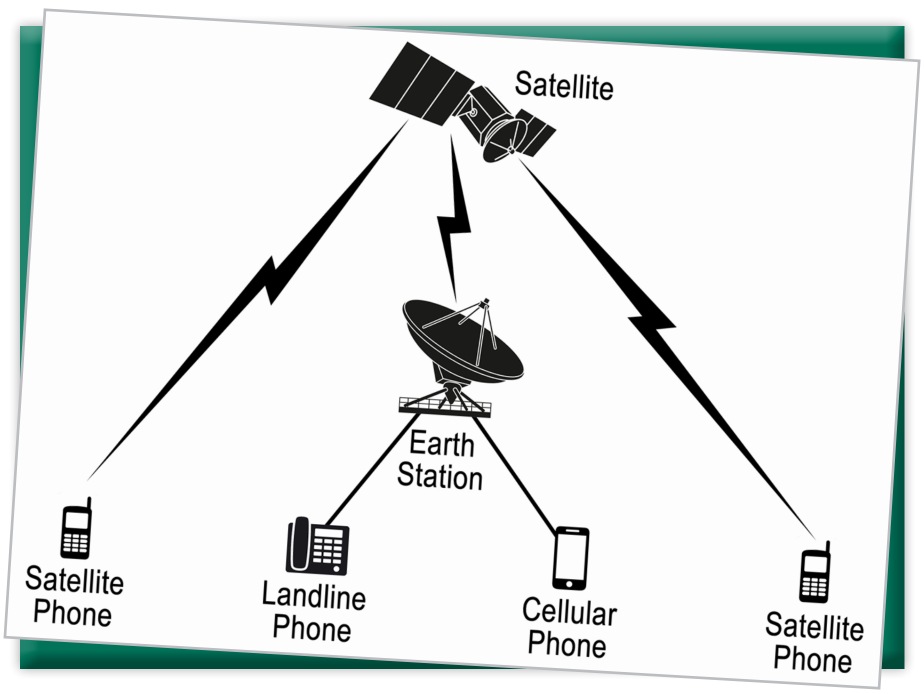
Cellular and Satellite Communications

We use our cellular phones every day for communication. We take pictures, store information, access the internet, watch movies, and the list goes on. These functions all depend on cellular communications. Does cellular communication use space satellites? The answer is surprisingly no. So, how do they work? Cellular communications *use on-land towers to send and receive signals*. A group of towers, or cells, make up a cellular network, which can be used for voice, data, and other types of content. When we use cellular phones to call friends or to navigate using GPS, our phones transmit and receive data from the nearest cell tower. Some phones, however, contain an actual GPS chip that can locate GPS satellites.

In comparison, satellite cellular phones *use satellites orbiting the Earth to send and receive signals*. This allows much greater coverage than a cellular phone. Why? Unlike our typical mobile phones, satellite phones send signals directly to a satellite orbiting the Earth rather than using on-land towers.

Because satellite communication systems can receive a signal over a much wider area, they are particularly useful in remote locations where cellular communications are not available. Because of the coverage capabilities, satellite phones are valuable for military and disaster relief efforts.

The satellite phone comes with a much greater price tag, though. The makers of satellite phones spend millions of dollars to support the technology with each satellite, making the cost to the consumer much great than that of a cellular phone.



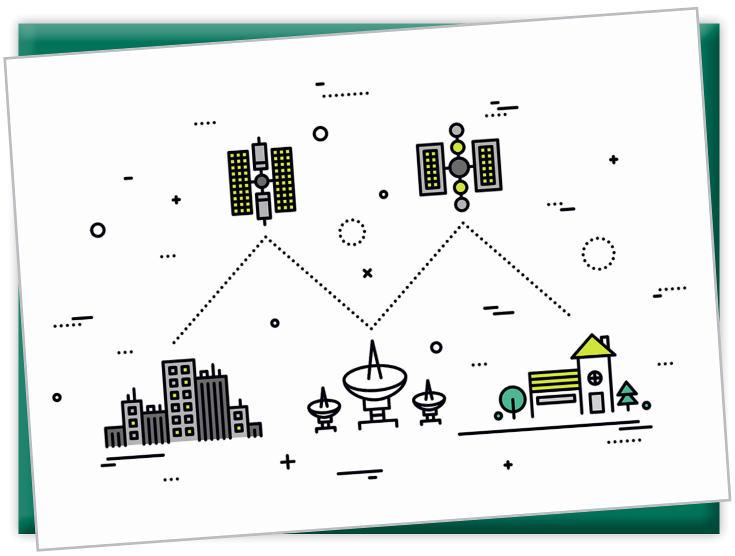
Cellular phones versus satellite cellular phones transmissions.

Did You Know?

Cellular phones may not send and receive signals directly to satellites, but they can act as satellites themselves! In a NASA-sponsored project, PhoneSat , three phones were launched into orbit and performed successfully as very tiny satellites.

Broadcast Satellites (TV and Radio)

Satellite broadcasting is the distribution of multimedia content over or through a satellite network. Television and radio companies use satellites to transmit signals worldwide. From anywhere in the world, they can send a signal across satellite dishes on the ground. The signal is then boosted across the world using geostationary satellites. Satellite broadcasting was first initiated in the 1960s, but by the 1980s a newer, more efficient method was developed. Direct-broadcast satellites (DBS) allow for direct-to-home broadcast programming using a dedicated satellite. Think of companies such as DirecTV®, DISH Network®, or SiriusXM® radio. They deliver programming by relaying a signal off a communications satellite from the broadcaster's location. This signal is received by an antenna or satellite dish, then the signal is decoded through receivers, allowing television viewing or radio listening.



Thin line flat design of satellite communication system, global network service provider, transmitting high speed internet, radio, and TV data.

Courtesy of Bloomicon/Shutterstock

Digital television is an advanced broadcasting method that has changed the viewing experience for many television customers. In fact, you may not remember a time when digital television was not available. In the past, television companies would pick up the broadcast signal from the satellite and then disperse that signal through a series of ground satellites. The signal and picture quality would suffer using these methods. Now the signal is so strong that you can pick up the satellite signal directly from your residence rather than having the television companies broadcast the signal. Most homes are set up for digital television.

The Right Stuff

Today, you probably receive internet access in your home via fiber optic or cable services. The internet signal is sent to your home using fiber optic or cable wiring and then transferred into wireless internet by a router. If you live in a rural area, you may have satellite internet instead. Satellite internet is received directly from space using a satellite installed on your home.

Elon Musk, CEO of SpaceX , suggests a new method of accessing the internet called "space internet." The SpaceX project, known as Project Starlink, has permission from the Federal Communications Commission (FCC) to set up a series of low earth orbit (LEO) satellites. The lower orbit was selected to reduce the risk of space junk collision. The satellites will provide direct Wi-Fi internet access to Starlink customers. Musk aims to have half of all internet traffic go through the Starlink satellites; however, others feel Starlink will most likely appeal to high-internet users who will pay big for faster connections.

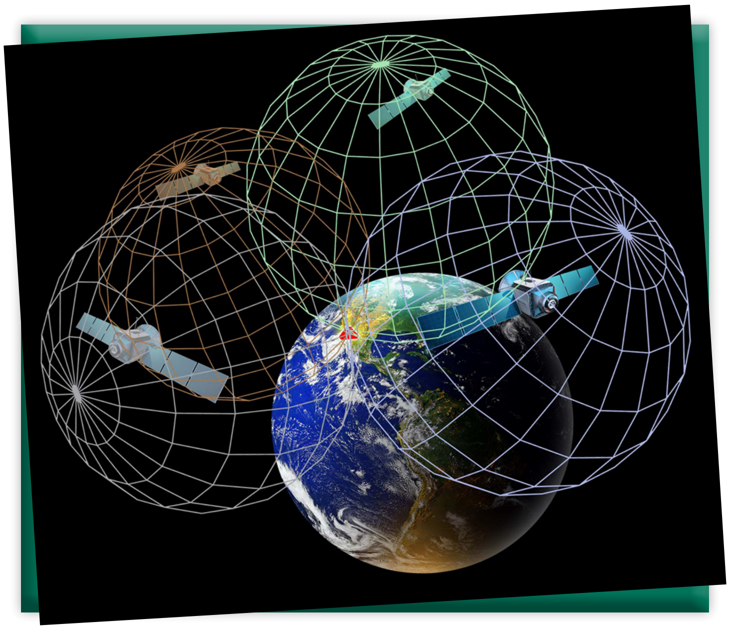
In the initial phases, Starlink will launch 4,425 satellites. The satellites will use lasers to send signals between one another and then beam the signals to ground stations using radio waves. The internet speed will be about twice as fast as current fiber optic networks. However, launching a single satellite costs tens of millions of dollars, so the cost for the service will be pricey. And because each satellite only lasts a few years, new satellites launches would need to occur every few weeks to keep up with the satellites needing replaced. But think of the possibilities! Global coverage would provide internet in locations that currently cannot receive it. Internet would be available in remote areas and at sea. Starlink satellites begin launching in 2019.

Navigation Satellites

Mass transportation systems like trains, buses, and airplanes use Global Positioning Systems (GPS) to ensure safe and efficient travel. First responders use GPS to quickly identify the location of emergency situations. Search and rescue teams also depend on the life-saving technology. It helps them find their way to disaster-relief sites and the individuals in need of care. Today in modern automobiles and smart phones GPS can be activated to provide navigation assistance to any location in the world.

How does it work? GPS, of course, is another function of satellites. A GPS receiver looks for one of at least four visible satellites among a constellation of 30 or more satellites orbiting above Earth at about 12,000 miles. Each satellite provides data about its position and time. Satellites transmit data to a GPS receiver at the speed of light. The receiver determines its distance from the satellites based on how long it took to receive the signals.

More specifically, GPS uses a process called trilateration. Trilateration is *when a GPS receiver calculates the distances to satellites by measuring angles*, as shown in the illustration. This gives us data accurate within five meters!



GPS trilateration.

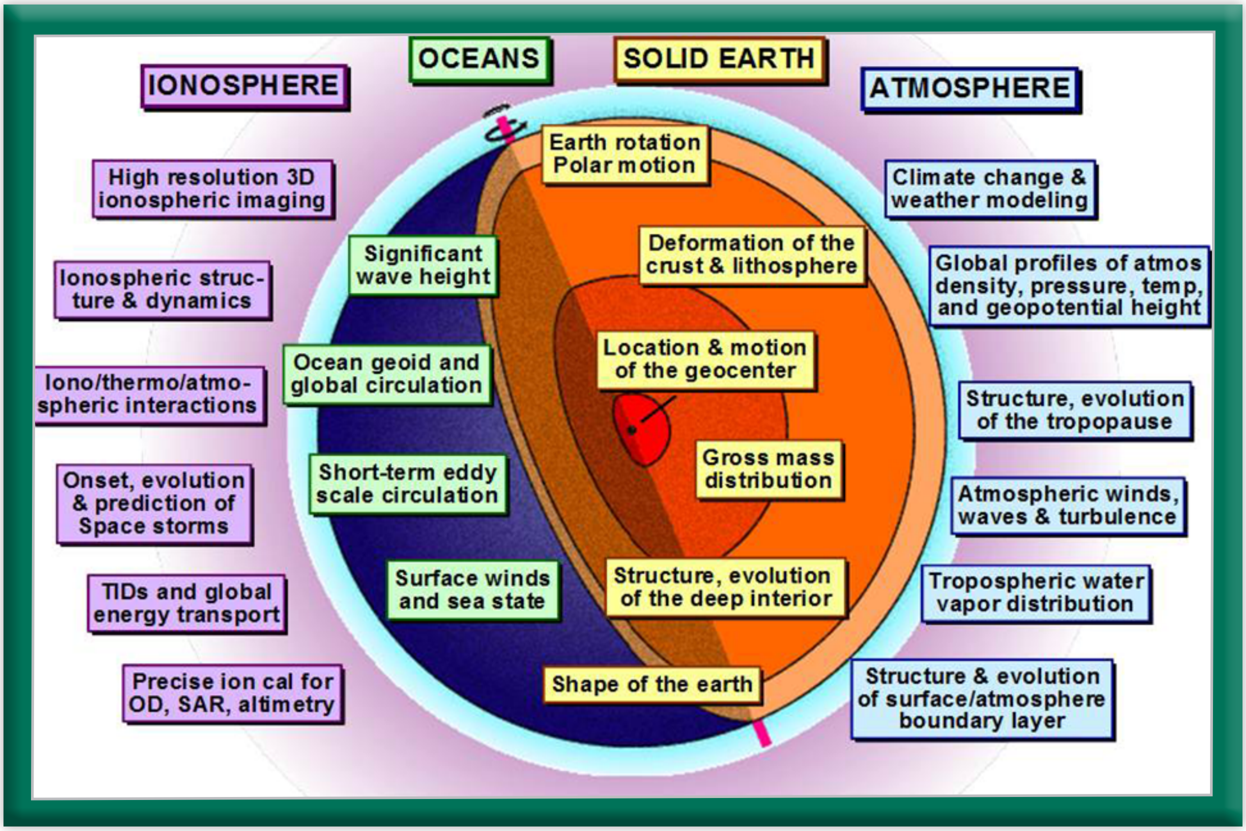
GPS Uses

GPS was developed by the US Department of Defense during the Cold War as a means to fire ballistic missiles accurately from a submarine. In the early 1990s, the US Air Force launched a navigational satellite into orbit that completed development of the Navstar constellation of satellites, or GPS as we now know it. GPS remains owned and operated by the US Department of Defense. It gives us essential positioning capabilities for the military, and it is free to users around the world.

Today, we use GPS receivers most commonly for pinpointing our locations on Earth and for navigating from point A to point B. Simply enter an address into Google Maps, or similar navigational program, and you're there!

As powerful as GPS is for navigating our world, there are many other uses. Aviation and boating industries use GPS for positioning and tracking. The technology allows them to determine the best and safest routes possible. Farmers use GPS zone maps for accurate planting and harvesting.

Other uses include surveying, tracking for law enforcement, animal tracking, emergency services, public safety and disaster relief. Personal uses of GPS continue to expand with technology development. Imagine, in the near future, cars that drive themselves. With GPS and some innovative auto manufacturing, robotic cars can use GPS to navigate safely to their destinations.



NASA GPS applications enable greater spacecraft autonomy and more advanced space science and Earth monitoring applications.

Courtesy of NASA

Did You Know?

In the 1939 film, The Wizard of Oz, Dorothy finds her way back home thanks to her ruby slippers. Turns out that was not such a far-fetched idea! Thanks to GPS-enabled shoes like GPS SmartSole®, wearers can navigate to any place on Earth. For young children and seniors with memory issues, these special shoes can be lifesaving!

Military Satellites

Hundreds of military satellites orbit the Earth. The most common missions are intelligence gathering, navigation, and military communications. The exact number of military satellites is not known due to secrecy, and some serve a dual purpose serving military and civilian organizations.

Did You Know?

The People's Republic of China demonstrated its ability to launch a land-based kinetic kill vehicle into a satellite when it fired a missile into an aging satellite and destroyed it on January 11, 2007. Kinetic kill vehicles use the speed gained through acceleration to destroy another object on impact.

1983 military artist's concept of an anti-satellite missile after being launched from an F-15 Eagle aircraft.
Courtesy of Everett Historical/Shutterstock

The first use of military satellites was for reconnaissance, which is *the military observation of a region to locate an enemy or ascertain strategic features*. There were attempts to develop satellites as weapons, but this was halted in 1967 with a multinational treaty banning weapons of mass destruction from being placed in space. However, this has not fully prevented the development of weaponized satellites. Anti-satellite weapons (ASAT) are types of space weapons designed to incapacitate or destroy other countries' satellites for strategic purposes.

Several nations have operational ASAT systems; some weapon systems are ground launched and can track and destroy a satellite in orbit; and some satellites themselves can maneuver in space to destroy or incapacitate another satellite. Intercepting a satellite of another country could seriously hinder that country's military operations. There are many ways to destroy or incapacitate a satellite, something every country takes seriously.

How Much Does a Satellite Cost?

Satellites are complex pieces of equipment that contain expensive technology and must last in space for long periods of time. Satellites come with a high price tag! A typical weather satellite costs around $290 million, while a spy satellite could cost around $390 million. A company that has a satellite in space must also pay for satellite bandwidth, which is the cost to maintain satellites. Think of this like your cell phone bill. You purchase your phone and then pay a monthly fee to maintain services on the phone. The bandwidth costs for a satellite are approximately $1.5 million per year.

The development and maintenance costs are not the only cost considerations for a satellite. Launching a satellite into space is quite expensive, as well. Launch of a satellite can cost between $10 to $400 million.

Space Technology in Everyday Use

Since its beginning, NASA has provided leading-edge innovations for space exploration and discovery. New information about scientific principles in our solar system can be used to create new products here on Earth.

Consider the fields of transportation, communications, construction, and food processing. Many of the new products we enjoy today come from NASA research. Stronger, longer-lasting radial tires for cars, GPS technology for navigation, highway safety grooving, and improved baby formulas are just some examples of NASA technology transfer. Additional examples include life-saving insulin pumps, water purification systems, memory foam, and athletic shoes. All of these products come from NASA research!

Not only do these products benefit us individually, they also help to bring us all together as one large human society.

So how do NASA innovations make their way to the private sector? The Space Technology Mission Directorate (STMD) manages NASA's Technology Transfer (T2) program. This program shares the innovations developed for exploration and discovery with the public. The program opens up its patent portfolio , containing nearly 2,000 NASA technologies, its software catalog (with over 1,000 programming codes), all for free.

The program also offers almost 2,000 examples of technology transfer through its Spinoff website and publication. Spinoffs *are the technologies, products, and processes based on NASA innovations*.

Aside from the patent portfolio, software catalog, and Spinoff website, there's more! The T2 University program brings NASA technologies to the classroom for aspiring businesspeople. Interested students build business proposals using T2 research and content to plan commercial applications. The program has already generated success. Building off of the NASA-patented sensor designed for space shuttle orbiter window inspection, a team of graduate business students successfully licensed the sensor as a new commercial product. Royalties from the product are collected by NASA to fund additional technology research and development.

CHECKPOINTS

Lesson 3 Review

Using complete sentences, answer the following questions on a sheet of paper.

1. What are satellite relays and how do they work?
2. Why was the Early Bird satellite developed?
3. How did INTELSAT satellites work?
4. What is the difference between a geostationary-orbit and a polar-orbit?
5. How do satellite cellular phones compare to typical mobile phones?
6. How does the process of trilateration work?
7. Who owns and operates GPS in the United States?
8. What are the most common missions for military satellites?
9. How does NASA's Technology Transfer (T2) program share technology innovations?

APPLYING YOUR LEARNING

10. Based on what you have discussed in this lesson, how do you think satellites can be used to improve everyday life?