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The Importance of the Space Program

An Interactive Qualifying Project Report
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by

Patrick Gaw

Patrick Gaw

Joshua Paquette

Brian Farragher

Brian Farragher

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Professor Carlos J. Morales, Major Advisor

Abstract

This IQP explores the importance of the space program in society. It focuses on the impact of how space technology enhances our lives on Earth. We present a history of the space program and describe five examples of space technology and specific uses: remote sensing, GPS, radar, SAR, and lidar. We conclude with a brief cost assessment and survey in support of the view that space funding is justifiably valuable.

Acknowledgments

Mr. Carlos Morales, Assistant Professor, Mathematical Sciences, WPI

Mr. Donald Heighton, Facilities Manager, Abbott Bioresearch Center, Worcester, MA

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1. Introduction

What impact does the space program have on your life? Is the 1% of the federal budget given to the space program worth it to you? While this paper does not fully answer these questions it hopes to shed light on the importance of the space program in society and its impact on everyday life. The paper begins with a brief history of some types of technology used in space, focusing on the 1950's to the present day. We then focus on the past, present, and future missions to the planet Mars, outlining the goals and objectives carried out by each mission. The report also discusses the different types of satellites and the technologies we use that enhance our lives on Earth. Some of these technologies include remote sensing, GPS, radar, lidar, and SAR. All this information is in support of our main objective, which is to argue that funds spent on the United States space program is justifiably worth it. Through our brief cost assessment and survey, it is evident that the more people know about how much the space program actually does for us here on Earth, the more the individuals agree the money is put to good use.

2. The U.S. History of Space Exploration 1950's – Present

This section details the history of space exploration from approximately 1950 to the present. It outlines the missions, accomplishments, and shows the progress made by the space program over the years.

2.1 1950's

October 4, 1957- In 1957 the Russian Space Center beat the Untied States into outer space by launching the first artificial satellite. This was called Sputnik 1, and weighed 184 pounds. This satellite transmitted radio signals back to earth for only a short time but this was a major leap in Space technology.

November 7, 1957- The Russians again beat the U.S. into Space by launching Sputnik 2. This mission proved that animals could survive in a controlled environment for a certain amount of time. This mission lasted for 8 days.

Figure 1: Sputnik2

January 31, 1958- This was a historic day for the United States. The U.S. Army launched our first satellite called Explorer 1. It contained several scientific instruments but more importantly revealed that the planet Earth is surrounded by radiation belts.

October 1, 1958- This was the year that the National Aeronautics and Space Administration (NASA) were founded. It now took over the responsibilities of the NACA, (National Advisory Committee on Aeronautics).

January 2, 1959- Russian satellite, Luna 1 launched towards the moon. Its objective was to hit the moon but the moon's gravity carried it out to space.

September 12, 1959- Russian satellite, Luna 2 is the first man-made object to land on the moon.

October 4, 1959- Russian satellite, Luna 3 is launched to orbit the moon. This mission was a success because it was able to photograph 70% of the moon's far side.

2.2 1960's

April 1, 1960- The U.S. launched Tiro 1 into Space. It was the first successful weather satellite used in space. Two TV cameras were located in the satellite and they transmitted images of clouds above the earth. It was only operational for 78days but it was a major success that proved we could survey weather conditions through satellites.

August 18, 1960- The U.S. launches the first camera equipped spy satellite (Discoverer XVI).

April 12, 1961- Russian Cosmonaut, Yuri Gagaria, became the first human to venture in space.

August 2, 1962- Mariner 2 was the first spacecraft to successfully encounter another planet, Venus.

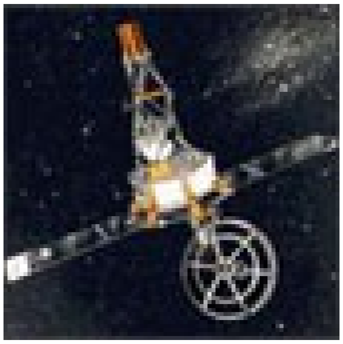

Figure 2: Mariner 2

May 5, 1961- U.S. astronaut, Alan Shepard became the first American to be launched into space. It only lasted 15 minutes.

February 20, 1962- John H. Glenn orbited the earth 3 complete times, which lasted 4 hours and 56 minutes. He was aboard the Atlas D. Rocket.

July 14, 1965- Mariner 4 arrived on Mars and gave scientists their first look at the planet. The photo's shown depicted no sign of water canals or any forms of life at that time.

February 3, 1966- Russian spacecraft, Luna 9 landed on the moon. This was a major mission because now the world knew the moon could support the weight of a spacecraft.

June 2, 1966- Surveyor 1 was the first American spacecraft to land on the moon. It transmitted 11,000 photographs before its departure.

January 27, 1967- First U.S. space tragedy. Gus Grissom, Ed White, and Roger Chaffee were killed by an explosion on the launch pad.

October 11, 1968- Apollo 7 became the first manned mission to orbit the earth once. Walter M. Schirra, Don Eisele, and Walter Cunningham were aboard.

July 20, 1969- Apollo 11 makes the first successful landing on the moon. Neil Armstrong and Edwin Aldrin Jr. became the first humans to ever walk on the moon.

2.3 1970's

April 19, 1971-The Russians launch Salyut 1 space station. It remains in orbit until May 28, 1973.

July 30, 1971- David Scott and James Irwin drove the first moon rover while exploring the Moon's surface on Apollo 15.

Figure 3: Apollo 15

November 13, 1971- Mariner 9 is the first spacecraft to orbit Mars. Over the next year, it photographs 100 percent of the Mar's surface.

May 14, 1973- The U.S. launches the first U.S. space station Skylab, It will be occupied by three crews and be an important area for certain scientific experiments.

July 17, 1975- U.S. launches Apollo 18 and Russian spacecraft Soyuz 19 dock in space together. This was known as the Apollo-Soyuz Test Project, this important mission proved that U.S. and Russian crews could work together in space.

July 20, 1976- Pictures of the Mar's surface are taken by Viking 1, this was the first U.S. attempt to land a spacecraft on another planet.

September, 1976- The U.S. Viking 2 lands on Mars, where it discovered water frost.

March 5, 1979- The U.S. Voyager 1 spacecraft, (launched in 1977), arrives at Jupiter and begins sending back images of the planet and the moon's surrounding it.

2.4 1980's

April 12, 1981 - The first manned mission of the Space Transportation System (STS-1), *Columbia,* is launched.

Figure 4: STS-1 Columbia

June 19, 1981 - The European Space Agency launched its third Ariane rocket.

December 20, 1981 - The ESA launched its fourth Ariane rocket.

March 1, 1982 - *Venera 13* lands on Venus, and provides the first Venusian soil analysis.

April 19, 1982 - Soviet *Salyut 7* space station is launched by the Russians.

May 13, 1982 - Soviet Cosmonauts Anatoly N. Berezovoi and Valentin V. Lebedev are sent to rendezvous with *Salyut 7*, the first team to inhabit the space station. They returned to Earth 211 days later, which set a Space record.

August, 1982 - *Voyager 2* completes its flyby of Saturn.

November 11, 1982 – The U.S. space shuttle *Columbia's* fifth mission, deploying two satellites. Vance Brand, Robert Overmyer, Joseph Allen, and William Lenoir were onboard.

April 4, 1983- America's second Space Shuttle, Challenger, embarks on its first mission into space. The mission includes America's first space walk in nine years.

June 19, 1983 - The First U.S. woman to travel in space, Sally K. Ride traveled on *Challenger* mission STS-7.

October 10, 1983 - Soviet Venera 15 returns the first high-resolution images of the Venus polar area, and compiled a thermal map of most of the northern hemisphere.

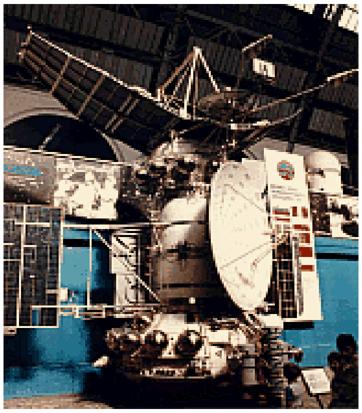

Figure 5: Venera 15

November 28, 1983 - The U.S. space shuttle Columbia carries the ESA Spacelab-1 into orbit. Ulf Merbold, A German and first ESA member in space.

January-November, 1983 - The Infrared Astronomical Satellite finds new comets, asteroids, galaxies, and a dust ring around the star Vega that may be new planets.

January 24, 1985- The Voyager 2 spacecraft arrives at Uranus, giving us our first close-up views of the blue planet and its moons.

January 26, 1986- The space shuttle Challenger explodes after liftoff of mission STS-51L, resulting in the loss of the spacecraft and her crew.

February 20, 1986-The first phase of the Russian Mir space station is successfully launched and placed into Earth orbit.

2.5 1990's-Present

April 24, 1990- Space Shuttle Discovery lifts off, carrying the Edwin P. Hubble Space Telescope (HST). The telescope is successfully deployed, but is found to contain a seriously flawed primary mirror resulting in fuzzy images.

August 10, 1990- U.S. spacecraft Magellan arrives at Venus and begins mapping the planet's cloud-covered surface using radar.

April 5, 1991 - Space Shuttle *Atlantis* carries the *Compton Gamma Ray Observatory* into orbit. This new space telescope was the first to provide an all-sky continuous survey in the gamma-ray and X-ray spectra.

June 5, 1991 – U.S. Shuttle *Columbia* carries the *Spacelab* SLS-1 into orbit, to conduct investigations into the effects of weightlessness on humans.

September 25, 1992 – U.S. launches the *Mars Observer*, this was the first American probe to Mars in 17 years, since *Viking 2*. This probe is intended as an orbital mapper to study the red planet's atmosphere, surface, and geological make-up.

February 6, 1995- Eileen M. Collins becomes the first woman to fly a Space Shuttle on mission STS-63. During the mission, Space Shuttle Discovery maneuvers to within 37 feet of Russian space station Mir, in preparation for a future shuttle-Mir docking.

July 4, 1997-The Mars Pathfinder probe lands on the surface of Mars. A small robotic rover examines the land, sending back images of the planet's surface.

February 14, 1998 - The four satellites *Globalstar 1, 2, 3, and 4* are the first in Globalstar's planned 44-satellite constellation of medium-Earth- communications satellites for providing voice and data links worldwide from both remote and home telephones.

December 4, 1998- The Space Shuttle Endeavour lifts off for space carrying the Unity module for the International Space Station.

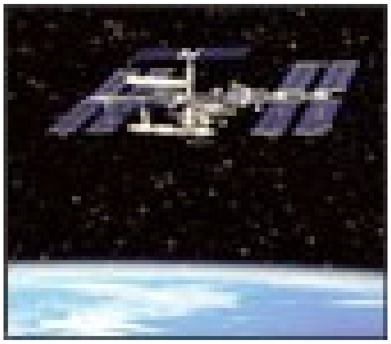

Figure 6: International Space Station

December 19, 1999 - Space Shuttle *Discovery* lifts off for the third maintenance mission to the Hubble Space Telescope. They perform three space walks, installing six new gyroscopes, a new guidance sensor, and a new computer, a voltage/temperature kit for the spacecraft's batteries, a new transmitter, a new solid state recorder, and thermal insulation blankets.

February 14, 2001- U.S. astronauts Thomas Jones and Robert Curbeam Jr. make history as they perform the 100th spacewalk in the United States space program.

April 7, 2001 - the *2001 Mars Odyssey* probe is launched to Mars, with a mission similar to that of the *Mars Climate Orbiter* launched December 1998. *Mars Odyssey* successfully enters Mars orbit on October 24th.

As you can see many discoveries and a lot of progress has been made over the years in our Space program. There have been a few set backs but many technological breakthroughs. The future of the Space program looks promising and the technology will only get better. The new discoveries and technology developed will greatly benefit us in the years to come.

3. Mars

Is Mars inhabited? Is there water present? Brought about by mere earth-based observations, these questions and many more have surrounded the fiery red planet for thousands of years. The answers, however, could only be found by direct observation.

3.1 The Mariner Mars Missions

Mariner 4 was the first spacecraft in the exploration of Mars. With its launch on November 28, 1964, Mariner 4 was designed with three main objectives. First, the probe on the spacecraft was to conduct field and particle experiments in interplanetary space. Secondly, Mariner 4 was to provide close range images of Mars in order to provide us with the most detailed surface pictures ever obtained of the planet. (Note: images with earth-based telescopes were all we had prior to Mariner 4) Finally, the mission was to offer experience in operational and engineering techniques required for long-term interplanetary missions. And as it turned out, the Mariner 4 mission was a success. The relayed surface images revealed a cratered and moon-like surface and thus the Mariner 4 was the first spacecraft to obtain and transmit close range images of Mars.

Mariner 6 & 7, which were identical spacecraft, were next up in the exploration of Mars in 1969. The probes on these spacecraft were designed to concentrate entirely on Mars. The primary objective of this mission was a hope that the surface images of greater quality and quantity would provide a more complete picture of the Martian surface. Also, when these images were combined with the atmospheric data, there was a hope that these things would be able to aid in the planning of future missions in search of life on Mars. The mission, after a temporary loss of Mariner 7, was a complete success. In total, 201 images of Mars were acquired, covering about 10% of the Martian surface.

The images essentially told us two things: (1) There was no correlation between geographical features and the light and dark areas seen by the previous Earth based images, and (2) They still did not show the widely varied terrain that was hoped for. However, later missions did reveal the truth about the interesting surface of Mars.

The subsequent spacecraft, Mariner 9, which happened to weigh more than Mariner 6 and 7 combined, was the first of NASA's Mars orbiters. The spacecraft itself was launched on May 30, 1971 designed to provide the most complex view of Mars ever obtained. Using techniques similar to those used on previous Mariner missions, mission goals were to map over 70% of the Martian surface as well as look for signs of volcanic activity denoted by heat anomalies on the surface using infrared radiometry. Mariner 9 was also responsible for analyzing Mars' two moons, Phobos and Deimos. Mariner 9 not only met these goals, but it far exceeded its expectations in every way. To begin with, the spacecraft obtained some 7329 images, covering about 80% of the planet and revealing the surface and atmosphere of Mars to be as varied as planetary scientists had hoped. Some of these surface features included ancient riverbeds, craters, massive extinct volcanoes, canyons, layered polar deposits, ice clouds, localized dust storms and more. In addition to all of this, many other observations were made. These observations included:

- A lack of evidence for volcanic activity
- Irregularities in Mars' gravity field
- Properties of the daytime ionosphere
- Measurements of atmospheric water vapor content
- Altitude measurements

- Ultraviolet spectrum of Phobos

After the Mariner missions, the existence of life on Mars was intensified. It was clear that a lander would be best suited to land on Mars. These results paved the way for the Viking program.

3.2 The Viking Missions

The Viking mission to Mars was composed of two spacecraft, each consisting of an orbiter and a lander. The primary objective of this mission was to obtain high-resolution images of the Martian surface, characterize the structure and composition of the atmosphere, and search for evidence of life.

The beginning of the mission was marked by the launch of Viking 1 on August 20, 1975. The spacecraft reached Mars on June 19, 1976 and spent its first month of orbit devoted to imaging the surface to find appropriate landing sites for the Viking landers. Then on July 20, 1976 the lander separated from the orbiter and finally touched down on the red planet.

Viking 2 was launched approximately one month later than Viking 1 on September 9, 1975. It entered Mars orbit on August 7, 1976 and the lander touched down on September 3 of the same year. Both orbiters imaged the entire surface of Mars at a resolution of 150 to 300 meters as well as selected areas at a resolution of eight meters. The Viking 2 orbiter was powered down on July 25, 1978 after 706 orbits while the before mentioned Viking 1 was powered down on August 17, 1980 after over 1400 orbits.

The results obtained from the Viking mission have given us our most complex view of Mars to date (as of April 2002). The orbiter images showed evidence of volcanoes, lava plains, immense canyons, wind-formed features as well as surface water. The images also made the planet appear as if it was divisible into two main regions, northern low plains and southern-cratered highlands. However, maybe the most important piece of information obtained from this mission came from the biology experiment at each landing site that produced no evidence of life whatsoever.

3.3 Mars Pathfinder

The next mission of importance was that of the Mars Pathfinder (Figure 7). The Mars Pathfinder, consisting of a stationary lander and a surface rover, was launched on December 4, 1996 and entered the Martian atmosphere on July 4, 1997. The landing site was an ancient flood plain in Mars' northern hemisphere known as Ares Vallis. It happened to be among the rockiest parts of Mars, but, ironically enough, it was chosen because scientists believed it to be a relatively safe surface to land on. Scientists also showed great interest in the wide variety of rocks deposited on that surface during a catastrophic flood.

Figure 7: Artistic picture of Mars Pathfinder

The most important objective of this mission was to demonstrate the feasibility of low-cost landings on the Martian surface. This was done by communication tests between the rover and lander as well as between the lander and Earth, tests of the imaging devices and sensors, and also tests of the maneuverability of the rover on the surface. Other, more scientific objectives included long-range and close-up surface imaging, rock and soil composition experiments, and the general idea to characterize the Martian environment for further exploration.

When it was all said and done, the Mars Pathfinder returned 2.3 billion bits of information, including more than 16,500 images from the lander and 550 images from the rover. It was also able to obtain more than fifteen chemical analyses of rocks and soil as well as extensive data on winds and other weather factors. Ultimately, findings from the investigations carried out by scientific instruments on both the lander and the rover suggest that Mars was at one time in its past warm and wet, with water existing in its liquid state and a thicker atmosphere.

3.4 Mars Global Surveyor

The Mars Global Surveyor, (Figure 8) or MGS for short, entered orbit on September 12, 1997, and after a year and a half of trimming its orbit from a looping ellipse to a circular track around the planet, the spacecraft finally began its primary mission in March 1999. The mission studied the entire Martian surface, atmosphere, and interior, and has returned more data about the planet than all other Mars missions combined. It was just recently, January 31, 2001, that the MGS completed its primary mission.

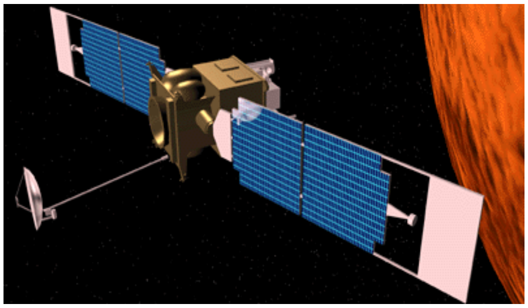

Figure 8: Mars Global Surveyor

Some of the key findings in the MGS mission include pictures of gullies that suggest there may be current sources of liquid water, similar to an aquifer, at or near the surface of the planet. Also, new temperature data and close-up images of the Martian moon Phobos show its surface is composed of powdery material at least one meter think, most likely caused by millions of years of meteoroid impacts. And data from the spacecraft's laser altimeter have given scientists their first 3-D views of Mars' north polar ice cap.

3.5 Current Missions

In 2003, two new rovers made their way to the red planet with each designed to carry a sophisticated set of instruments allowing them to search for liquid water that may have been present in Mars' past. The two rovers greatly resembled the Mars Pathfinder, but the rovers' far greater mobility allowed them to trek up to forty meters across the surface in a Martian day (forty meters is more than the Pathfinder trekked over its entire lifetime). Ultimately, the rovers were completely identical to each other, but each had its own predetermined landing region.

Figure 9: Mars Exploration Rover

The landing portion of the mission featured a design much different than the before mentioned Pathfinder. For example, the Pathfinder had scientific instruments on both the rover as well as the lander while these new rovers carried all their instruments solely on the rover. The reason for this was because immediately after landing, each rover was to begin reconnaissance of the landing site by taking a 360-degree visible color and infrared panorama. Soon after, they began their exploration.

With the images and spectra taken daily by the rover, scientists were able to command the rover to rock and soil targets of interest and examine their composition at texture at microscopic scales. Initial targets happened to be close to the landing site, but others were a seemingly great distance away. These rocks and soil samples were analyzed with a set of five instruments as well as a special tool called the “RAT,” or rock abrasion tool, used to expose fresh rock surfaces for study. Initially, surface operations were to extend to late April 2004, but because the health of the vehicle has been well maintained, they continue to be carried out as we speak.

3.6 Future Missions

3.6.1 2005 Mars Reconnaissance Orbiter

According to NASA, a Mars Reconnaissance Orbiter is scheduled for launch sometime in August 2005. It will be equipped with cameras to zoom in for extreme close-up photography of the Martian surface as well as carry a sounder to find subsurface water. In fact, the onboard camera will be the most powerful camera ever flown on a planetary exploration mission, focusing on details of Martian terrain with extraordinary clarity. Previous cameras on other Mars orbiters were asked to solely identify objects no smaller than a dinner table, but this camera will be able to spot something as small as a dinner plate. This new technology will not only provide incredible detailed footage of the geology and structure of the planet, but will also help identify obstacles that could jeopardize the safety of future landers and rovers. Other science instruments on this new spacecraft will identify surface minerals and study how dust and water are transported in the Martian atmosphere. A second camera will provide medium-resolution images to place in context the detailed observations made by these other instruments.

Figure 10: 2005 Mars Reconnaissance Orbiter

An extremely interesting feature of the Mars Reconnaissance Orbiter is that it will become the first installment of an "interplanetary Internet," a crucial service for future spacecraft. It will be the first link in a communications bridge back to Earth to be used by numerous international spacecraft in coming years. In addition to all of this, the orbiter will test an experimental optical navigation camera that will serve as a high-precision interplanetary lighthouse to guide incoming spacecraft as they near Mars. NASA expects the orbiter to land sometime in March 2006.

3.6.2 The Phoenix Mission

The Phoenix Mission, named for the resilient mythological bird, will use a lander that was intended for use by the Mars Surveyor lander before NASA opted for its cancellation. After its scheduled launch in August 2007, the Phoenix will land (proposed landing is May 25, 2008) on the icy northern pole of Mars in the continuing pursuit of water. Once it touches down, Phoenix will deploy its robotic arm and dig trenches up to half a meter into the layers of water ice found on the poles. Scientists believe these layers are affected by seasonal climate changes and could contain organic compounds that are necessary for life. In order to analyze the samples collected by the robotic arm, Phoenix will also carry an "oven" and a "portable laboratory" that will heat the selected samples to release volatiles that can be examined for their chemical composition and other characteristics.

Another key feature of the Phoenix Mission is that it will scan the Martian atmosphere up to twenty kilometers, obtaining data about the formation, duration and movement of clouds, fogs, and dust plumes in order to update NASA's understanding of Martian atmospheric processes.

3.6.3 Beyond 2009

The second decade of the century calls for additional science orbiters, landers and rovers as well as the first mission to return Martian rock and soil samples back to Earth. As it stands now, the first sample return mission will be launched no earlier than 2014. The program also envisions a strong international participation, particularly from France and Italy. Working with NASA, the French and Italian space agencies plan to conduct collaborative scientific orbital and surface investigations and make major contributions to sample collection & return systems, telecommunications assets and launch services.

4. Types of Satellites

This section discusses the many different types of satellites that enhance our life today. It also gives examples of the specific types of satellites, what exactly they do and the technologies that they use.

A satellite is any object that orbits a celestial body. However, the term is often used in reference to the man-made objects that orbit the earth, either in a geostationary or a polar manner. Each manufactured satellite has a specific job which relates to the type of satellite launched into space. The following pages will discuss the different types of satellites.

4.1 Astronomy Satellites

An astronomy satellite is a satellite that is very similar to a telescope floating in space. A telescope is a device used in astronomy to see distant objects. Most telescopes use lenses and mirrors to magnify light coming from phenomena deep in space. This makes the objects look bigger and closer. The astronomical satellites use infrared radiation to create images in order to see things in space. The satellites vision is not clouded by the gases that make up the Earth's atmosphere because it is in orbit above the Earth. The infrared imaging is not confused by the heat of the Earth. Astronomy satellites can see up to ten times better than a telescope.

After getting an infrared image, they then analyze the electromagnetic spectrum. The different wavelengths of light, such as ultraviolet, x-ray, visible spectrum, microwaves, and gamma rays, make a picture of something far away in space. Pictures from astronomy satellites are not photographs from a regular camera, these images are created from the analysis of electromagnetic waves which make up the light spectrum.

Astronomy satellites have many different applications to the world. Below is a general list of what they provide for us:

- They can be used to make star maps
- They can be used to study mysterious phenomena such as black holes and quasars
- They can be used to take pictures of the planets in the solar system
- They can be used to make maps of different planetary surfaces

Astronomy satellites are different from space exploration satellites because they collect their data from Earth orbit. Space exploration satellites are really probes that are sent out into deep space.

An example of an astronomy satellite is the Hubble Telescope. The Hubble Telescope was launched by NASA in April, 1990. It is the largest astronomical observatory ever built to go into space. Hubble was supposed to be extremely powerful and able to look deep into space. Soon after Hubble's launch, Hubble was not sending back to Earth the types of images that should have come from such a powerful telescope. Scientists then discovered that one of the mirrors, known as the primary mirror, had been made too flat on one edge. The total size of the error amounted to 1/50 of the width of a human hair, but it was still enough to make Hubble's pictures fuzzy. In order to fix this problem they had a special shuttle mission, in which the astronauts took a corrective lens up to space with them and they fitted it on Hubble. Since then, the Hubble has been sending amazing images of distant galaxies and stellar phenomena that have never been seen before.

Hubble uses an internal computer system called the Tracking Data Relay Satellite (TDRS) system. This computer sends the data Hubble collects back to Earth and it also allows us to send instructions back to the satellite. The Hubble telescope orbits the earth in about 95 minutes and the data collected can be broadcasted immediately.

Figure 11: The Hubble Telescope

There is another very similar type of satellite called the space exploration satellites. Space exploration satellites basically do the same kind of research that the astronomy satellites do, except there research is done in a very different location. While astronomy satellites collect their data from Earth orbit the space exploration satellites are really just probes that are sent out into deep space and the solar system. These space probes send back detailed pictures of other planets and phenomena using remote sensors. These probes were responsible for discovering Jupiter's rings and many of astronomy's achievements.

4.2 Atmospheric Studies Satellites

Atmospheric studies satellites are satellites that are designed to study the Earth's atmosphere. These satellites were some of the very first satellites launched into space and they have low Earth orbits so they are capable of studying the atmosphere. The Earth's atmosphere is composed of several layers of gases that separate our planet from space, which includes the air we breathe. The major gases in the Earth's atmosphere are nitrogen and oxygen. Below is a list of the many things an atmospheric satellite can and will study in the very near future in order to help us better understand our Earth's atmosphere.

- Monitor atmospheric pollutants, track the interplay of gases relevant to global climate change, and observe levels of atmospheric ozone.
- Monitors conditions in the lower regions of Earth's magnetic field
- Observes aurora, which is when charged or electronically excited atmospheric particles relax back into there normal state. The relaxing of the particles results in a release of energy which produces colored light known as aurora.
- Collects temperature and humidity readings throughout the atmosphere by monitoring the deflection of radio beams from military GPS (Global Positioning System) satellites by the atmosphere
- Studies the changes in the mesosphere by observing certain high clouds. The mesosphere is the portion of the atmosphere from about 20 to 50 miles above the earth's surface, characterized by temperatures that decrease from 10°C to -90°C (50°F to -130°F) with increasing altitude.

- Studies the lower thermosphere and its relation to climate change by measuring nitric oxide density and its variation. The thermosphere is the outermost shell of the atmosphere, between the mesosphere and outer space, where temperatures increase steadily with altitude
- Take measurements of stratospheric gases, solar particles, radiative fluxes, and upper atmosphere winds.
- Monitor stratospheric gases, solar particle and radiative fluxes, and upper atmosphere winds.

An atmospheric satellite launched by NASA in February of1996 is Polar, which has an orbital period of 18 hours and is being used to gather information that will help scientists protect future satellites from radiation and other atmospheric dangers. Polar has studied the aurora and collected some data about the equatorial inner magnetosphere.

It has also shed light on energy exchange between the magnetosphere and the ionosphere. The data that Polar is receiving will help engineers design future spacecraft that will be able to withstand the electromagnetic activity in space.

Figure 12: NASA's Polar atmospheric satellite

4.3 Remote Sensing Satellites

Remote Sensing satellites collect and observe our Earth from a distance without any contact. Satellite remote sensing uses spacecraft and satellites to take photographs at great heights above the Earth's surface. There are numerous satellites circling the earth today, some of which being geostationary and the others polar orbiting. Geostationary satellites remain over the same point above the Earth, which means that they are traveling at the same speed as the rotation of the Earth. Polar orbiting satellites orbit round the Earth in a polar direction. Each pass over the equator is about 30 degrees west of the previous orbit because the Earth continues to rotate below the satellite. Pictures can be done best from space because a satellite in orbit can normally take photographs of large expanses of land all over the world. Since these satellites are able to take photographs and observe areas all over the globe, the satellite is able to monitor areas in which the climate is very harsh, or which are nearly impossible to reach by land.

Canada's main remote sensing satellite launched in 1995 is called Radarsat. This satellite aids in research and resource management in agriculture, oceanography, forestry, hydrology, geology, cartography, meteorology, and many other environmental fields. Even though this like many other satellite program was very expensive, Radarsat is expected to bring in about $800 million to Canada in return for the data it collects. Because it is circling the globe from pole to pole in a sun-synchronous orbit, it passes over each area of the globe that it covers at the same time every day. For example, it might make observations of the North Pole at noon everyday and of Ottawa at six pm everyday. In a dawn to dusk orbit, Radarsat solar panels will be in sunlight almost constantly so that it can rely mostly on solar power, not battery power.

It covers the entire Earth every 24 days while the date it collects is stored on the satellite's computer until the spacecraft is within range of a receiving station. The processed data becomes available to people who are hooked up by computer and have paid for Radarsat's services only a few hours after the satellite has passed over an area. This is possible because Radarsat is equipped with an on board computer that can process and transmit information daily to several stations on Earth.

Figure 13: RADARSAT

The remote sensing technology will be explored with much greater detail later on in Section 5.

4.4 Reconnaissance Satellites

You may have heard more about the other types of satellites that we have explored, the ones that are used for scientific research, communications, navigation, or for monitoring weather. Reconnaissance satellites, which have far less public uses, are solely launched into space by countries to provide military and intelligence information on the military activities of foreign countries.

Secret programs that dealt with spying on foreign countries first started in the late 1950’s for the United States and the Soviet Union. The armed forces mainly used these orbiting satellites to research battlefield information, locate known or missing troops, ensure communication, and take pictures. There are certain satellites that keep watch on signs of a possible potential nuclear missile and a nuclear explosion. There are also satellites that are able to detect missile launches, pick up radio transmissions and some satellites can be used as an orbital weapon by placing warheads on a low orbit satellite to be launched at a ground target.

There are four major types of reconnaissance satellites. First, there are the early-warning satellites that detect enemy missile launchings. Second, there are the nuclear-explosion detection satellites that are designed to detect and identify nuclear explosions. Next there are the photo-surveillance satellites to provide photographs of enemy military activities. These satellites can also be divided into two other categories; close-look satellites which provide high resolution photographs that are returned to earth via a re-entry capsule and area survey satellites which provide lower resolution photographs that are transmitted to earth via radio. Some of these satellites today were designed to combine these two functions. Other satellites use radar to provide images of enemy activity when there is cloud cover or it is dark. Electronic-reconnaissance or ferret satellites are able to pickup and record radio and radar transmissions while passing over a foreign country.

The information available on reconnaissance programs for the United States is available only for programs occurring after 1972. Some information prior to this time is still classified. It is very difficult to get information on any recent reconnaissance programs because mostly all are classified although sometimes information is leaked on accident.

One reconnaissance satellite currently in space is the $500 million satellite called the Lacrosse. The Lacrosse has an image sensor that allows us to see objects on Earth through clouds and darkness. The Lacrosse beams microwave energy to the ground and the sensor reads the weak return signals in space. This is very similar to remote sensing which is discussed in much more detail in section 5. The Lacrosse also uses Synthetic Aperture Radar (SAR) technology. This technology allows the satellite to see about only three feet across which is sufficient to be able to see military hardware in foreign companies. Lacrosse provides a series of snapshots as it orbits the earth, unlike other satellites that will present a constant stream of images, like radars.

4.5 Navigation Satellites

Navigation satellites were created for one purpose although today they have many applications. The navigation satellites were made in order for ships to know where they exactly were at any given time. Most of the navigation systems use time and distance to determine location. If you are given the velocity and the time required for a radio signal to be transmitted between two points, the distance between the two points can be computed. All you have to do is measure the time it take for a signal to travel from the transmitter to the receiver and back then you can multiply the exact speed of light to obtain the distance between the two positions. There are many navigation satellites in space such as the Transit, Timation, Nova and Navstar which we will talk about later. All of these satellites allow users to determine where they are located within a few meters. Soldiers can now determine their location with extreme accuracy making a map reading far more reliable than previously. These satellites allow aircraft to fly anywhere in the world and without using conventional navigation equipment they can determine their location within a hundred feet.

An example of a navigation satellite is the Navstar satellites. The Navstar satellite is a three dimensional satellite that enables the user to find out his or her position anywhere on or above the planet. The Navstar will provide the user with the time, the precise orbital position of the satellite and the position of other satellites in the system. There are about 24 orbiting Navstar satellites devoted to navigation. These 24 Navstar satellites make up the Global Positioning System (GPS)

In order to use this system the user can buy a locator and with that locator can calculate distance by measuring the time it takes for the satellite's radio transmissions, traveling at the speed of light, to reach the receiver. When the distance from four of the satellites is known, the position is then given in three dimensions (latitude, longitude, altitude). The new GPS receivers do all the work for the users as all the mathematics are pre-programmed into the locators, and the information is displayed automatically. Global Positioning System and its many other applications will be discussed in greater detail in section 5.

Figure 14: Navstar Satellite

4.6 Search and Rescue Satellites

Search and rescue satellites are able to detect and locate emergency beacons carried by ships, aircrafts, or individuals in remote places. The idea of the search and rescue satellites came from the weather satellite programs. Some weather satellites are able to analyze signals sent out from buoys floating in the ocean. The buoys collect weather information and are then able to transmit the data back to the satellite. The satellite is also able to determine the location of the buoy by using the Doppler Effect which is very similar to the technology used today for the search and rescue highlights. The Doppler Effect is a shift in the frequency of a wave. The frequency of a sound wave determines the pitch, and the distance of the source of the sound from the sound's observer determines the amount that the frequency seems to have shifted, known as the Doppler shift. Satellites equipped with search and rescue equipment are able to receive an emergency signal while flying above the beacon. Using mathematical calculations involving the Doppler Effect, scientists can translate that signal into coordinates and determine the location of the distress signal.

The National Oceanic and Atmospheric Administration (NOAA) is a vital part of worldwide search and rescue. The NOAA operates the Search and Rescue Satellite Aided Tracking System (SARSAT) which detects and locates ships, planes and recreational enthusiasts in distress. NOAA is able to locate a user almost anywhere in the world at anytime and in most conditions. The SARSAT system uses NOAA satellites in low-earth and geostationary orbits to detect and locate aviators, mariners, and land-based users in trouble. The SARSAT system is made up of a network or satellites and stations. The network of satellites is capable of relaying the distress signals from emergency beacons to the ground station and also the U.S. Mission Control Center (USMCC) in Suitland, Maryland. The USMCC then processes the emergency signal and in turn alerts the appropriate search and rescue authorities about who and where they are located. NOAA-SARSAT is a part of the international Cospas-Sarsat Program to which 36 nations and two independent SAR organizations belong to.

Listed below are some very impressive statistics for the number of lives saved from the COSPAS-SARSAT Program. These statistics are as of July 1, 2004.

- Worldwide – Over 17,000+ Persons Rescued (since 1982)
- United States – 4,771 Persons Rescued (since 1982)

Number of Persons Rescued To Date in the United States in 2004: 114

- Rescues at sea: 101 lives saved in 39 incidents
- Aviation rescues: 1
- PLB rescues: 12 lives saved in 7 incidents (all in Alaska)

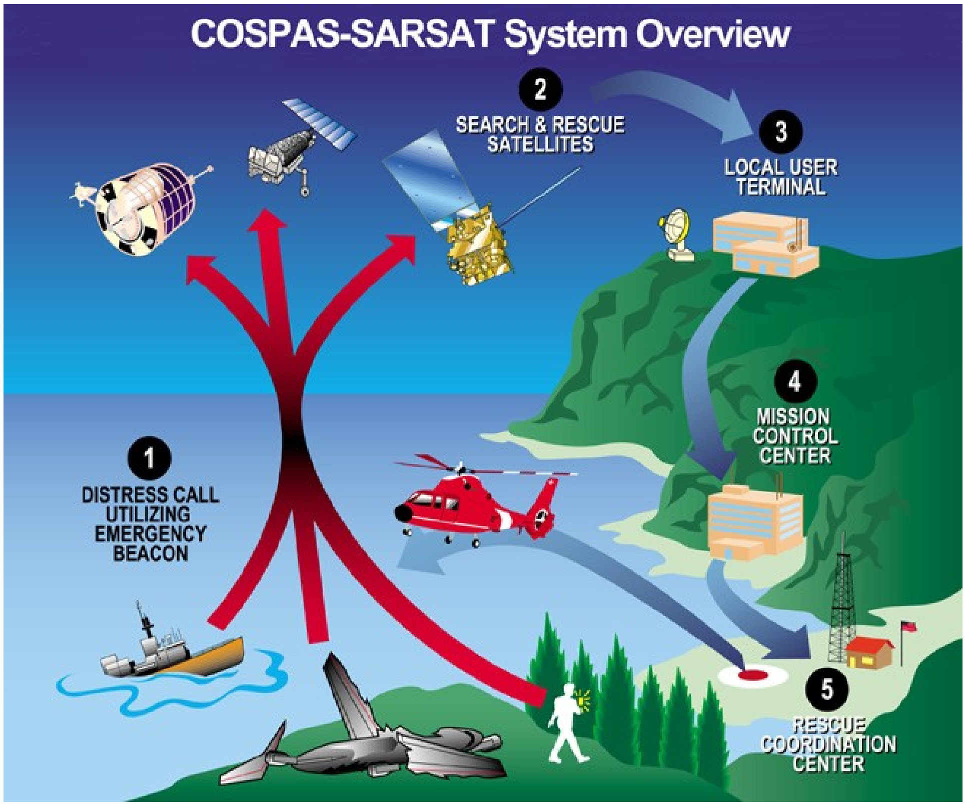

Figure 15: COSPAS-SARSAT System Overview

4.7 Communication Satellites

Communication satellites are probably the most significant satellites that have a direct effect on you. Quite likely, this type of satellite plays the biggest role in your life as it is essential for many of society's everyday operations to take place. Communication satellites allow us to listen to the radio, watch television and use telephones anywhere in the world. Before the innovation of these satellites, transmissions over long distances were very difficult, if not impossible. The signals are straight signals so they are not capable of bending around the earth. The satellites, because they are in orbit, are able to receive and redirect the straight signals to other satellites until they can be transmitted directly to the destination.

Communication satellites can have a passive role in communications, in which they just bounce the signals from the Earth back to another location on the Earth. They can also contain electronic devices called transponders for receiving, amplifying, and re-broadcasting signals to the Earth. Communication satellites are at a high orbital altitude of 35,800 kilometers. These satellites are in geostationary orbit meaning they orbit the Earth in the same amount of time it takes the Earth to revolve once. This means that the satellite is always above the same area of Earth and this area, the area to which it can transmit, is called the satellite's footprint.

Some smaller communication satellites that are very small aperture terminals also known as VSATs relay digital data for a multitude of business services. The International Mobile Satellite Organization (INMARSAT) is a mobile telecommunications network, providing digital data links, telephone, and facsimile transmission or fax, service between ships, offshore facilities, and shore-based stations throughout the world. Soon enough the network will also allow for voice and fax transmission to aircraft on international routes. The latest development in satellites is the use of networks of small satellites in low earth orbit, 2,000 km or less, to provide global telephone communication. Special telephones that communicate with these satellites allow users to access the regular telephone network and place calls from anywhere on the globe. Anticipated customers of these systems include international business travelers and people living or working in remote areas.

4.8 Weather Satellites

Weather satellites allow anyone to find out the weather anywhere in the world at any time of day. Meteorologists use weather satellites to determine may things that are valuable to society by studying satellite images. Below is a list of examples that weather satellites can do.

- Play a very significant role in emergency weather warnings. Weather satellites make it possible to warn populations of pending dangers from hurricanes, monsoons, tidal waves, fires and earthquakes. The number of lives saved is uncountable in result of evacuations prior to sever weather in that particular location.
- Radiation measurements from the earth's surface and atmosphere and give information on amounts of heat and energy being released from the Earth and the Earth's atmosphere.
- Monitor the temperature of the sea which is very valuable information for fishers.
- Satellites monitor the amount of snow in winter, the movement of ice fields in the Arctic and Antarctic, and the depth of the ocean.
- Infrared sensors on satellites examine crop conditions, areas of deforestation and regions of drought.
- Some satellites have a water vapor sensor that can measure and describe how much water vapor is in different parts of the atmosphere.
- Satellites can detect volcanic eruptions and the motion of ash clouds.

- During the winter, satellites monitor freezing air as it moves south towards Florida and Texas, allowing weather forecasters to warn growers of upcoming low temperatures.
- Satellites receive environmental information from remote data collection platforms on the surface of the Earth. These include transmitters floating in the water called buoys, gauges of river levels and conditions, automatic weather stations, stations that measure earthquake and tidal wave conditions, and ships. This information, sent to the satellite from the ground, is then relayed from the satellite to a central receiving station back on Earth.

There are two basic types of weather satellites, those in geostationary orbit and those in polar orbit. The geostationary satellites orbit the Earth in the same amount of time it takes the Earth to revolve once. These satellites are always above the same area of the Earth which allows the satellite to monitor the same region all the time. Geostationary satellites usually measure in "real time", which allows them to transmit photographs to the receiving system on the ground as soon as the camera takes the picture. A series of photographs from these satellites can be displayed in sequence to produce a movie showing cloud movement as you see on many weather channels. This allows forecasters to monitor the progress of large weather systems such as fronts, storms, and hurricanes. Forecasters can also find out the wind direction and speed by monitoring cloud movement. The polar orbiting satellites orbit in a path that closely follows the Earth's meridian lines, passing over the north and south poles every time it revolves around the earth. Each pass of the satellite monitors a narrow area running from north to south, to the west of the previous pass. These strips can be pieced together to produce a picture of a larger area. Polar satellites circle at a much lower altitude at about 850 km rather than about 35,800km like geostationary satellites. This means that polar satellites can photograph clouds from closer than the high altitude geostationary satellites. Polar satellites, therefore, provide more detailed information about violent storms and cloud systems. Below is a picture of the geostationary weather satellite, Meteosat which sends digitally encoded, high resolution infrared and visible light images to its operational base station in Germany.

Figure 16: Meteosat

5. Technologies Used by the Satellites

Section five discusses the types of technologies the different satellites use. It deals with several different technologies, how they work, and how their applications improve every day life. These technologies include Remote Sensing, GPS, Radar, Lidar, and SAR.

5.1 Remote Sensing

Figure 17: Applications of remote sensing

5.1.1 How it works

Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information. This technology consists of collecting geophysical information about targets on earth without making physical contact. Remote sensing has been recognized as a valuable tool for viewing, analyzing, characterizing, and making decisions about our environment. Remote Sensing technology has many uses in many different fields and aids in human life by an immeasurable amount. It is used in the military and for a variety of environmental analysis applications that relate to land, ocean, and atmosphere issues.

This technology is used in aircraft and satellite platforms, photographic systems, sensors that convert energy, and in dealing with the electromagnetic spectrum or electronic signals.

Today, we define satellite remote sensing as the use of satellite-borne sensors to observe, measure, and record the electromagnetic radiation reflected or emitted by the Earth and its environment. The data is then analyzed in order for the extraction of information. Below are seven fundamentals of the remote sensing process.

1. The first requirement for remote sensing is to have an **energy source which illuminates** or provides electromagnetic energy to the target of interest. Two characteristics of electromagnetic radiation are particularly important for understanding remote sensing, which are the wavelength and frequency. Frequency refers to the number of cycles of a wave passing a fixed point per unit of time. The wavelength is the length of one wave cycle, which can be measured as the distance between successive wave crests. The shorter the wavelength the higher the frequency as is the longer wavelength the lower the frequency. Understanding the characteristics of electromagnetic radiation in terms of their wavelength and frequency is crucial to understanding the information to be extracted from remote sensing data. Different wavelengths represent different colors on the electromagnetic spectrum. The portion of the spectrum of more recent interest to remote sensing is the microwave region from about 1 millimeter to 1 meter. This covers the longest wavelengths used for remote sensing.

2. Another important part of remote sensing is **radiation and the atmosphere**. As the energy travels from its source to the target it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor This is a very difficult path as scattering occurs which is basically the radiation being redirected from its original path because they came into contact with particles or large gas molecules. Another problem for radiation is absorption which deals with the ozone, carbon dioxide, water vapor. These three main atmospheric constituents absorb radiation. Those areas of the spectrum which are not severely influenced by atmospheric absorption and are useful to remote sensors, are called atmospheric windows.

3. The next step is once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation. Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface. There are three 3 forms of interaction that can take place when energy strikes upon the surface, which are absorption, transmission, reflection. Absorption occurs when radiation is absorbed into the target while transmission occurs when radiation passes through a target. Reflection occurs when radiation "bounces" off the target and is redirected. In remote sensing, we are most interested in measuring the radiation reflected from targets. By measuring the energy that is reflected or emitted by the target on the Earth's surface over a variety of different wavelengths, we can build up a spectral response for that object. By comparing the response patterns of different features we may be able to distinguish between them, where we might not be able to, if we only compared them at one wavelength. Knowing where to look spectrally and understanding the factors which influence the spectral response of the features of interest are critical to correctly interpreting the interaction of electromagnetic radiation with the surface.

4. After the energy has been scattered by, or emitted from the target, we require a **remote sensor to collect and record** the electromagnetic radiation. There are two ways of doing this - by passively sensing natural radiation levels associated with the matter called *passive sensing* or by sending a beam of EM radiation towards the object, and observing the scattered return of the beam called *active sensing*.

Passive Sensing

Remote sensing systems which measure energy that is naturally available are called passive sensors. Passive sensors can only be used to detect energy when the naturally occurring energy is available. For all reflected energy, this can only take place during the time when the sun is illuminating the Earth. There is no reflected energy available from the sun at night. Energy that is naturally emitted, such as thermal infrared, can be detected day or night, as long as the amount of energy is large enough to be recorded.

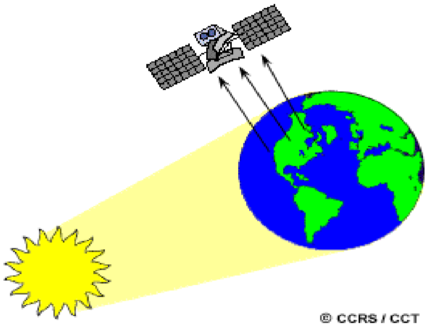

Figure 18: Passive Sensing

Passive remote sensing works in one of three ways:

- The first way the passive remote sensing works is by the process of extinction. This process observes how radiation changes, as it passes through matter. An example of this would be sunlight as it passes through a thin cloud.
- The second way allows us to observe how radiation is emitted by the object of interest. An example of this is the emission of infrared radiation by clouds.
- The third process allows us to observe how radiation is scattered by objects. An example of this is a visible satellite image taken from space.

These three methods take full advantage of the naturally occurring radiation around us, such as natural sunlight and infrared radiation emitted by certain objects. These methods provide us with a lot of valuable information that is useful in our everyday life. Just like satellites in space, we as human beings using a type of passive remote sensing in our eyes. Human eyes serve as types of passive remote sensing devices. They capture scattered and emitted visible light, which then allows our brain to process them into images. Most satellites use the passive only sensors. Currently the GOES (Geostationary Operational Environmental Satellite) series of satellites use this way of sensing and in return provide us with a great deal of information about certain aspects of our environment.

Active Sensing

Active remote sensing devices work a little different then the Passive method. The active sensing works by emitting a signal, such as radiation and then processing the return of that signal. The key points that they look for are how long the signal takes to return, the strength of that signal when it returns, and changes in the orientation of the signals.

The radiation reflected from that target is detected and measured by the sensor. Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season. Active sensors can be used for examining wavelengths that are not sufficiently provided by the sun, such as microwaves, or to better control the way a target is illuminated. However, active systems require the generation of a fairly large amount of energy to adequately illuminate targets. Some examples of active sensors are a laser fluorosensor and a Synthetic Aperture Radar (SAR).

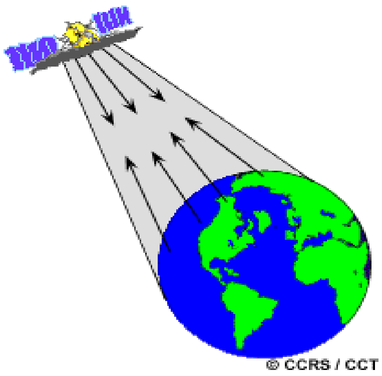

Figure 19: Active Sensing

Just like humans use passive-sensing, bats, dolphins, and whales use the active method. This method is also referred to by humans as sonar. The bats emit ultrasonic squeaks and in return wait for the squeaks to bounce of the objects around them. By listening to these returning signals they are able to track down their prey in the dark and see images as the signal returns.

Satellite-based active remote sensing systems include RADARs and LIDARs. These work by emitting electromagnetic radiation in the form of either radio waves for the radar systems and laser beams for the lidar systems. Once the radio waves or laser beams are sent to the object a parabolic dish is used to collect the return information. It is then processed by a computer system and that displays the results.

There are many different types of sensors that are used depending on what you are looking for on earth. You can use optical, RADAR, LIDAR, FLIR, video cameras, laser fluorosensors. Each sensor has its own advantages and disadvantages in relation to the many different characteristics of sensing.

There are a couple characteristics that the actual sensors have and each characteristic is distinguished as to what you want to look for on Earth. Spectral Resolution is the width or range of each spectral band being recorded. Spectral Resolution will not be as sensitive to vegetation stress as a narrow band in the red wavelengths, where chlorophyll strongly absorbs electromagnetic energy. Spatial resolution refers to the visible detail in the image. Detailed mapping of wetlands requires far finer spatial resolution than does the regional mapping of physiographic areas. Temporal resolution refers to the time interval between images. There are applications requiring data repeatedly and often, such as oil spill, forest fire, and sea ice motion monitoring. Some applications only require seasonal imaging such as crop identification, forest insect infestation, and wetland monitoring.

In a case where repeated imaging is required, the revisit frequency of a sensor is important which means how long before it can image the same spot on the Earth again. Optical sensors have limitations in cloudy environments, where the targets may be obscured from view. In some areas of the world, particularly the tropics, this is virtually a permanent condition. Polar areas that suffer from inadequate solar illumination, for months at a time usually require the use of Radar. Radar provides reliable data, because the sensor provides its own illumination, and has long wavelengths to penetrate cloud, smoke, and fog, ensuring that the target won't be obscured by weather conditions, or poor illumination.

Most of the time it takes more than a single sensor to adequately address all of the requirements for a given application. The combined use of multiple sources of information and different types of sensors is needed most of the time to receive sufficient information.

5. The next step involves the **transmission, reception, and processing** of the energy recorded. The energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data is processed into an image, either in the format of a hardcopy and/or digital copy.

Some data obtained during airborne remote sensing missions can be retrieved once the aircraft lands. It is then processed and delivered to the user. Other data acquired from satellite platforms need to be electronically transmitted to Earth, since the satellite continues to stay in orbit during its operational lifetime. There are three main options for transmitting data acquired by satellites to the surface. The data can be directly transmitted to Earth if a Ground Receiving Station (GRS) is in the line of sight of the satellite. If this is not the case, the data can be recorded on board the satellite for transmission to a GRS at a later time. It can also be relayed to the GRS through the Tracking and Data Relay

Satellite System (TDRSS), which consists of a series of communications satellites in geosynchronous orbit. The data are transmitted from one satellite to another until they reach the appropriate GRS. Ground Receiving Stations have been set up around the world to capture data from a variety of satellites.

The data is received at a GRS in a raw digital format, it then must be processed to correct systematic, geometric and atmospheric distortions to the imagery, and be translated into a standardized format. The data is written to some form of storage medium such as tape, disk or CD and then typically archived at most receiving and processing stations. Libraries of data are managed by government agencies as well as commercial companies responsible for each sensor's archives.

For many sensors it is possible to provide customers with imagery that is needed as fast as possible after it is collected. Near real-time processing systems are used to produce low resolution imagery in hard copy or digital format within hours of data acquisition. Such imagery can then be faxed or transmitted digitally to users. One application of this type of fast data processing is to provide imagery to ships sailing in the Arctic, as it allows them to assess current ice conditions quickly in order to make navigation decisions about the easiest and safest routes through the ice. Real-time processing of imagery in airborne systems has been used, for example, to pass thermal infrared imagery to forest fire fighters at the scene.

Low resolution quick-look imagery is used to preview archived imagery prior to purchase. The spatial and radiometric quality of these types of data products is degraded, but they are useful for ensuring that the overall quality, coverage and cloud cover of the data is appropriate.

6. The processed image then needs to be **interpreted and analyzed**, visually and/or digitally, to extract information about the target which was illuminated. We must be able to extract meaningful information from the imagery. Interpretation and analysis of remote sensing imagery involves the identification and measurement of various targets in an image in order to extract useful information about them. Targets in remote sensing images may be any feature or object which can be observed in an image, and have the following characteristics:

- Targets may be a point, line, or area feature. This means that they can have the form of a bus in a parking lot, a plane on a runway, a bridge or roadway, a large expanse of water or a field.
- The target must be distinguishable meaning it must contrast with other features around it in the image.

Much interpretation and identification of targets in remote sensing imagery is performed manually or visually by a human interpreter. In many cases this is done using imagery displayed in a picture or photograph-type format, independent of what type of sensor was used to collect the data and how the data were collected. The data can be represented in a picture in a couple different ways. In some cases we refer to the data as being in analog format. Remote sensing images can also be represented in a computer as arrays of pixels, with each pixel corresponding to a digital number, representing the brightness level of that pixel in the image. The data may also be in a digital format. Visual interpretation may also be performed by examining digital imagery displayed on a computer screen. Both analogue and digital imagery can be displayed as black and white images, colorless, or as color images by combining different channels or bands representing different wavelengths.

When remote sensing data are available in digital format, digital processing and analysis may be performed using a computer. Digital processing may be used to enhance data in order for a better visual interpretation by a human. Digital processing and analysis may also be carried out to automatically identify targets and extract information completely without using a human interpreter. Rarely is digital processing and analysis carried out as a complete replacement for human interpretation as it is mainly done to enhance and assist the human analyst.

Both manual and digital techniques for interpretation of remote sensing data have their respective advantages and disadvantages. Digital processing and analysis is more recent with the advent of digital recording of remote sensing data and the development of computers. Manual interpretation requires little, if any, specialized equipment, while digital analysis requires specialized, often expensive equipment. Manual interpretation is often limited to analyzing only a single channel of data or a single image at a time due to the difficulty in performing visual interpretation with multiple images. The computer environment can handle complex images of several channels which can even be from several different dates. Digital analysis is useful for simultaneous analysis of many spectral bands and can process large data sets much faster than a human interpreter. Manual interpretation is a subjective process, meaning that the results will vary with different interpreters. Digital analysis is based on the manipulation of digital numbers in a computer and is thus more objective, which results in more consistent results. However, determining the validity and accuracy of the results from digital processing can be difficult. Both methods have there advantages and disadvantages and are not mutually exclusive. The most common approach is to use a mix of both methods and the final decision on the value and significance of the information at the end of the analysis process, still must be made by humans.

7. The final element of the remote sensing process is achieved when we **apply** the information we have been able to extract from the imagery about the target. We do this in order to better understand the information, reveal some new information, or assist in solving a particular problem. As we previously learned about sensors, each one was designed with a specific purpose. With optical sensors, the design focuses on the spectral bands to be collected. With radar imaging, the incidence angle and microwave band used plays an important role in defining which applications the sensor is best suited for. Each application itself has specific demands, for spectral resolution, spatial resolution, and temporal resolution. Remote sensing has numerous applications that enhance and aid life on earth. Many of these applications are discussed briefly below.

5.1.2 Applications

5.1.2a Agriculture-

Satellite and airborne images are used as mapping tools to classify crops, examine their health and viability, and monitor farming practices. Agricultural applications of remote sensing include the following:

-crop type classification

-crop condition assessment

-crop yield estimation

-mapping of soil characteristics

-mapping of soil management practices

-compliance monitoring (farming practices)

Remote sensing can provide structure information about the health, changes in growth, moisture content, and nutrient deficiencies. It can also detect insect, fungal or weed infestations which can aid in the farmer's decision on where to put more fertilizer, pesticide or herbicide. Most of this type of monitoring requires that the results are provided frequently and quickly enough so he can make changes to the land in order improve the overall production of his crops.

Figure 20: Infrared images of crops used to monitor the irrigation

This remote sensing image in Figure 20 is distinguishing between irrigated and non-irrigated land. The irrigated crops appear bright green in a real-color simulated image, while the darker areas are dry rangeland with minimal vegetation. In a color infrared simulated image, where the infrared reflectance is displayed in red, the healthy vegetation appears bright red, while the rangeland remains quite low in reflectance.

5.1.2b Forestry-

Forests are a vital resource that provides food, shelter, fuel, paper, medical ingredients and oxygen. Remote sensing plays a very important role in monitoring the forests around the world. Remote sensing can do all of the following things:

-depletion monitoring

-measuring biophysical properties of forest stands.

-forest cover type discrimination

-agroforestry mapping

-timber supply

-vegetation density

-biomass measurements

-clear cut mapping / regeneration assessment

-burn delineation

-forest/species inventory

-monitoring the quantity, health, and diversity of the Earth's forests.

-deforestation

-watershed protection

-coastal protection

-forest health and vigor

One of the big effects of remote sensing on forests is the way in which it aids in fighting fires. Remote sensing can be used to detect and monitor forest fires and the regrowth following a fire. Remote sensing makes it possible to observe remote and inaccessible areas; these images are used to alert monitoring agencies to the presence and extent of a fire. Remote sensing can define active fires and remaining "hot-spots" when optical sensors are hindered by smoke, haze or darkness. Comparing burned areas to active fire areas provides information as to the rate and direction of movement of the fire. Remote sensing data can also assist in route planning for both access to, and escape from a fire and supports logistics planning for fire fighting and identifying areas not successfully recovering following a burn. It can also aid in letting humans know the regenerative status years after a fire has burned an area.

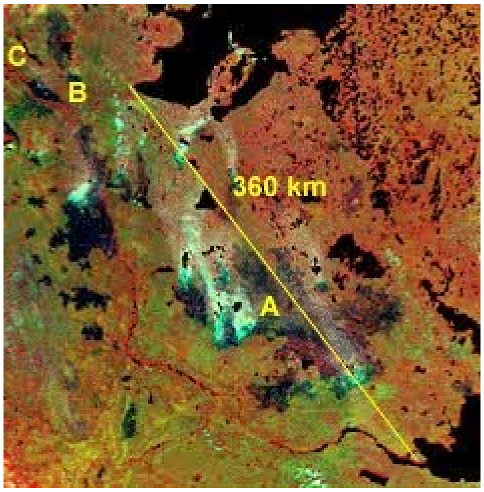

Figure 21: Image of Burned/Burning Forest

This remote sensing image in Figure 21 is monitoring the effects of a territory which suffered a major fire which devastated the land. The extent of the burned area, and the areas still burning, can be identified as dark regions labeled **A**.   The two dark areas in the lower right and upper middle are two lakes. Haze and smoke reflect a large amount of energy at shorter wavelengths and appear as blue on this image.

5.1.2c Geology-

Remote sensing is used as a tool to extract information about the land surface structure, composition or subsurface of the earth. Geological applications of remote sensing include the following:

-surface deposit / bedrock mapping

-lithological mapping - physical character of a rock or rock formation

-structural mapping

-sand and gravel (aggregate) exploration/ exploitation

-mineral exploration

-hydrocarbon exploration

-environmental geology

-geobotany

-baseline infrastructure

-sedimentation mapping and monitoring

-event mapping and monitoring

-geo-hazard mapping

-planetary mapping

5.1.2d Hydrology-

Hydrology is the study of water on the Earth's surface, whether flowing above ground, frozen in ice or snow, or retained by soil. Water is an even more vital resource of earth and humans therefore it is also very important to monitor and keep a close watch on it.

Below is a list of all of the applications remote sensing is used for hydrological purposes:

-wetlands mapping and monitoring,

-soil moisture estimation,

-snow pack monitoring / delineation of extent,

-measuring snow thickness,

-determining snow-water equivalent,

-river and lake ice monitoring,

-flood mapping and monitoring,

-glacier dynamics monitoring (surges, ablation)

-river /delta change detection

-drainage basin mapping and watershed modeling

-irrigation canal leakage detection

-irrigation scheduling

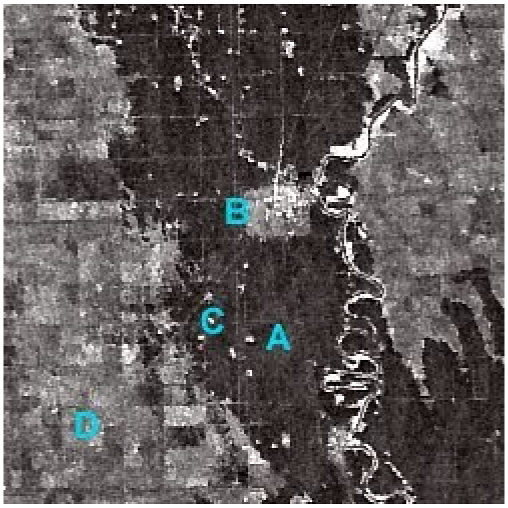

Figure 22: Image of Manitoba Flood

Figure 22, in 1997, shows the Red River flooded fields and towns in the states of Minnesota, North Dakota, and the Canadian province of Manitoba. Radar remote sensing provided some excellent views of the flood, because of its ability to image in darkness or cloudy weather conditions, and its sensitivity to the land/water differences. In this image, the flood water **(A)** completely surrounds the town of Morris (**B)**, visible as a bright patch within the dark flood water. The flooded areas appear dark on radar imagery because very little of the incident microwave energy directed toward the smooth water surface returns back to the sensor. The town however, has many angular (corner) reflectors primarily in the form of buildings, which cause the incident energy to "bounce" back to the sensor. Transportation routes can still be observed. A railroad, on its raised bed, can be seen amidst the water just above **(C)**. Farmland relatively unaffected by the flood **(D)** is quite variable in its backscatter response. This is due to differences in each field's soil moisture and surface roughness.

5.1.2e Sea Ice-

Ice covers a substantial part of the Earth's surface and is a major factor in commercial shipping and fishing industries, Coast Guard, construction operations and global climate change studies. Remote sensing data can be used to identify and map different ice types, locate large navigable cracks in the ice and monitor ice movement. This information can be passed to the client in a very short timeframe from acquisition. Users of this type of information include the Coast Guard, port authorities, commercial shipping and fishing industries, ship builders, resource managers such as oil, gas and mining, infrastructure construction companies, environmental consultants, marine insurance agents, scientists, and commercial tour operators. Remote sensing applications involving sea ice are:

-ice concentration

-ice type / age /motion

-iceberg detection and tracking

-surface topography

-tactical identification of leads: navigation: safe shipping routes/rescue

-ice condition (state of decay)

-historical ice and iceberg conditions and dynamics for planning purposes

-wildlife habitat

-pollution monitoring

-meteorological / global change research

5.1.2f Land-

Resource managers involved in parks, oil, timber, and mining companies, are concerned with land uses as are local resource inventory or natural resource agencies. Changes in the land will be examined by environmental monitoring researchers, conservation authorities, and departments of municipal affairs. Some government agencies are also concerned with the general protection of national resources, and become involved in publicly sensitive activities involving land use conflicts. Land use applications of remote sensing are listed below:

-natural resource management

-wildlife habitat protection

-baseline mapping for GIS input

-urban expansion / encroachment

-routing and logistics planning for seismic / exploration / resource extraction activities

-damage delineation (tornadoes, flooding, volcanic, seismic, fire)

-legal boundaries for tax and property evaluation

-target detection - identification of landing strips, roads, clearings, bridges, land/water –interface

5.1.2g Mapping-

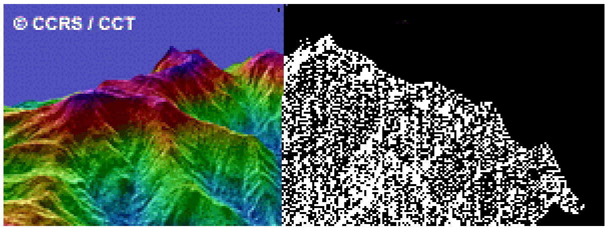

Figure 23: Elevation Mapping

Mapping is a common product of remote sensing analysis. Maps are essential for planning, evaluating and monitoring. They can also aid in military or civilian reconnaissance, or land use management. Elevation information is crucial to many applications and is often the key to present day mapping programs. Remote sensing aids in these types of maps and also the types of mapping below:

-*planimetry*- the identification and location of basic land cover generally required for large-scale applications - urban mapping, facilities management, military reconnaissance, and general landscape information.

-*digital elevation models* (*DEM's*) used for guiding cruise missiles, tourism, route planning, and golf course development

-*baseline thematic mapping / topographic mapping*- consists of elevation contours and planimetric detail of varied scale, and serve as general base information for civilian and military use

5.1.2h Ocean-

Remote sensing can provide us with a much better understanding of the oceans' dynamics. Remote sensing can monitor currents, shears, eddies, different zones, waves, and also depths of water. It can also monitor water temperature, water quality as well as fish stock and marine mammal assessment. The sensors can also forecast storms and its effects such as shoreline delineation, beach dynamics, and water interface. Another big impact it can have is how it can help humans clean up oil spills. The sensing can predict oil drift and identify natural oil seepage areas which aid emergency response decisions.

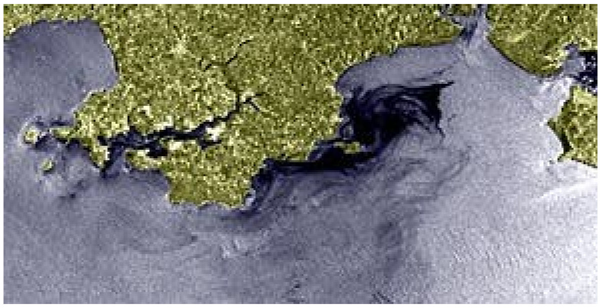

Figure 24: Image from an oil spill

Figure 24 represents an image using remote sensing taken a week after an oil spill around Great Britain.

5.2 GPS

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites placed into orbit by the U.S. Department of Defense. GPS was initially intended solely for military applications, but in the 1980s, the government made the system available for civilian use as well. These days GPS is finding its way into cars, boats, planes, construction equipment, farm machinery, and even laptop computers. GPS has clearly changed navigation forever.

5.2.1 The GPS satellite system

The 24 satellites that make up the GPS space segment are orbiting the earth about 12,000 miles above us. They are constantly moving (roughly at speeds of 7,000 mph), making two complete orbits in less than 24 hours. GPS satellites are powered by solar energy, but they do have backup batteries onboard in the event of a solar eclipse in which there is no solar power. There are also small rocket boosters on each satellite that keep them flying in the correct path.

More interesting facts about the GPS satellites, also called NAVSTAR (the official U.S. Department of Defense name for GPS), are listed below.

- The first GPS satellite was launched in 1978.
- A full constellation of 24 satellites was achieved in 1994.
- Each satellite is built to last about 10 years. Replacements are constantly being built and launched into orbit.
- A GPS satellite weighs approximately 2,000 pounds and is about 17 feet across with the solar panels extended.

- Transmitter power is only 50 watts or less.

5.2.2 How does GPS work?

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to the earth. GPS receivers then take this information and use triangulation to calculate the user's exact location. In other words, by very accurately measuring the distance from three satellites the user can "triangulate" his or her position anywhere on the earth. For example, suppose we measure our distance from a satellite and find it to be 11,000 miles. Knowing that we are 11,000 miles from a particular satellite narrows down all the possible locations we could be in the whole universe to the surface of a sphere that is centered on this satellite and has a radius of 11,000 miles (Figure 25).

Figure 25: Our distance from one satellite

Next, we measure our distance to a second satellite and find that it is approximately 12,000 miles away. This tells us that we're not only on the first sphere but we're also on a sphere that is 12,000 miles from the second satellite. More specifically, we are somewhere on the circle where these two spheres intersect (Figure 26).

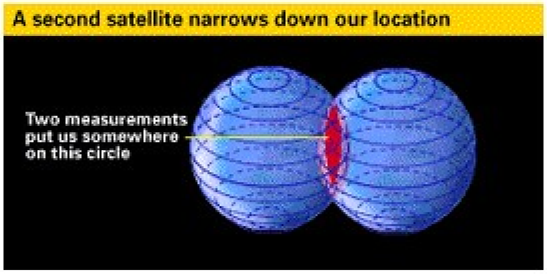

Figure 26: Our location with two satellites

If we then make a measurement from a third satellite and find that we're 13,000 miles from that one, than that narrows down our position even further to the two points where the circle that is the intersection of the first two spheres (Figure 27). To decide which of the two points our true location is, we could make a fourth measurement, but usually one of the two points is a ridiculous answer and can be rejected without a measurement. Ridiculous answers are obvious and easily detected because they are either too far from the earth or are moving at an impossible velocity.

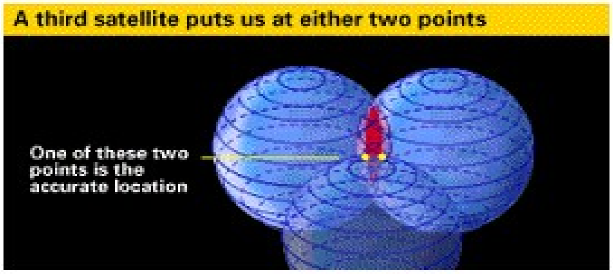

Figure 27: Our location with a third satellite

To summarize, a GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude, and altitude). Once the user's position has been determined, the GPS unit can then calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset times, and more.

5.2.3 How do we measure distance from a satellite?

The distance to a satellite is determined by measuring how long a radio signal takes to reach our receiver from that satellite. In a sense it all boils down to the formula:

Velocity * Time = Distance

Where the velocity is equal to the speed of light or roughly 186,000 miles per second. The problem with this formula, though, is measuring the travel time. First of all, the times are going to be awfully short. For example, if a satellite were right overhead, the travel time would be something like 0.06 seconds. So, in order to measure this travel time we are going to need some extremely precise clocks.

On the satellite side, timing is almost perfect because they have incredibly precise atomic clocks on board. These atomic clocks use the oscillations of a particular atom as their "metronome." This form of timing is the most stable and accurate reference man has ever developed.

The receivers here on ground are a different story. To begin with, it needs to be noted that both the satellite and the receiver need to be able to precisely synchronize their pseudo-random codes to make the system work. The pseudo random code is a fundamental part of GPS. Physically, it is just a very complicated sequence of “on” and “off” pulses, but this signal is so complicated that it almost looks like random electrical noise. Hence the name “pseudo-random.” However, there does happen to be several good reasons for this complexity. First, the complex pattern helps make sure that the receiver doesn't accidentally sync up to some other signal. It's highly unlikely that a stray signal will have exactly the same shape. Secondly, this complexity guarantees that the receiver won't inadvertently pick up another satellite's signal. This, in turn, allows all the satellites to use the same frequency without jamming each other. In fact, the pseudo random code gives the Department of Defense a way to control access to the system. The third reason for the complexity of this so called "random code" is crucial to making GPS economical. And that is that the code makes it possible to use information theory to amplify the GPS signal. This is why GPS receivers don't need big satellite dishes to receive the GPS signals. In short, the pseudo random code is one of the brilliant ideas behind GPS. It not only acts as a great timing signal, but it also gives us a way to amplify the very weak satellite signals.

So what about our receivers on the ground? Well, if our receivers needed atomic clocks, which cost upwards of $50K to $100K, nobody could afford it. Luckily, the designers of GPS came up with a way to get by with much less accurate clocks in our receivers. The secret is to make an extra satellite measurement. For example, if our clocks were perfect then all our satellite ranges would intersect at a single point (which is our position). However, with imperfect clocks, a fourth measurement, done as a cross-check, will not intersect with the first three. The receiver's computer then realizes that the measurements must not be perfectly synced with universal time. Since any offset from universal time will affect all four measurements, the receiver, in turn, looks for a single correction factor that it can subtract from all its timing measurements that would cause them all to intersect at a single point. That correction brings the receiver's clock back into sync with universal time and it is then that you have atomic accuracy time.

Once it has that correction it applies to all the rest of its measurements and thus you have precise positioning.

5.2.4 Satellite Positioning

How do we exactly know where these GPS satellites are when they are floating close to 11,000 miles up in space? Well, it turns out, that the 11,000 miles is actually a good thing because something that high is well clear of the atmosphere. In other words, it will orbit according to very simple mathematics.

On land all GPS receivers have an almanac programmed into their computers that tells them where in the sky each satellite is at all times. The basic orbits do happen to be quite exact, but to make sure things are perfect, the GPS satellites are monitored by the Department of Defense (DoD) with very precise radar to confirm each satellite's altitude, position, and speed. In order to ensure this faultless idea, the DoD checks for what are referred to as "ephemeris errors" because these are what affect the satellite's orbit, or ephemeris. Such errors are caused by gravitational pulls from the moon and sun and also by the pressure of solar radiation on the satellites. These errors are usually very insignificant, but they must be taken into account if the DoD wants to maintain great accuracy.

So what happens once the DoD has measured a satellite's exact position? Well, once a satellite's exact position has been measured, the DoD then relays that information back up to the satellite itself. The satellite, in turn, includes this new corrected position in the timing signals it is broadcasting. This tells us that a GPS signal is more than just pseudo-random code. It also contains a navigation message with the satellite's orbit information as well.

5.2.5 How accurate is GPS?

Today's GPS receivers are extremely accurate, including Garmin®[*] GPS receivers which are accurate to within 15 meters on average. However, newer Garmin GPS receivers with Wide Area Augmentation System, or WASS, capability can improve accuracy to less than three meters on average. No additional equipment or fees are required to take advantage of WAAS. Users can also get better accuracy with Differential GPS, or DGPS, which corrects GPS signals to within an average of three to five meters. The U.S. Coast Guard operates the most common DGPS correction service. This system consists of a network of towers that receive GPS signals and transmit a corrected signal by beacon transmitters. In order to get the corrected signal, users must have a differential beacon receiver and beacon antenna in addition to their GPS.

The extreme accuracy of these Garmin receivers is due primarily in part to their parallel multi-channel design. Garmin's twelve parallel channel receivers are quick to lock onto satellites when first turned on and they maintain strong locks, even in dense foliage or urban settings with tall buildings. However, there are certain atmospheric factors and other sources of error that can affect the accuracy of GPS receivers.

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[*] Garmin® is a leader in GPS technology and an innovator in consumer electronics.

5.2.6 GPS Applications

So now that we have an understanding of GPS and how it works, we need to talk about the diverse uses of GPS technology all over the world. The following is a list of the innovative ways that GPS is being put to work along with a real life example:

- *Archaeology & Educational Research* – GPS was used by marine archaeologists to guide their research vessel while hunting for a 300-year-old shipwreck off the coast of Corpus Christi, Texas.
- *Aviation* – Airport operators in Juneau, Alaska are now using a differential GPS landing system to guide planes safely into a remote airport surrounded by rugged mountains.

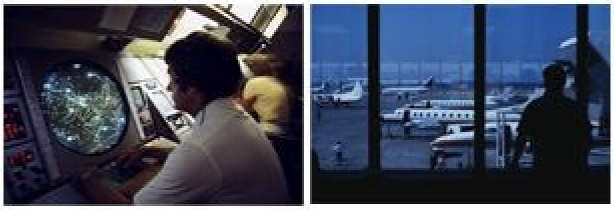

Figure 28: Aviation is just one of many GPS applications

- *Entertainment* – GPS units are used to develop new and safe routes in mountain climbing.
- *Environment* – GPS enables marine biologists to theorize that whales and dolphins look for feeding spots just as land mammals look for watering holes by finding these spots from the points where the marine mammals were last seen.
- *Forestry & Agriculture* – Anthropologists use GPS for aircraft navigation and mapping the location of villages, rivers and other important sites in preservation of indigenous civilizations in the Amazon Basin of Venezuela.

- *Ground Transportation* – In 1995, BMW began installing a GPS-based in-car navigation system in several of its models that offers turn-by-turn directions and menu-driven navigation controls.
- *Natural Disasters* – Scientists worldwide have been using GPS data to study earthquakes to try to determine their triggers in hope of someday providing warning systems to prevent the death and property damage typically associated with earthquakes.
- *Public Health & Safety* – GPS's precise-positioning technology is used by companies in Argentina to help police find stolen and hijacked vehicles.
- *Weather Forecasting* – The U.S. National Weather Service sends up radiosonde balloons now equipped with GPS technology to provide a more accurate representation of the time and location at which temperature, humidity, pressure, and wind readings are taken.

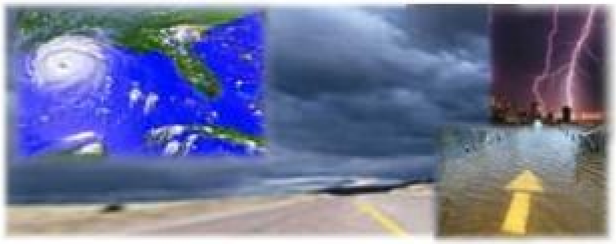

Figure 29: Weather Forecasting is one of the more popular GPS applications

- *Wildlife Biology* – GPS is used to study the movements and activities of the Puerto Rican Boa, and endemic endangered snake.

As you can see there are a wide variety of GPS applications used in every aspect of our daily lives. It is now clearly safe to say that GPS technology has matured into a resource that has gone far beyond its original design.

5.3 RADAR

Radar is something that is normally invisible but it is used all around us. Radar is the use of radio waves to detect and monitor various objects. The simplest function of radar is to tell you how far away an object is. To do this, the radar device emits a radio wave and listens for any echo being received. If there is an object in the path of the radio wave, it will reflect some of the electromagnetic energy, and the radio wave will bounce back to the radar device. Radio waves move through the air at a constant speed, so the radar device can calculate how far away the object is based on how long it takes the radio signal to return.

When people use radar, they are usually trying to accomplish one of three things:
Detect the presence of an object at a distance - Usually the object being detected is moving, but radar can also be used to detect stationary objects buried underground.
Detect the speed of an object - This is the reason why police use radar.
Map something - The space program and orbiting satellites use Synthetic Aperture Radar to create detailed maps of the surface of planets and moons.

Radar is not just a technology used in our space program, but rather it is used all around us everyday. Air traffic control uses radar to track planes both on the ground and in the air, and also to guide planes in for smooth landings so there are not any accidents. Police use radar to detect the speed of passing motorists. NASA uses radar to map the Earth and other planets, to track satellites and space debris and to help with things like docking and maneuvering. The military uses it to detect the enemy and to guide weapons and Meteorologists use radar to track storms, hurricanes and tornados. As you can see we use radar everyday of our lives, and are greatly affected by the use of it.

5.4 LIDAR

LIDAR technology is another form of technology used in our Space Program. LIDAR stands for Light Detection and Ranging and it uses basically the same principle as RADAR does. The lidar instrument works by transmitting light out to a specific target and the transmitted light then interacts with and is changed by the target it approaches. Some of the light that is transmitted is then reflected back to the instrument where it is analyzed. When the data is being analyzed they look for the change in the lighting and also the time it takes for the light to travel out to the specific target and back. The amount of time this takes helps determines the range to the target.

The three basic types of LIDAR include:

Range finders - Range finder lidars are the simplest lidars. They are used to measure the distance from the lidar instrument to a solid or hard target.

DIAL - Differential Absorption Lidar (DIAL) is used to measure chemical concentrations. These include items such as water vapor, pollutants, and the ozone layer. This item uses two different laser wavelengths one is absorbed by the molecule of interest and the other wavelength is not. The difference in intensity of the two return signals can be used to determine the concentration of the molecule being explored.

Doppler lidars- Doppler lidar is used to measure the velocity of a target. When the light transmitted from the lidar hits a target moving towards or away from the lidar, the wavelength of the light reflected off the target will be changed slightly. If the target is moving away from the lidar, the return light will have a longer wavelength, if it is moving towards the lidar the return light will be at a shorter wavelength. The target can be either a hard target or an atmospheric target. These are the targets of interest to us as they are small and light enough to move at the true wind velocity and then enable a remote measurement of the wind velocity to be discovered.

5.5 SAR

SAR technology provides information in a very unique way. Synthetic Aperture Radar gives us the ability to do environmental monitoring, earth-resource mapping, and military systems imaging at high resolutions. Many times these three items are detected in inclement weather or during the night and the SAR system can handle these complications. SAR systems take advantage of the long-range radar signals and the complex information processing capability of modern digital electronics to provide high resolution images.

Synthetic aperture radar technology has provided terrain structural information to geologists for mineral exploration, oil spill boundaries on water to environmentalists, sea state and ice hazard maps to navigators, and reconnaissance and targeting information to military operations.

The military rely heavily on this form of technology. Many applications for synthetic aperture radar are for reconnaissance, surveillance, and targeting. These applications are driven by the military's need for all-weather, day-and-night imaging sensors. SAR can provide sufficiently high resolution to distinguish terrain features and to recognize and identify selected man made targets.

This system also has the ability to monitor other nations for treaty compliance and see if they are taking part in making nuclear, chemical, or biological weapons. Monitoring these items is not easy and this system allows them to do this no matter what type of conditions is present. SAR provides the all-weather capability and complements information available from other airborne sensors, such as optical or thermal-infrared sensors.

Recent studies have shown that SAR may provide a limited capability for imaging selected underground targets. These targets include utility lines, arms caches, bunkers, mines, etc. Depending on the type of soil on the ground, the penetration and depth of the images vary. Individual measurements have shown the capability for detecting 55-gallon drums and power lines at depths of several meters. In dry sand, penetration depths of 10's of meters are possible.

6. Survey

6.1. Survey Design

In order to assess how people felt about the United States space program, we decided to develop a survey (Appendix A1). We began the survey by asking people whether or not they believed that the sixteen billion dollars or so that goes into the program through federal spending is well spent. We then presented a few other areas in which they would rather see some of this money spent. Next, in order to try and convince some of them that the one percent of the total federal budget that goes toward the space program is well worth it, we presented them with a list of very interesting facts that might convince them that the money spent in the space program is worth it. After presenting what we hoped to be very persuasive points, we then asked them if what was just presented to them changed their mind about the money, or lack there of, spent on the program and why. Our goal with this approach was to see if people changed their opinion on the amount of money spent on the U.S. space program after they knew of examples of how much the program does for us.

6.2 Survey Sampling

Distribution of the survey was done here on the WPI campus as well as off campus at Abbott Bioresearch Center*. With a relatively small sample size (approximately 125 surveys were filled out), questions arose about selection bias as well as our information not being totally representative of the population. For example, everyone that took the survey is either a student at WPI, a university dedicated to science

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* Abbott Bioresearch Center is one of the world's leading healthcare companies, employing approximately 55,000 people worldwide and last year reported sales in excess of $19 billion. Note: Our distribution was done at the Worcester site.

and technology, or a scientist at one of the world's leading health care companies, most of which have his or her PhD. Of course it is great to receive responses from such well educated and well rounded individuals, but those individuals that have no more than a high school education and may not know a thing about the space program are not included in our results. So does this mean that our information is useless and cannot be used? Not really. We expect that the type of people surveyed is the type of people that might change their mind when presented with hard facts. After all, we expect scientists to behave in this manner. In the general population we expect that the percentage of people to be swayed by the positive facts about the space program not be as large as it is for our sampled groups. However, it is important to assess the sensitivity of this important well-educated group to the information and how they might change their minds when facts are presented to them.

6.3 Data Results/Analysis

The results from our survey are shown below.

		Before Answer	
		Yes	**No**
After Answer	**Yes**	**68**	**38**
	No	**0**	**20**

The information that is of most importance to us is the answers expressed in column two. As you can see, more people (almost twice as many) changed their mind after reading the information on the United States space program than those whose opinions remained unchanged. More specifically, out of the 126 people who took the survey, roughly 46% initially responded no when asked for the first time whether or not the money granted to the space program was well spent. After reading some of the more intriguing facts of how much of an effect the program itself has on us as individuals, 66% of the previous 46% changed their opinion when asked for the second time if the money was put to good use. These results show us that by presenting just a few facts about the impact of space technology on society, we can alter the beliefs of close to 50% of humans who disagree with the space program's funds. We are also left to assume that there is a substantial gap of knowledge between the space program and its critics. So, in total, when you take all the individuals who originally answered yes and those who changed their view, 84% of the population surveyed believes that the money the federal government gives to the U.S. space program is well worth it.

However, there is still one question left; where did those people that initially answered no feel the money would be put to better use? The five options we gave them to choose from were defense, education, Medicare/health, scientific research, and social security. The results we obtained are given below:

• Medicare/Health	27.9%
• Education	27.9%
• Scientific Research	25.6%
• Defense	11.6%

- Social Security 7.0%

As you can see health, education, and scientific research accounted for a little over 80% of the total responses we received. These results turned out to be exactly what we expected them to be because, once again, of the background of the individuals who took the survey. For instance, both the students here at WPI and the scientists at Abbott Bio have all been and still are involved in some type of science related field. Don't forget too that Abbott Bio happens to be a worldwide leader in healthcare. So, needless to say, these results didn't come as too much of a surprise to us, but it did bring up the question, is the space program's less than 1% of the federal budget worth giving to other areas considering how much some of these areas already receive? In our opinion, no. The money the space program receives doesn't even compare to areas such as the military that already receive close to 50% of the federal budget, or human resources (social security, education, health, etc.) that receive approximately 33% of the $1,926 billion (total federal funds, 2005). That 1% that goes into the space program is so small that it would have little, or no effect on these areas whatsoever. When it comes down to it, it's not worth it to use portions of this 1% and put it into something else, essentially losing what space technology (i.e. satellites) truly provides us with.

7. Is the Space Program worth it?

Space exploration has been an ongoing debate since the space era began. It has been argued and is still argued today whether or not the money spent on space exploration would be better off spent somewhere else, particularly to meet the needs of the poor. Unfortunately, the benefits of the space exploration are not self evident. NASA and other national space programs around the world today are isolated from many humans on earth. This gap needs serious and urgent attention by Congress, the president and leadership of NASA. The critics of the space program, who are genuine in their worry that money is being wasted in space, need their concerns addressed.

The high profile of space exploration makes it appear more expensive than it actually is. The uninformed citizen is under the impression that the money would make a difference in the fight against poverty when poverty is in reality out of proportion with the money spent space. The space program in the United States spends about $15 billion every year. This $15 billion represents less than 1% of the federal government's budget. The federal government spends more than 30% on helping the poor people in the United States. These numbers translate into the fact that if the space program was eliminated than every poor person instead of receiving $1.00, they would now receive $1.03. Do you think that this extra money is what is really needed to save them? What do we lose when we eliminate the space program?

Without the space program we lose all of the following;

Prevention of environmental disaster: Remote sensing satellites allow us to monitor the ozone hole, global warming, air, water and ocean pollution, the effect of oil spills, the melting of the ice caps, the loss of rain forests and other environmental threats to human survival. These systems can help us trace our recovery from the worst environmental threats and improve our quality of life.

Creating a global network for modern communications, entertainment and networking: Communication satellites provide global connectivity for; the telephone, fax, internet, radio and television. The use of satellites extends far beyond the reach of fiber optic cables. Thousands of television channels are now available via satellite and well over 200 countries and territories are linked via satellite.

Global education and health services: Over 2 billion of the 6 billion people in our world today lack formal educational systems, health care services, drinkable water or power. The only way to provide global education and health care services in coming decades at reasonable cost and broad coverage is via space-based communication systems.

Cheap and environmentally friendly energy: NASA scientists and engineers already have gone a long way to develop space technology that can provide unlimited low cost energy from space. The operational systems, however, still need to be developed and proven in practice. For the next trip to the Moon or Mars, many engineers want something to do with routing power back to Earth on board the space shuttle.

Transportation safety: The 6,000 commercial airplanes that are aloft at one time during peak periods in the U.S. depend on satellite navigation for safe operation. New systems can provide better fuel efficiency, earlier warnings of safety hazards and alert of terrorist attack. This is one of the ways that future space systems can provide greater transportation safety in decades to come.

Emergency warning and recovery systems: The ability to warn populations of pending dangers from hurricanes, tornados, monsoons, tidal waves, fires and earthquakes are increasingly dependent on space-based systems. Rescue operations, from emergency communications to disaster assessment to recovery operations, are dependent on satellite networks as well.

Protection of our information networks from cyberterrorists: Many of our current electronic information networks that control transportation systems, energy grids, banking systems and governmental databases are vulnerable. New types of security systems based on GPS location and encryption systems are dependent on space-based systems.

National defense and strategic security: National security systems are increasingly based on smart technologies and instruments that operate in outer space. Military operations are based heavily on space systems and future systems will be even more so.

Protection against catastrophic planetary accidents: We are bombarded by meteors from space daily. The dangers are greatest not from a disastrous collision, but from not knowing enough about solar storms, cosmic radiation and the ozone layer. An enhanced Spaceguard Program is actually a practical course that could save our species in time.

Creation of new jobs and industries -- a new vision for the 21st century and a mandate to explore truly new frontiers: Most of the economically advanced countries such as Japan, Canada, Australia and Europe, not to mention China, India and Russia, use their space programs to stimulate their economy, expand their educational and health care networks, improve their agriculture, upgrade their information networks, enhance their entertainment networks and create new jobs. A well conceived space program may well be our only hope for long-term survival.

Looking at it from another aspect, we now explore how the money put into the space program compares to the amount of money spent on a number of other things.

Many of the critics of the space program point there finger at the U.S. government for wasting their tax money in space instead of helping the poor, but they are not feeling guilty for their own consumerist life style.

This year the total pet-related sales in the United States are estimated to be $31 billion which is double the $15 billion NASA budget. An estimated $5 billion worth of holiday season gifts were offered, not to the poor, but to the roving family pets which is six times more than NASA spent on its own roving Martian explorers, Spirit and Opportunity, who cost the American taxpayer $820 million both.

There is $20.3 billion spent in the U.S. on the human popular toy industry which is less than any space rocket cost for the space program.

Americans spend $586.5 billion a year on gambling. The space program is 40 times less than that.

$31 billion go annually in the US on tobacco products, twice the NASA budget, and $58 billion is spent on alcohol consumption, almost four times the NASA budget. $250 billion are spent annually in the US on the medical treatment of tobacco and alcohol related diseases which is sixteen times more than space exploration.

All of this adds up to more than $976 billion dollars, almost a trillion, spent every year in the US on pets, toys, gambling, alcohol and tobacco. It is 63 times the amount spent on space exploration.

These numbers put up a strong case that a lot of our money is being used for the wrong things. This money would be much better off, not in the space program, but in the places that the critics of the space program say need more money such as, social security, Medicare, education, or scientific research.

A protest, against the spending of the government on the space program in comparison to helping the poor, was held on the eve of the launch of Apollo 11. At the protest, Thomas Paine, the administrator of NASA, said “if we could solve the problems of poverty by not pushing the button to launch men to the moon tomorrow, then we would not push that button." The space program is like child’s play compared to the problems of the poor.

7. Conclusion

In conclusion, we hope to have given you the reader a clear understanding of the point we are presenting in this report. Our main objective here was to provide an in-depth look at the space program and some of the things associated with the program itself. Why? Well, first of all, we wanted to make the reader aware of how important the space program is to our everyday life. From predicting the weather forecast to plotting a military attack, the space program and its technologies are responsible for it all. Secondly, we strived to change people's opinions regarding the space program by giving them information on all the things that affect them and hardly even know it. For example, GPS has truly changed the navigation world forever. Who would have thought that satellites would be able to relay information to the driver of a car, boat, or plane regarding their exact position on the Earth and point them in their desired direction? All advances such as these have been made possible by the space program and are given little or no credit by society. Maybe this is due to the fact that our own federal government doesn't acknowledge the space program as much as other areas. Regardless, the space program is worth more than a mere 1% of the total federal budget. We're not exactly sure how much more, but after our experience researching and writing this report, it is clear to us that the space program does so much for us that they should be given more recognition than it currently receives.

One significant point not discussed in the report that we would briefly like to present is the difference between sending people up to space compared to just satellites. As portrayed in this report is the fact that satellites and their experiments provide us with an immeasurable amount of information and technology that greatly enhances our life on earth. Satellites supply us with much more than many people can imagine. Questions that we have asked ourselves are how much have we gotten in return for sending people into space? What are we gaining by sending humans to the moon or mars? Besides a lot of risk to those humans, in which case there have been accidents that have lead to multiple deaths, we have not received anything that can help us in the future. By reading our section on Mars, how many important discoveries have we made that can help life on earth? Are these trips to Mars and the moon for bragging rights? We have come to a conclusion that we should discontinue sending humans to the moon, which would save some money, and keep our focus on sending satellites that improve our lives.

Appendix A1

Space Program Survey

Please provide: *Age*___________ *Gender*______________

#1. The federal government grants NASA approximately sixteen billion dollars each year. Do you think this money is well spent? Y/N

#2. If no, where else, in your opinion, could this money be put to better use? Please check one or specify one that is not listed.

___Defense	___Medicare/Health	___Social Security
___Education	___Scientific Research	Other_____________

Did you know…?

- The federal government spends less than 1% of its total budget on the space program.
- Since 1982, over 17,000 lives have been rescued as a result of Search and Rescue Satellites (SARSAT).
    - 4,820 of those 17,000 have been rescued in the United States alone.
    - The number of rescues to date in 2004 is 163.
- Communication satellites provide global connectivity by means of the telephone, fax, the Internet, radio and television.
- Satellite technology helps monitor and predict forest fires on Earth.
    - Earth-observation satellites provide data combined with weather information in order to estimate how fast a fire is to spread as well as where it might spread.
- Weather satellites allow us to determine the weather around the world at any given time of the day.
    - For example, weather satellites have allowed us to evacuate potential disaster areas due to Mother Nature, most recently aiding in the hurricanes that have hit the state of Florida.
- Military satellites help in detecting missile launches and nuclear explosions.
    - These satellites allow us to monitor military actions in foreign countries for our own protection.

*This general information is just a selection from all that satellites really do for us here on Earth.

#3. If you answered no to question #1, did any of this information change your opinions/views about the money spent on our space program? Y/N

#4. If no, briefly explain why.

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