TOPIC 6

Above the Atmosphere and Under Control

In Topics 4 and 5 you learned about ground-based optical and radio telescopes. However, Earth's atmosphere still prevents astronomers from getting a clear view of the universe. To get a clear view, astronomers have to place their telescopes into orbit above Earth's atmosphere. In Topic 6, you will learn about two technologies that make it possible to put telescopes and spacecraft into orbit and keep them there — rockets and computers.

Did You Know?

What is the action/reaction principle? Suppose you are standing on a stationary skateboard holding a heavy ball, and the only way you can move is to throw away the ball. The ball goes one way and you and the skateboard go the other way. Similarly, the only way a rocket can move is to "throw away" the exhaust from its fuel. The exhaust goes one way and the rocket goes the other. This is an example of Isaac Newton's action/reaction law.

Rockets—Getting Up There

Rockets were invented hundreds of years ago and were used for fireworks and weapons. A **rocket** is a tube that contains combustible material in one end. On the other end of the rocket is the **payload**, the device or material that the rocket carries. The products of the combustion (the exhaust) escape out one end and the tube is pushed in the other direction by the action/reaction principle. The payload can be an explosive, a measuring device, or even a person.

Rocket Fuel

Rockets need a combustible fuel to make them fly. All fuels create exhaust that comes out of the rocket. The speed at which the exhaust leaves the rocket is called the **exhaust velocity**. The exhaust velocity is one factor that determines the rocket's range, (how high or how far a rocket travels). For hundreds of years, rockets used solid fuels, usually forms of gunpowder. Solid fuels, however, have lower exhaust velocities than liquid fuels. Robert Goddard, an American physics professor, was the first scientist to successfully launch a liquid fuel rocket in 1926.

Goddard also knew that if a rocket had more than one stage — a **staged rocket** — it would fly faster and higher. A stage is a section of a rocket that drops off once its fuel is used up. This makes the remaining part of the rocket lighter.

Figure 5.40 This is Dr. Robert Goddard and his first successful liquid fuel rocket, which he launched in 1926. The whole rocket was over 2 m tall and made of two sections connected by rods in which the gasoline and oxygen flowed.

The *V-2* Rocket

Werner von Braun was a German scientist. During World War II, he experimented with liquid fuel rockets to help the Nazi war effort. The world's first ballistic missile was their *V-2* rocket, launched in 1942. A **ballistic missile** is a bomb that is powered by a rocket engine. The *V-2* test rocket successfully hit a target about 200 km away from the launch site. Almost every rocket flown today (for military uses and for space exploration) is a variation on this design.

Near the end of World War II, the Americans and Russians both wanted to capture von Braun and his team of engineers. The Americans captured them first, and sent them to the United States to continue developing rockets. This team of scientists helped launch the U.S. space program. Werner von Braun's team built the rockets that took the first U.S. astronauts into space in the 1960s.

After the war ended, the allies assembled three *V-2* rockets for test flights. A Russian army colonel, Sergi Korolev, watched these *V-2* tests in Europe. He later became the chief designer of the *Vostok*, *Voshkod*, and *Soyuz* rockets. These rockets launched all of the Soviet cosmonauts into orbit. "**Cosmonaut**" is the Russian term for astronaut.

Cool Tools

Canada's first commercially successful sounding rocket was the *Black Brant*. A sounding rocket is one that carries some measuring device as its payload. Many of these were fired to learn about Earth's upper atmosphere. The first one was launched in 1959. These rockets are manufactured by Bristol Aerospace in Winnipeg.

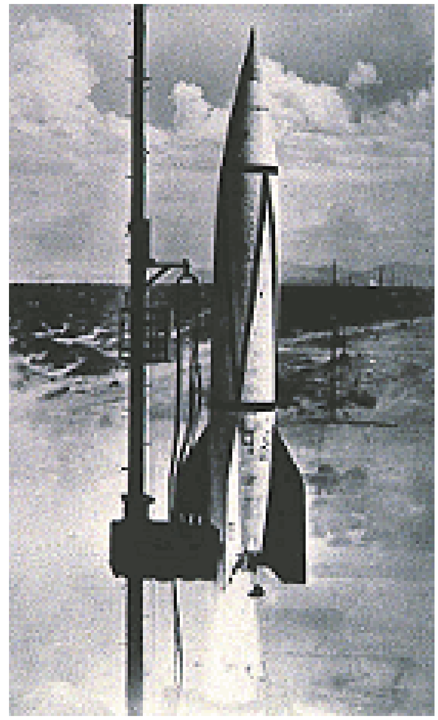


Figure 5.41 The *V-2* rocket was the world's first ballistic missile. Near the end of World War II, Germany launched many of these at Great Britain.

Computers—Making Adjustments

The Americans and Russians used rockets to launch spacecraft into Earth orbit in the 1960s. Once the spacecraft were there, they needed a way to calculate and control their orbits. Computers did this job. The first electronic computers were invented during World War II and used to decipher coded messages. The first computers were so large that their central processors filled entire rooms.

The flights of the earliest spacecraft were controlled from the computers on the ground. Eventually, computers were made small enough to fit inside spacecraft. The computers inside the spacecraft worked with the ground computers to control the flight.

In fact, without computers the achievements of the last 40 years may not have happened. Computers are used to calculate orbits, keep track of other satellites (and pieces of space junk from other flights so the satellites don't hit each other in space), collect, store, and analyze data, and to execute orbital manoeuvres of the satellites.

In the next investigation, you will examine basic design features to simulate a rocket blasting off. After that, you will explore some specific ways in which computers control rocketry and our view of the stars.

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Blast Off!

Challenge

Design and **construct** a water rocket from 1 L or 2 L pop bottles that will out perform your teacher's demonstration rocket.

Safety Precaution

Rockets launch at high speed. Do not stand over your rocket while launching it. Find an open place to launch your rocket.

Apparatus

inflating needle
rubber stopper
bicycle pump
plywood (or any attachment that keeps the rocket standing on the launch pad)
wood blocks (or something to serve as launching blocks)

Materials

1 L or 2 L empty pop bottle
water
any materials you want to use to make fins or parachutes

Teacher's demo: the simplest rocket

Design Specifications

A. Your rocket must be made with plastic 1 L or 2 L pop bottles. You may connect more than one together.

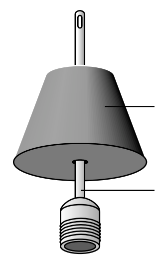
B. The only energy source your rocket may use is compressed air and water.

C. Brainstorm with your group ways to improve your teacher's rocket design (streamlining straight flight, soft landing, add fins, parachutes, etc.) Your teacher must approve your design for safety.

D. The rocket must be launched by having air pumped into it with a bicycle pump.

Plan and Construct

1. A needle for inflating a basketball or football is an excellent device for pressurizing the air in your pop bottle. Insert the needle through a rubber stopper as shown in the diagram. The stopper can then be attached to your rocket, and air pumped into it with the bicycle pump.



2. Brainstorm with your group for ideas on how to attach fins, what to make fins with, how to streamline the rocket, etc.

Evaluate

1. How straight did your rocket fly? What improvements could you make to your design to help the rocket fly straighter?

2. If you built a two-stage rocket, would it fly higher? Explain why.

3. How could you make your rocket fly higher by modifying the launcher instead of the rocket?

Extend Your Skills

4. Modern rockets carry a payload. Design a payload for your rocket. Include a diagram of the payload and a description of what it would do. You don't have to actually launch it.

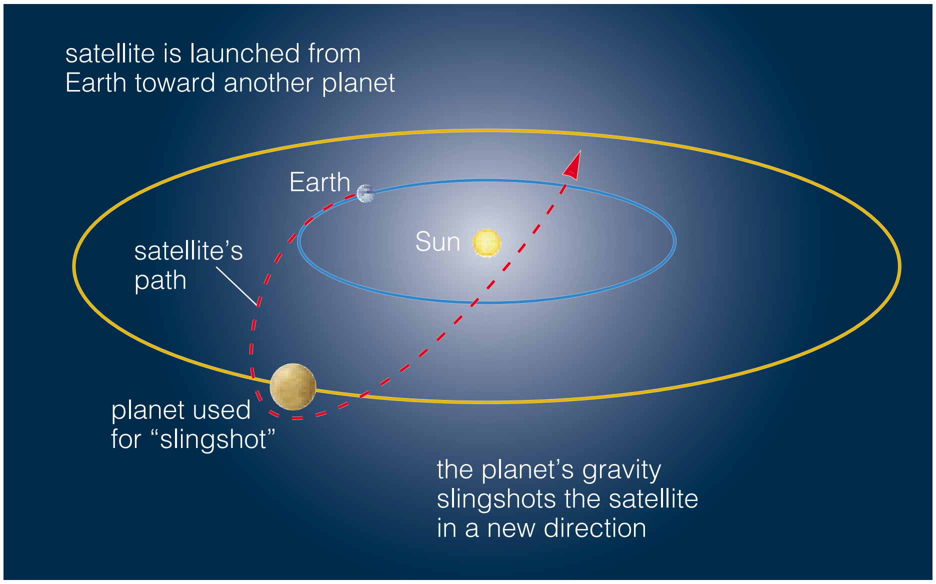


Figure 5.42 Gravitational assists give spacecraft extra speed.

Using Gravity

Rockets used today can blast spacecraft into Earth's orbit, but we don't have powerful enough rockets to send heavy spacecraft on long journeys throughout the solar system. So scientists developed a technique called gravitational assist. **Gravitational assist** is a method of acceleration which enables a spacecraft to gain extra speed by using the gravity of a planet. The craft is sent around one planet. The planet's gravity attracts the craft, causing it to speed up and change direction. The craft "slingshots" away from the planet at a higher or lower speed than it had before its encounter with the planet. The extra speed it gains is used to send the craft toward another planet. Computers are needed to calculate the orbit around the first planet in order for the gravitational assist to work properly.

DidYouKnow?

There is practically no friction in space and therefore a probe will never speed up or slow down once it is moving. If a probe encounters gravitational forces, however, this will cause it to speed up, slow down, or change direction.

Clarifying Images

Computer technology has improved our ability to look at the stars. Today, large telescopes use **charge coupled devices (CCDs)** instead of photographic plates to record the images. These devices convert light signals into electric signals in digital format. The images are then sent to a computer. Then the images can be processed in many ways using computer software. A light sky can be darkened, video "noise" can be erased, and images can be sharpened. Noise is any part of a signal caused by things other than what is supposed to produce the signal.

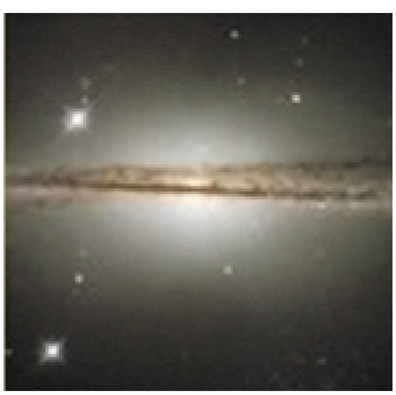


Figure 5.43A This Hubble telescope image shows a natural colour image of a galaxy. The actual imaging did not use visible light at all! A computer calculated the colours mathematically.

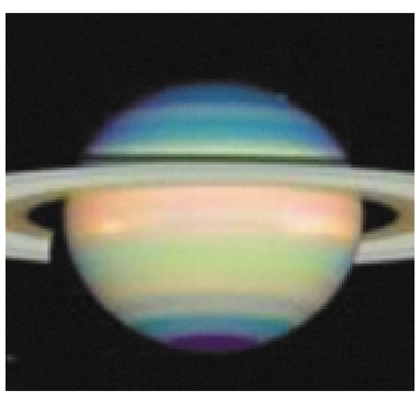


Figure 5.43B This Hubble image shows Saturn imaged in infrared radiation (heat). The colours represent the infrared radiation coming from the planet.

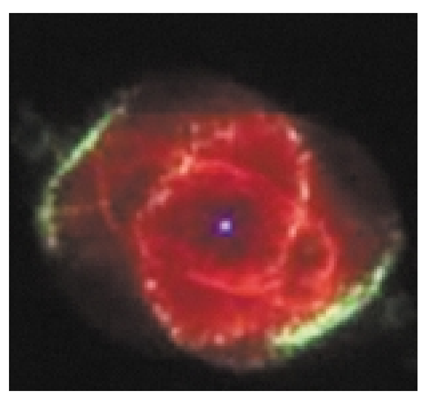


Figure 5.43C This Hubble image shows the actual colours of a nebula. However, the colours are enhanced to bring out finer detail.

Aiming the Hubble Space Telescope

Astronomers designed the Hubble space telescope (named after astronomer Edwin Hubble) to get a clearer view of the stars from above Earth's atmosphere. In April 1990, the space shuttle Discovery blasted off with the Hubble space telescope on board. The telescope is the size of a bus, with a main mirror 2.4 m in diameter. Computers on the ground communicate with on-board computers to direct Hubble's actions. The Hubble telescope is a great example of how rocketry and computing are essential for space exploration.

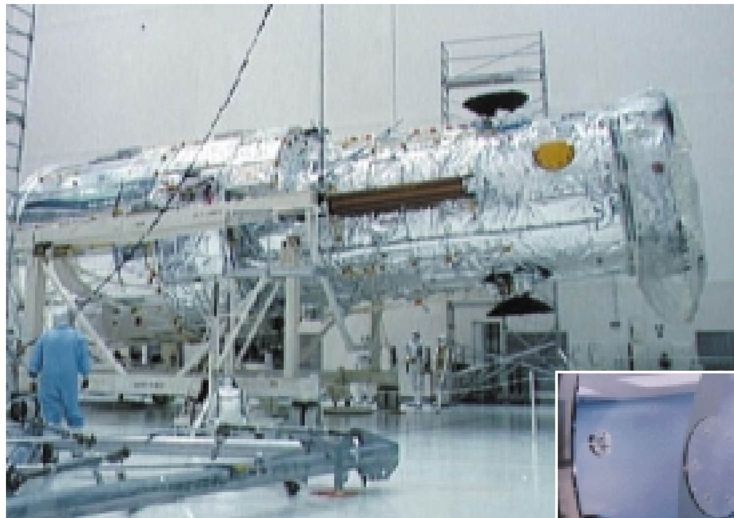


Figure 5.44A The instruments on the Hubble telescope consist of cameras and spectrometers. The images it records are transmitted to another satellite, which relays them to Earth. Earth's atmosphere neither blocks the radiation nor distorts the images the telescope receives. This has enabled the Hubble space telescope to record images that no other telescope on Earth could.

Figure 5.44B Technicians inspect the 2.4 m main mirror before assembly.

Looking at Earth

Astronomers use artificial satellites, such as the Hubble space telescope, to look out into space. An **artificial satellite** is a device made by humans, like a spacecraft or telescope. An example of a naturally occurring satellite is the Moon or even Earth — remember, Earth orbits the Sun! Artificial satellites are also used to look down at Earth itself. These types of satellites are used for communications, observation and monitoring, navigation, and mapping. They carry instrumentation (including computers) and their own power source, usually in the form of solar panels.

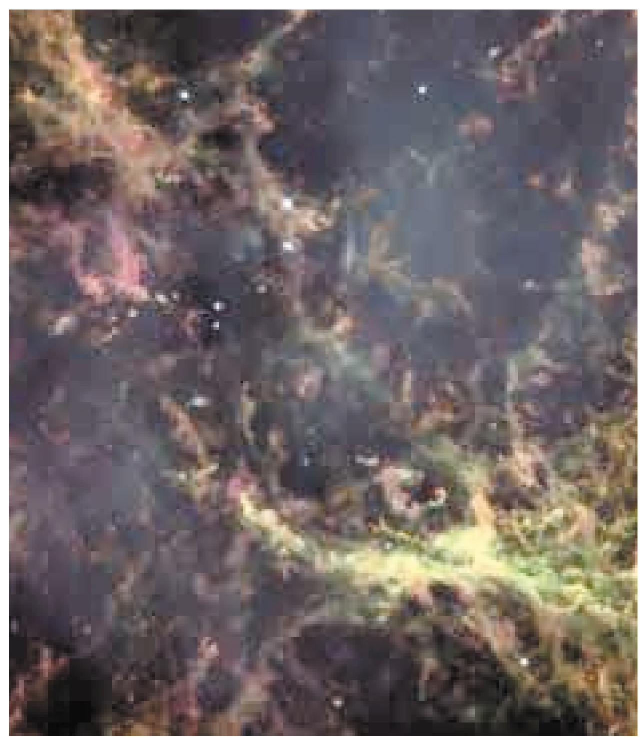


Figure 5.45 This Hubble image shows the very centre of the Crab nebula. Near the centre of this nebula is a pulsar.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Images from the Hubble space telescope are available to everyone on the Internet. Take a look into deep space for yourself. Go to the web site above, and click on Web Links to find out where to go next. Prepare a computer slide-show presentation of some of the Hubble space telescope's images.

Communication Satellites

Today, we are able to watch the World Cup of soccer as it happens in Europe, listen to a news correspondent report live from a conference in Asia, and talk by phone with someone located just about anywhere on Earth. In the last thirty years, the world has become a "global village" of instant communications, thanks to orbiting satellites.

Some communications satellites are placed in **low Earth orbit**, while others are placed in **geosynchronous orbit**.

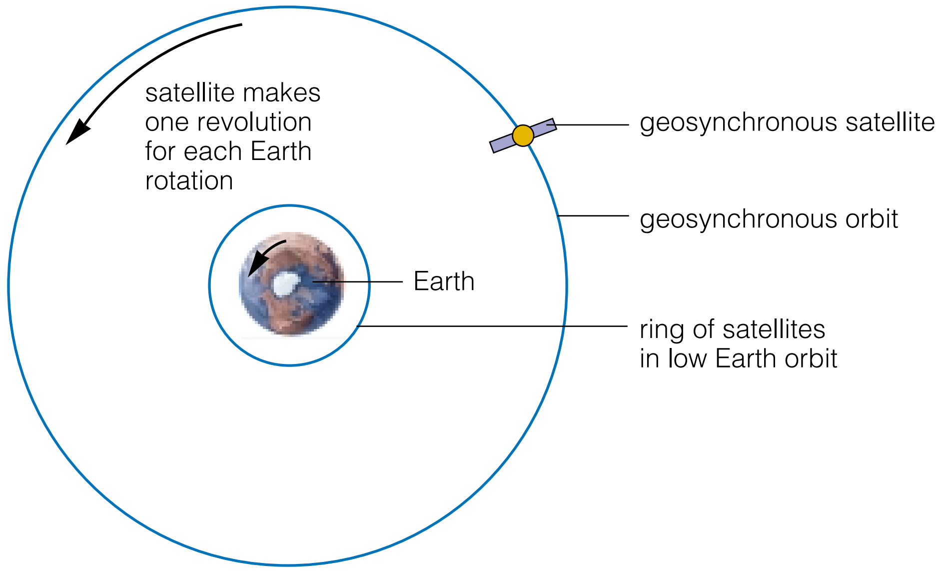


Figure 5.46
Geosynchronous Orbit: These satellites move in the same direction as Earth rotates. They are placed in orbit about 36 000 km above Earth, directly over the equator. At this altitude they take 24 h to orbit Earth once. They are synchronized with Earth's rotation. They appear to be motionless over a point on Earth's surface. Stationary antennae are used to track these satellites.

Low Earth Orbit: These satellites are placed 200–800 km high above the ground. They complete one orbit of Earth in about 1.5 h. Earth rotates 15° each hour, so as the satellite completes one orbit, Earth moves underneath it about 22.5° ($15°/h \times 1.5h = 22.5°$). These satellites circle Earth faster than Earth rotates. This means that, to an observer on the ground, the satellites move across the sky in a matter of minutes. To track signals coming from these satellites, moving antennae are used to follow their paths.

Word CONNECT

Look up the word "geo-synchronous." Explain the meaning of *geo* and *synchronous*.

Radio and television satellites are usually placed in geosynchronous orbit. Suppose a Canadian television network wants to place a satellite in orbit to deliver continuous television signals to Canadians. When you point a receiver at the satellite, you will receive a continuous signal. This is because the satellite is placed in orbit above the equator and always stays in the same place in the sky for everyone in Canada. If a Canadian television satellite were not always visible in the sky, then often you would miss your favourite show because the satellite signal would be out of range.

One problem with geosynchronous satellites for telephone communications is a noticeable time lag during telephone conversations. Low Earth satellites eliminate the lag because they are closer to the ground. This speeds up the signal transfer between the people who are talking. Fleets of low Earth satellites can accomplish the task of enabling people across the world to communicate with each other.

Math CONNECT

Satellite signals travel at the speed of light (3.0×10^8 m/s). How long does it take for a satellite signal to go to a geosynchronous satellite and back from a place directly under the satellite?

Observation and Monitoring Satellites

Observation satellites are used for forecasting weather, carrying out research, and helping ships, aircraft, and other vehicles determine their exact location on Earth.

Figure 5.47 Satellites are also used to measure depth of snow, the extent of ice buildup in Arctic waters, and the locations of forest fires. In this satellite image, you can see the smoke from fires burning in the summer of 1998 in northern Canada.

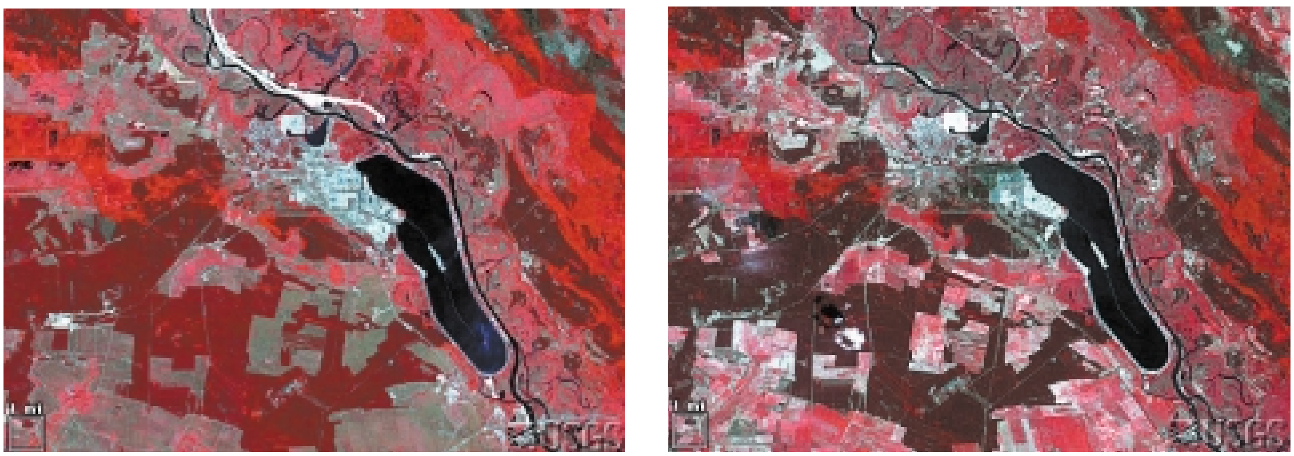


Figure 5.48 LANDSAT is a series of satellites designed to look at Earth — at land. Both images are infrared LANDSAT images. The left image shows the Chernobyl nuclear power plant just after the nuclear accident in 1986. The right image shows the same area six years later. There is evidence of farm abandonment during this time. The red fields in the left image indicate healthy vegetation. The darker fields in right image indicate dying vegetation.

Remote Sensing

The science of taking measurements of Earth (and other planets) from space is known as **remote sensing**. Here are some applications of remote sensing:

- Satellite images can be computer processed to show healthy versus unhealthy vegetation.
- Clear-cut and burned forests can be mapped to show the rates of their degradation.
- Water pollution can be imaged.
- Erosion can be tracked.
- Land use in cities can be observed.
- Weather can be tracked.

Word CONNECT

Why do you think the term "remote sensing" was chosen for how we monitor Earth from space?

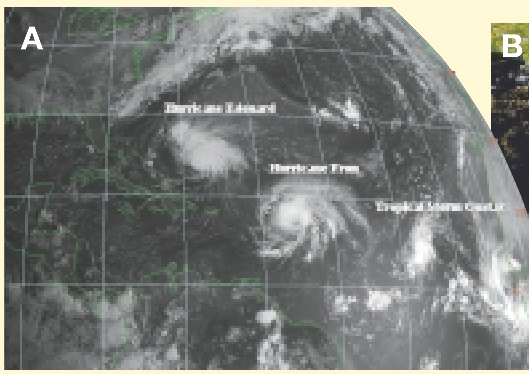
Find Out ACTIVITY

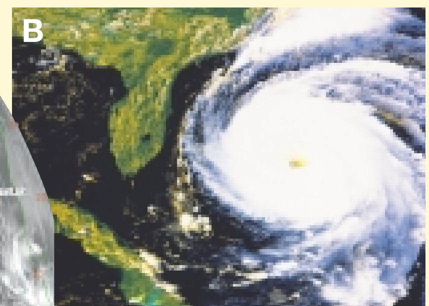
Interpreting Satellite Photographs

Different satellites provide different information, each better suited for particular purposes. This activity lets you explore these differences for yourself.

Procedure ✱ Analyzing and Interpreting

1. These two photographs were taken from two different satellites. Photo A shows a chain of three storms about to hit the U.S. east coast. Photo B, taken a week later, shows the second of the storms, Hurricane Fran, as it nears U.S. Shores. Study the photographs and analyze the information each provides.





What Did You Find Out?

1. Which photograph was taken by a satellite in geosynchronous orbit? Give two pieces of evidence to support your inference.
2. What are the advantages of each photograph in terms of information provided?
3. What uses can be made of the information discovered in the photographs?

Word CONNECT

"Anik" means "brother" in the language of the Inuit. Research the meaning of "Sputnik" and write it in your Science Log.

Cool Tools

Canada is a world leader in the development and use of communication satellites. On November 10, 1972, Canada's domestic communication satellite, Anik 1, was launched from Cape Canaveral in Florida. On February 5, 1973, the Canadian Broadcasting Corporation started network television transmissions to the Canadian North, becoming the first in the world to use satellites to transmit television. Canada was also the first country to place a satellite in geosynchronous orbit for domestic (non-military) purposes. More sophisticated Anik satellites have been launched since then.

The *Anik E2* satellite in this photograph makes it possible for students in Canada's North, who are often very far from a school, to participate in lessons and submit their assignments over the Internet.

Global Positioning System (GPS)

You learned earlier how the German military developed rockets to be used in war. Later, these rockets formed the basis of the technology that launched peaceful space missions. Another technology developed for the military now has non-military applications — the **global positioning system (GPS)**.

Using a small hand-held GPS unit, you can use satellite technology to find out where you are on Earth. The U.S. military placed a fleet of GPS satellites (called NAVSTAR, for navigation satellite tracking and ranging) 20 000 km above Earth. This isn't as high as geosynchronous satellites. GPS satellites take about 12 h to complete one orbit. However, there are enough GPS satellites in orbit so that there are always at least three above the horizon, wherever you are in the world, whatever time of day.

The satellites send out radio signals announcing their position and the exact time. Each hand-held GPS unit contains a receiver and a computer. It detects the radio signals and measures the distance to each satellite by comparing how long the signals take to receive. The unit then calculates your location on Earth, using the triangulation method that is programmed into the system. Most units can pinpoint your location to within about 30 m, although military units can be accurate to within a few centimetres.

Originally, the U.S. military used these satellites to provide their forces with around-the-clock navigation, in any kind of weather. Today, GPS receivers are used by fishers to mark good fishing spots, by pilots to track their airplane's position, and by paleontologists to mark dinosaur sites — even in the middle of a desert! People will always find new and interesting uses for the global positioning system.

Pause & Reflect

In addition to location, many advanced GPS units can calculate a person's speed, direction, and altitude. Name some practical tasks for which the GPS unit can be used. What jobs may change because of this advancing technology? Write your answers to these questions in your Science Log.

Did You Know?

The explorers who found *Titanic* used a GPS receiver to mark the location of the sunken ship. They had to ensure that they could find the vessel again because there were no landmarks to use in the middle of the Atlantic Ocean.

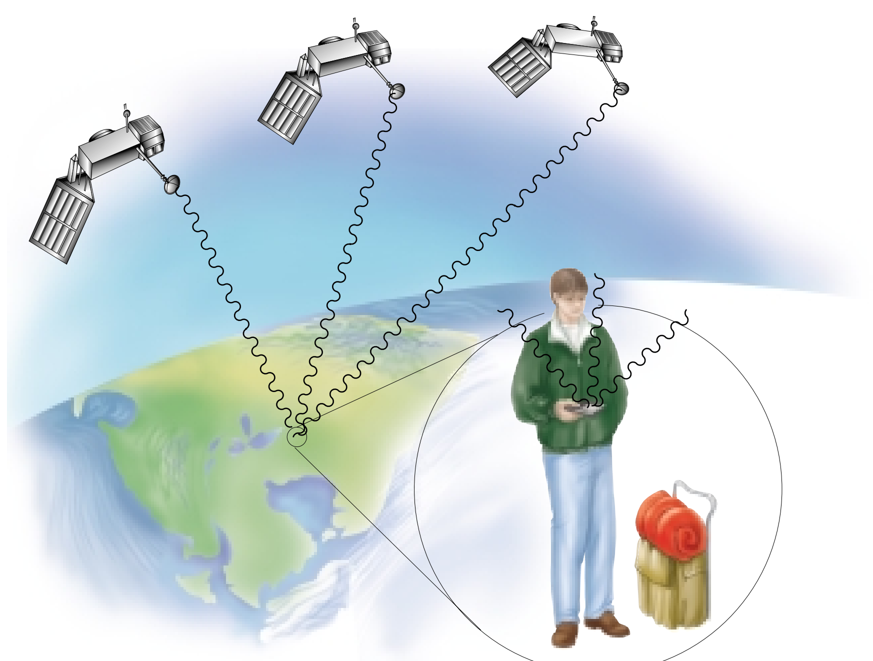


Figure 5.49 Using the GPS unit to determine your location.

Find Out ACTIVITY

Where Are You?

Satellites have been mapping Earth for nearly 40 years. There are many pictures of your location in the archives of many satellite systems.

Procedure ✷ Performing and Recording

1. Use the Internet to research satellite images of two Canadian locations, including your own. If possible, find two different images of these locations. The Canada Centre for Remote Sensing is a good place to start. Their web site has links to many remote-sensing programs. You could also search for the terms: LANDSAT, RADARSAT, SPOT, ERS, MOS, NOAA, JERS, remote sensing, or NASA.
2. Next, look for and analyze satellite images of an old city and a newer city. For example, Paris and Istanbul are old, while Edmonton and Calgary are new.

What Did You Find Out? ✷ Analyzing and Interpreting

1. How many different kinds of images did you find (photographs, infrared, false colour, etc.)?
2. What kinds of information can be "read" from the images? The captions for the images you found will have this information.
3. Describe visual evidence you see of human activity.
4. Can you tell a modern city from an old one? How?

TOPIC 6 Review

1. Why do modern rockets use liquid instead of solid fuel?
2. What is a two-stage rocket?
3. Compare the payloads of ancient and modern rockets.
4. Describe two types of artificial satellites. What are they used for?
5. What is remote sensing?
6. **Thinking Critically** How could you tell if a satellite dish was tracking a geosynchronous satellite or one in a low Earth orbit?
7. **Thinking Critically** A company wants to put a fleet of low Earth satellites in orbit to create a worldwide telephone link. There is less of a time lag in the conversations the closer to the ground the satellites are. What advantage is there to putting them 700 km up, instead of 250 km up in the sky?