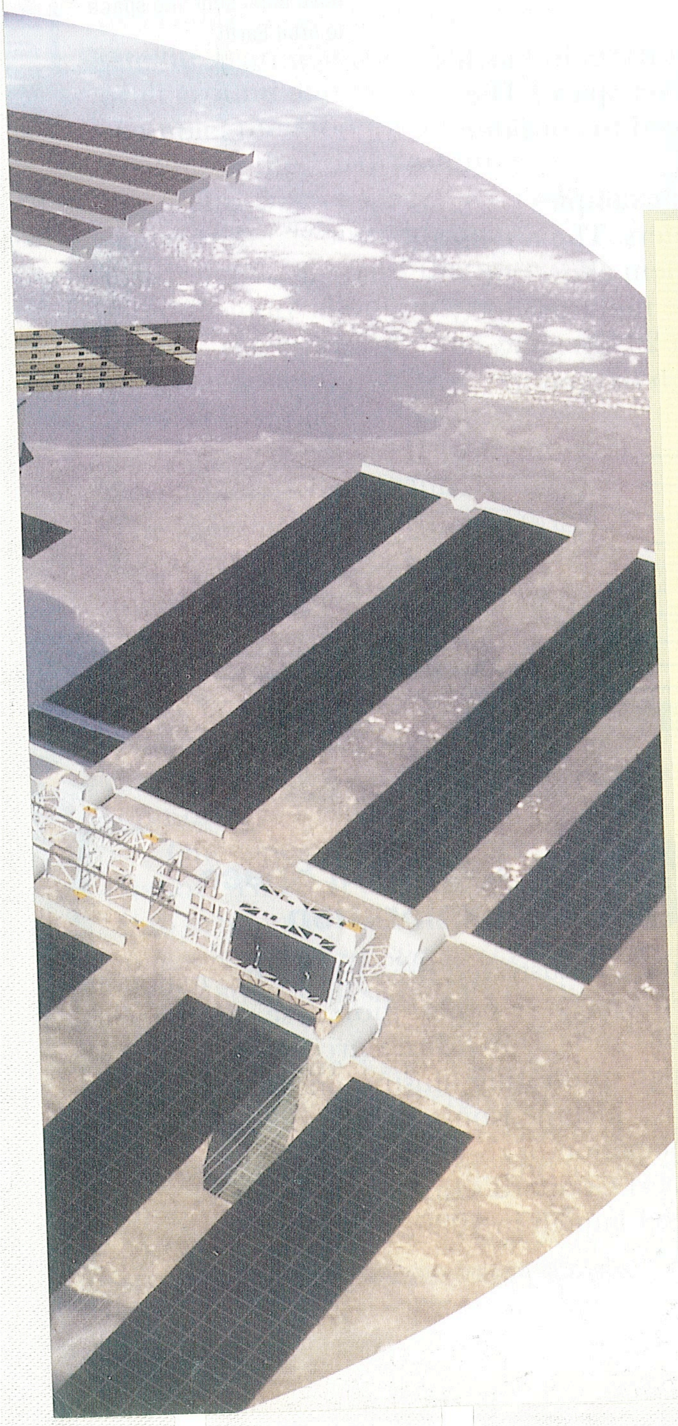
2 Although Canada's population is relatively small, our contribution to space technology is impressive. How does Canada contribute to space research, telecommunications, and international space programs? What are the positive and negative effects of this contribution on Canadians and on the rest of the world?

3 Astronauts travelling in a spacecraft in orbit around Earth look as if they are floating around in the craft. Why does this happen? How does this type of motion affect the human body and contents of the craft?

Reflecting

Think about the questions in 1, 2, 3. What ideas do you already have? What other questions do you have about satellites and humans in space? Think about your answers and questions as you read the chapter.



Try This A Packing List

Make a packing list of all your personal requirements for a three-month working tour on the Space Station. Your essential needs are air, warmth, water, and food.

1. Consider a typical day in your life here on Earth. Make a list of the activities you perform and what you need to carry out those activities.
2. Decide which of your daily needs on Earth you could live without for three months in space. Alter your list accordingly.
3. Consider what you would require in space that you would not require on Earth. Again, alter your needs list accordingly.
4. Assume that you will be in space for three months. Complete your needs list for the trip.
5. Compare your list with that of other students or groups. If necessary, make changes to your list.

16.3

Earth-Orbit Satellites

Have you ever watched a "live" event on television as it is happening in a country halfway around the world? Such live coverage on TV is made possible by satellites that continually orbit Earth relaying signals from place to place.

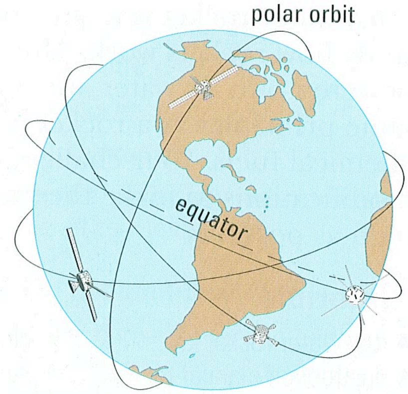


Figure 1
Examples of low Earth orbits may be around the equator, around the poles, or at any angle between the equator and the poles.

Satellites in Low Earth Orbit

In 1962, Canada became the third country in the world to send a satellite into space. *Alouette 1* was used for scientific research: to study particles in Earth's upper atmosphere by circling above it and collecting data.

Alouette 1 was an example of a satellite in **low Earth orbit**, an orbit at an altitude of between 200 km and 1000 km. At speeds of about 28 000 km/h, such satellites take only about 1.5 h to travel once around Earth (**Figure 1**).

Besides carrying out scientific research, the main function of low Earth-orbit satellites is **remote sensing**: making observations from a distance using imaging devices. We are familiar with images made from light: photographs. They can be recorded using traditional film cameras, but satellites use digital cameras so that the images can be sent back to Earth. Other types of images are created from infrared (heat) waves, radio waves, and other invisible waves of the electromagnetic spectrum. Each type of radiation registers different information and is used to watch for different phenomena (events). For example, radio waves can pass through cloud, so they can be used to create images of events that would otherwise be hidden by cloud cover. Satellites detect these different kinds of waves by using special cameras or antennas. The information gathered by the satellites is beamed to Earth using radio waves (**Figure 2**), which travel at the speed of light. On Earth, the signals are analyzed by computers and converted into visible images. Certain features of the image may have characteristics that make them particularly visible. For example, vegetation appears red in an image constructed from infrared radiation. This makes the image specially useful to foresters monitoring the regrowth of trees in a clear-cut area.

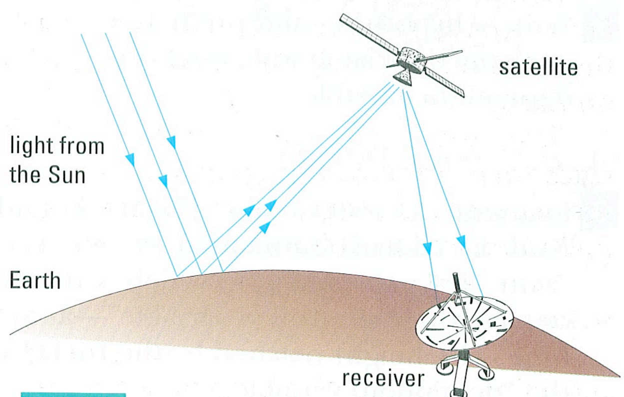


Figure 2
In daylight, visible light from the Sun reflects off Earth's surface or clouds. Digital cameras aboard a satellite capture the reflected light; then antennas on the satellite beam the digital information, using invisible radio waves, to a receiver on Earth.

Weather forecasting relies heavily on remote sensing, using images of cloud patterns around the world. With experience, weather forecasters can interpret these images to help predict what the weather will be like locally. They may even save lives by providing information on approaching storms, such as hurricanes (**Figure 3**).

Did You Know?

The cameras aboard some spy satellites are so sensitive that they are able to read letters and numbers about the size of a person's hand from hundreds of kilometres away.

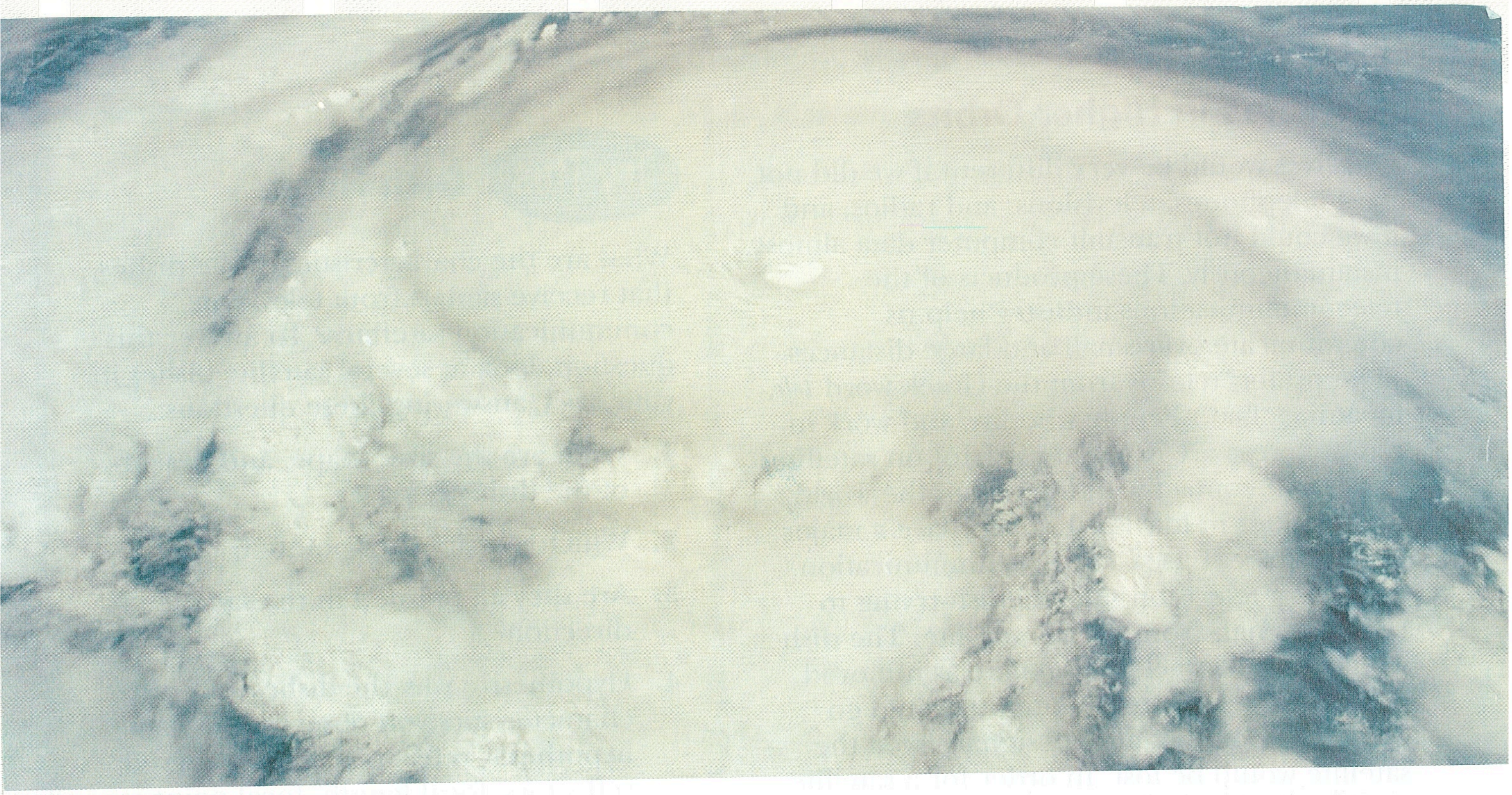


Figure 3
A satellite image showing a hurricane

Remote sensing is also used by the military. For example, some nations have spy satellites that obtain images of other nations' activities on Earth's surface.

Scientists also use images from satellites to study water resources, crop management, forests, insect damage, animal migration, pollution, and fault lines on Earth's surface.

Remote sensing satellites do not detect only naturally occurring radiation. They can also emit their own radiation and then pick up the reflections (**Figure 4**). Computers analyze the reflected signals and convert them into images. The types of radiation most often used are radio waves and microwaves. A Canadian satellite system called RADARSAT, featured on page 496, is used to construct radio-wave images of Earth's surface.

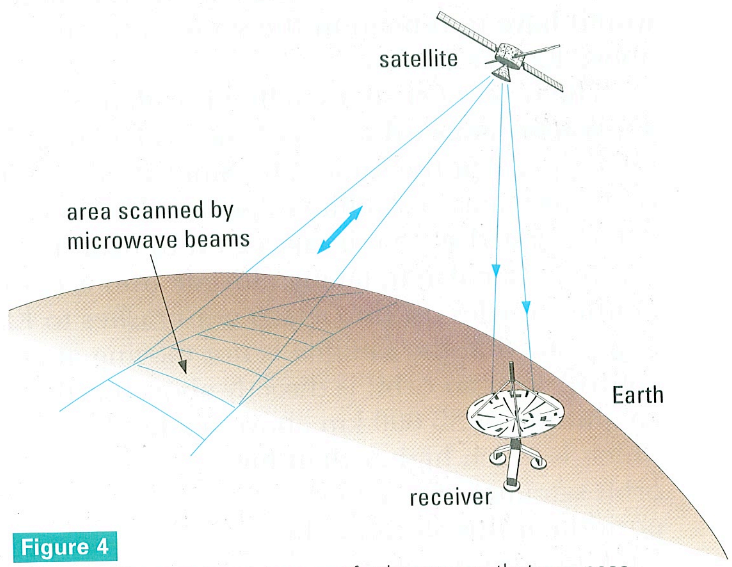


Figure 4
This satellite sends out beams of microwaves that can pass through clouds and reflect off Earth's surface. The satellite receives the reflected waves and converts the information to digital format and beams it back to a receiver on Earth.

Satellites in low Earth orbit can also be directed out toward space. To astronomers looking out into space from Earth's surface, the atmosphere acts like a fog, reducing their ability to see the stars, galaxies, and other parts of the universe clearly. Furthermore, there are parts of the electromagnetic spectrum that never get through Earth's atmosphere. Astronomers have known for a long time that they could improve their understanding of the universe if they could observe it from above the atmosphere. Telescopes aboard orbiting satellites, such as the Hubble Space Telescope, now enable them to make observations from space.

Did You Know?

Satellite phones and pagers can be used anywhere in the world if they are part of a communications network called Iridium. The system consists of 66 satellites in low Earth orbit (780 km).

Satellites in Higher Orbits

Our lives would be very different if we did not have telephones, televisions, and radios, and if we could not transmit computer data almost instantaneously. These products of the telecommunications industry help us communicate over small and large distances. (The prefix "tele" is from the Greek word *tele*, meaning "far.") People who live and work in remote areas are especially reliant on satellites to keep in contact with the rest of the world.

Satellites in low Earth orbits have a major disadvantage if used for TV communication. Imagine a television satellite dish trying to receive signals from such a satellite. The dish would have to track the satellite as it moved across the sky. Then the satellite would go below the horizon, and all signals from the satellite would be lost. In order for a satellite dish to receive signals constantly, the satellite would have to remain in the same location above Earth's surface.

The orbit of such a satellite is called a **geosynchronous orbit**. "Geo" means Earth and "synchronous" means taking place at the same rate. Since it takes Earth 24 h to turn once on its own axis, a satellite in geosynchronous orbit must travel at the correct speed so that it takes 24 h to orbit Earth. This speed must be carefully calculated, taking altitude into account, so that the satellite neither hurtles off into space nor crashes to Earth. From the ground, it appears that the satellite is not moving at all. The easiest place to control such an orbit is directly above Earth's equator, at an altitude of 36 000 km above sea level, which is much higher than low-orbit satellites. To keep its position at this altitude, the satellite must travel at a speed of 11 060 km/h (**Figure 5**).

Try This — Dish Hunt

What are the characteristics of the dishes that receive signals from television communication satellites? To answer this question, look at several satellite dishes in your area, answering these questions:

1. What are the size, shape, and design of the dishes?
2. Which way are they pointed?
3. Are they all pointed in the same direction?
4. Hypothesize why the dishes have the characteristics you observed. In your hypothesis, refer to shapes of curved reflectors, focal length, focal point, and wavelengths of waves.

Did You Know?

When Earth passes through a comet's tail, tiny particles of the tail can seriously damage a satellite, tearing its solar panels or even knocking it out of orbit.

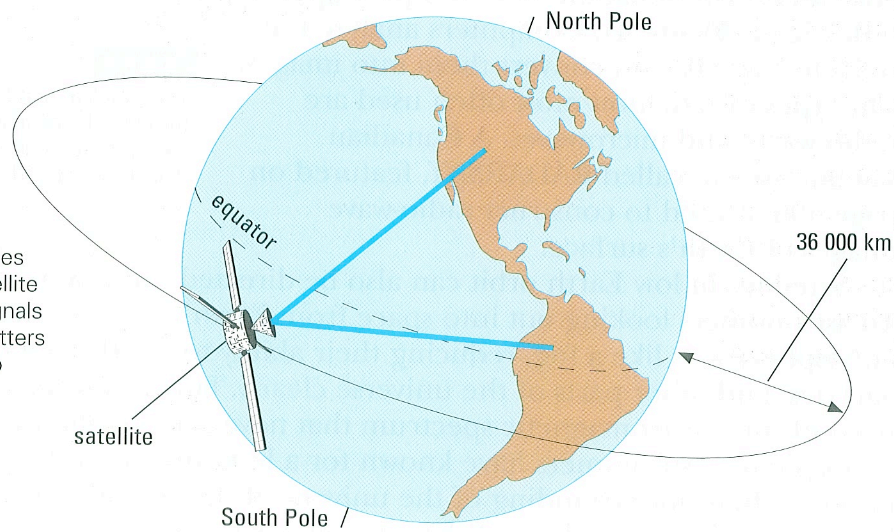


Figure 5
A geosynchronous orbit lies above the equator. A satellite located there receives signals from Earth-based transmitters and sends signals back to Earth-based receivers.

Canada has become a leader in telecommunications. The first satellite for domestic communications put into geosynchronous orbit was Canada's *Anik 1*, launched in 1972. There have been many versions of the *Anik* series, improving the area of coverage and the quality of radio, telephone, and TV signals. A recent technological advance includes a satellite that sends and receives signals from mobile telephones in cars, trucks, ships, and airplanes.

Some satellites not used for TV communication travel in orbits somewhat lower than geosynchronous orbits. For example, 24 satellites used for search and rescue operations travel in 12-hour orbits, 20 000 km above Earth's surface. They form the **Global Positioning System** (GPS). A portable GPS receiver is a small device that receives signals from three or more of the orbiting satellites. It then uses accurate clocks and preprogrammed information to calculate and display its own position. This position could then, if necessary, be relayed by radio to other people, such as a rescue team searching for a downed plane or a lost hiker.

Space Junk

As you have now read, we receive many benefits from orbiting satellites. Unfortunately there are also some disadvantages. One is the huge expense. Another is the accumulation of useless artificial objects orbiting Earth, commonly referred to as *space junk*. Satellites, for instance, are not designed to return to Earth once they become obsolete or malfunction. Another concern is that chunks of satellites and space stations could fall to Earth. There are other pieces of space junk, ranging in size from microscopic to huge pieces: blown-out bolts; bits and pieces from accidental explosions; discarded rocket engines; and even real garbage from piloted craft. These pieces are spread far apart in their orbits, so are difficult to clean up. Countries involved in the space program are discussing what to do about the problem of space junk.

Did You Know ?

In January 1978, the Russian nuclear satellite *Cosmos 954* crashed into the Thelon Game Sanctuary in the Northwest Territories, narrowly missing some explorers camping in the wilderness. Picking up every piece took months and, although it was somebody else's garbage, Canadian taxpayers had to pay most of the bill.

Understanding Concepts

1. What are the features of a low Earth orbit?
2. What is a geosynchronous orbit, and what type of satellite must use this orbit? Explain why.
3. What is the advantage of having an observatory in space?
4. Using the data given in the text and the equation
   speed = distance/time,
   calculate the speeds (in kilometres per hour) of
   (a) a geosynchronous satellite;
   (b) a satellite with an orbit 200 km above Earth's surface.
   Assume that Earth's radius is 6400 km. Compare your answers with the values given in the text.

Making Connections

5. Who should be responsible for the cleanup of pieces of spacecraft that crash to Earth? Give reasons. Are your answers affected knowing that some of these falling vehicles contain nuclear power plants?

Exploring

6. What else would you like to know about satellites? Make a list of questions, then try to find answers.
7. Search the Internet for satellite images of Ontario. What types of electromagnetic radiation are used to compile each image? What features do they reveal?

Challenge

Identify Canada's role and use of satellites to include in your information package.

Make a three-dimensional scale model of Earth and space beyond it to show the location of various satellites in orbit for your planetarium show.

16.4 Case Study

RADARSAT

In the spring of 1997, people in Manitoba were faced with one of the worst floods in their history. Soon after the flood began, satellite images helped emergency crews plan disaster control and relief (**Figure 1**). These images were provided by RADARSAT, a highly successful satellite system designed, built, and operated by Canadians.

Helping in emergencies is only one of the many uses of RADARSAT, as you will see.

The word **radar** is short for "radio detection and ranging." This means that a radar device emits bursts of radio waves and picks up their reflections to detect objects (detection) and find out how far away they are (ranging). Radio waves travel at the speed of light and can pass through clouds, so they can be used in all types of weather and at night.

(a) What are advantages of radio waves over visible light?

(b) Brainstorm some other uses of radar.

As its name suggests, RADARSAT is a satellite system that employs radar. It looks at features on land and on oceans using radio waves. Bats use a similar system of emitting high-pitched sounds and interpreting the reflections off obstacles or food sources.

In addition to floods, RADARSAT helps in various large-scale emergencies, such as earthquakes, mudslides, ice storms, ice jams, and oil spills on the ocean.

(c) How might RADARSAT help in your local area?

Many industries benefit from RADARSAT images. Many resources, such as oil, natural gas, water, and minerals are found underground. Often the surface features on the ground help scientists predict where these resources are. These surface features are much easier to find using satellite images. Images also let us monitor crop conditions, forests, soil humidity, river flows, fish stocks, and shipping conditions.

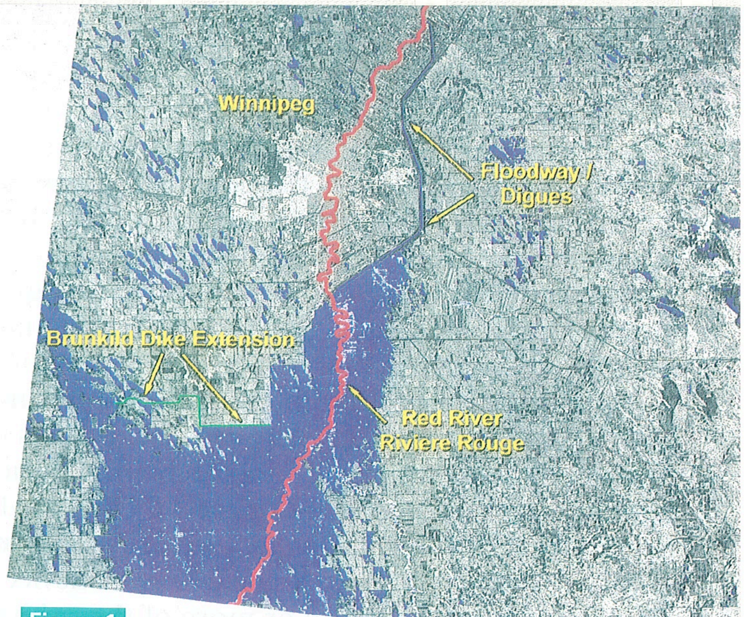


Figure 1
This radar image of part of Manitoba has been computer enhanced, so different features show up as different colours. The red line shows the normal course of the river. The blue area shows the area under floodwaters in 1997.

(d) Why might it be better to search for underground resources by using RADARSAT images than by ground surveying?

In order to provide a healthy planet for future generations, humans must learn to protect our environment. Satellites help us monitor the environment and make wise decisions about our actions.

(e) RADARSAT is an expensive system, but it provides great benefits. Is it worth the cost? How do we decide?

Understanding Concepts

1. In a list, summarize the benefits of using RADARSAT.

Exploring

2. Compare the properties of radio waves with the properties of other parts of the electromagnetic spectrum. (For more information about the electromagnetic spectrum refer to Section 14.6, page 449, or use a separate resource.)
3. Research other animals, besides bats, that use a ranging/detection system similar to RADARSAT. Compare the systems.

16.5 Activity

Tracking Satellites and Other Objects

Have you ever looked up into the sky on a clear evening just after sunset and seen a bright object slowly drifting across the sky? It could have been a satellite, a space shuttle, or perhaps even the *International Space Station*. In this activity, you will perform research to find out when satellites and other objects might be seen, then you can try to observe them and track their paths.

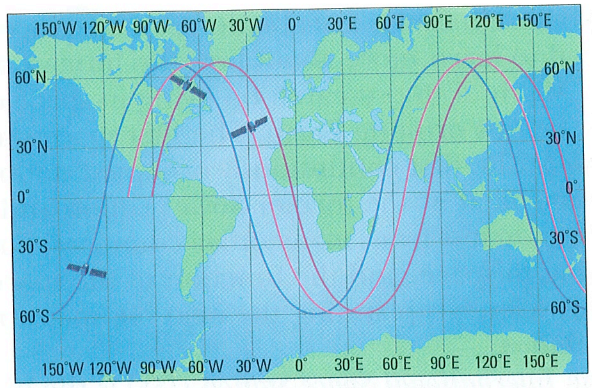


Figure 1
Example of a world map showing paths of satellites

Materials

- access to the Internet or appropriate software
- copy of seasonal star map (or a planisphere)
- observation sheets
- binoculars (optional)

Procedure

1 Research which large satellites (or other human-made objects) will be passing over your region in the next few weeks. Interpret the maps showing the satellites' paths (**Figure 1**).

(a) Describe what you have learned about predicting where and when to see a human-made object in the sky.

2 On your star map, trace the paths of two or more objects that may soon be visible on a clear evening. Label when the objects might be seen at various parts of the path. (Be sure to correct to local time if your resources use standard time.)

3 Choose a time to view the sky. Remember that just after sunset the sky will be dark but the satellite will still be in bright sunlight, and also that it will be difficult to see a satellite near the Moon.

Always obtain your parent or guardian's permission before going out to watch the night sky. Dress appropriately.

4 On a clear evening, try to observe the satellites you have researched. Binoculars might help you view the satellite once you have located it.

(a) Record whether or not you observed the satellites. Give reasons.

Understanding Concepts

1. Why can we see human-made objects in the night sky?
2. If you observe two satellites in the sky and they take different times to travel all the way across the sky, what can you judge about the motion or path of the satellites? Explain.
3. Do you think you would be able to see geosynchronous satellites in the sky? Explain.
4. Write a short report for the student newspaper, describing what satellites or other artificial objects can be seen at what times. Include appropriate safety precautions.

Exploring

5. Find out why people in Canada are unable to see the Hubble Space Telescope in the sky, yet people in the southern United States can. Share what you discover with your class.

Reflecting

6. Describe features of the software or Internet site you used that (a) you liked and (b) you think could be improved.

Challenge

Many people are unaware that satellites are often visible overhead. How would you try to increase that awareness in your planetarium show?

The International Space Station

Long before humans are able to colonize places like the Moon or Mars, we need to learn more about how the human body can survive in space. Much of the research on living in space can be carried out in space stations orbiting Earth. The first space station was *Salyut*, followed by *Skylab*. The first continuously occupied station, *Mir*, was constructed and controlled by the former Soviet Union and visited by astronauts and cosmonauts from many other countries. For many years, studies on surviving in space, and the function of the space station itself, provided data for scientists planning the next big space project: the *International Space Station*.

The ***International Space Station (ISS)*** is the biggest technological project ever built by humans. It involves the cooperation of space agencies from Brazil, Canada, Europe, Japan, Russia, and the U.S.A. When it is complete, it will have four research modules, a service module, a habitation module, remote robotic controls, a cargo block, a docking station for shuttle craft, and huge solar panels, all connected to a central truss over 100 m long. Forty-five launches of space shuttles and Russian boosters will carry up the more than 100 pieces—totalling 4.5×10^5 kg—for construction about 450 km above Earth's surface.

On board the station, six astronauts will live for three months at a time, performing numerous science experiments related to plants, animals, humans, materials research, crystal growth, chemical reactions, the environment, and other areas. Many of these experiments depend on the constant free fall (microgravity) conditions of the space station. The astronauts will also retrieve and repair satellites. This research could lead to better medicines, better crops, and better liquid fuels.

An artist's impression of the *ISS* is shown on page 486.

Did You Know?

The Canadian astronaut program, part of the CSA, holds recruiting drives every few years, searching for applicants with the right aptitude and qualifications. These qualifications include scientific studies in medicine, physics, or engineering.

Canada's Contribution to the *International Space Station*

Canada's space exploration activities fall under the control of the Canadian Space Agency (CSA). The National Research Council of Canada (NRC) is also involved in the development of technology for use in space. Canada, with its reputation for building sophisticated robots (**Figure 1**) as well as visual systems used on the ground and in space, is an important contributor to the *ISS*. **Figure 2** describes the robotic and visual systems designed, built, and maintained by Canadians.

Try This: Manual Dexterity

While working outside the *ISS*, astronauts have to wear bulky space suits to protect them from the cold, the vacuum of space, and the Sun's radiation. At the same time, they have to perform delicate procedures with extremely sensitive equipment. To get an idea of the challenge faced by astronauts, try the following tasks while wearing bulky or heavy gloves:

- tighten a nut on a bolt
- operate a VCR
- use tweezers to pick up a feather

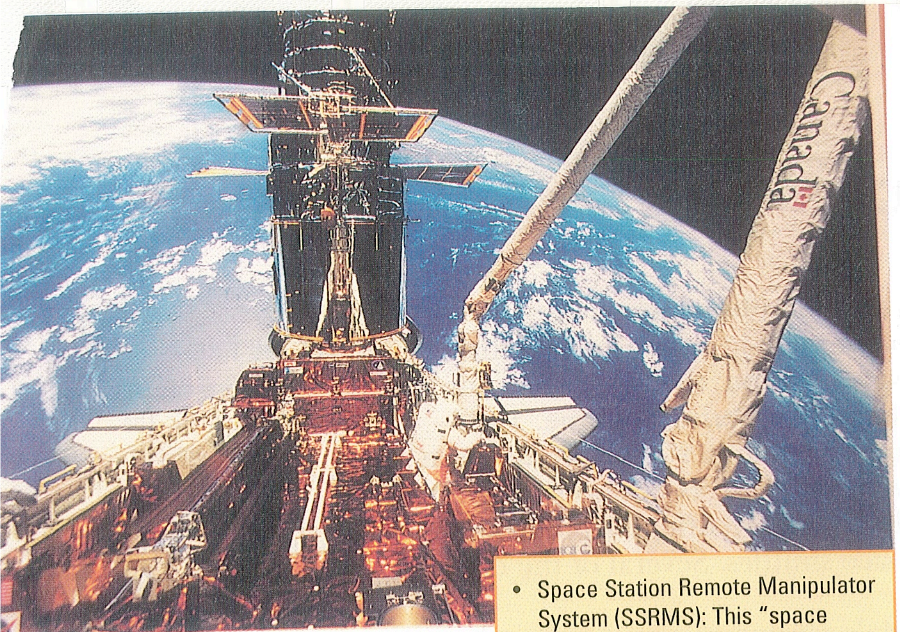


Figure 1
The Canadarm is the most famous of Canada's space robots.

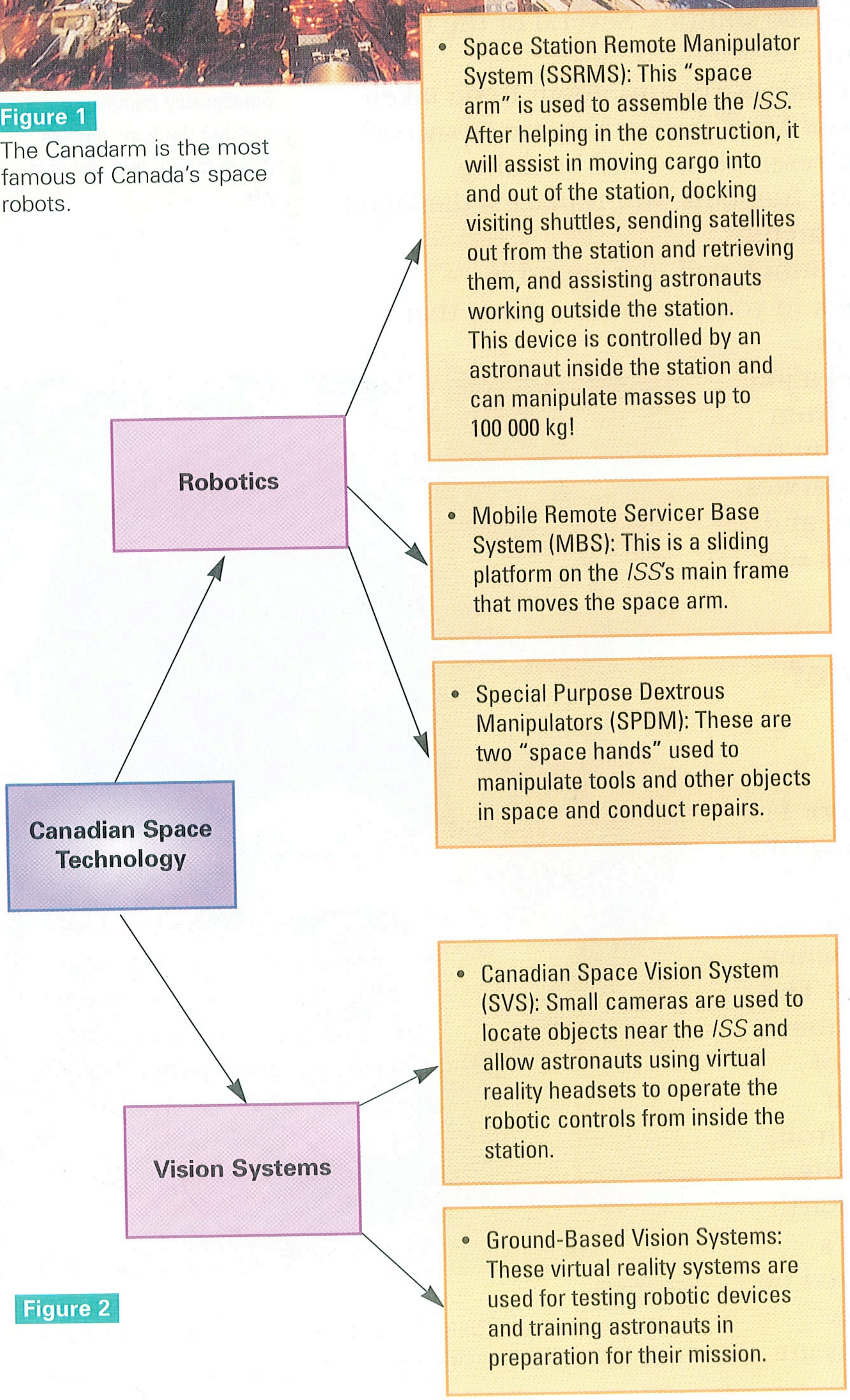


Figure 2

Understanding Concepts

1. Describe uses of space stations.
2. What areas of expertise do Canadians bring to the *International Space Station*?

Making Connections

3. Assume you have to design a robot to turn the pages of a book. What features would you use in your design? Start by breaking down the task into its component parts.

Exploring (3A)

4. To learn why Canada has a good reputation in the robotics industry, find out more about the Canadarm used on space shuttles. Identify the role of the National Research Council of Canada in its development. Make a visual presentation of what you discover.
5. Find out about robotic uses in space other than those mentioned in this section. Make a list of the uses you discover. In a group, create a mural that illustrates past accomplishments of and future expectations for robots in space.
6. The Russian space station, *Mir*, experienced many technical difficulties in the 1990s, sometimes threatening the lives of the crew. Research these problems and how they were solved.

Challenge

Which experiments on the *ISS* will be necessary to know how to survive on a space colony? How would you simplify an understanding of the significance of Canada's role in space technology for a younger audience?

SKILLS HANDBOOK: (3A) Research Skills

Humans in Space

Dr. Valeri Polyakov has spent a total of 22 months in space. He also holds the record for the most consecutive time in space: 14 months! He was a cosmonaut aboard the *Mir* space station, the first spacecraft designed to keep people in orbit for extended periods of time. The first module was launched in 1986, and several other components have been added since. It has housed between two and six cosmonauts and astronauts at a time, including Canadian Chris Hadfield, all of whom are transported to and from *Mir* by space shuttles. Several of the crew have remained in *Mir* for over a year.

Imagine that you are one of Canada's astronauts about to be taken in the space shuttle to the *International Space Station*. You are a payload specialist: an expert on the scientific research you will be doing. Another job you have is to replace the fuel tank and replace a damaged part of a Canadian communications satellite.

As the shuttle blasts off from the launch pad, the sound is tremendous, and you are pushed back in your seat with a force that makes you feel three times as heavy as normal. Within two minutes, you feel a jolt as the solid rocket boosters separate from the shuttle. About six minutes later, you feel another jolt as the main fuel tank separates. The force pushing you back eases off, and you feel as if you are floating; only the seat belt keeps you in your seat.

Did You Know?

In 1997 there was an accident on *Mir*. The space station collided with a spacecraft attempting manual docking, puncturing part of the station. Fortunately, the crew was able to take emergency measures, contain the leak, assess the damage, and stabilize *Mir*.

Floating in Space: A Result of Free Fall

Often people and objects in orbiting spacecraft appear to be floating (**Figure 1**). In an effort to explain this effect, the terms "zero gravity" or "microgravity" are sometimes used. These expressions are misleading: there is plenty of gravity acting on the spacecraft and everything in it. The *ISS*, for example, operates at 450 km above the ground. At that altitude, the pull of Earth's gravity is almost 90% of what it would be on the ground, which is far from zero! In fact, without the force of gravity pulling on it, the *ISS* could not orbit Earth at all. For a spacecraft to follow Earth's curvature, the downward motion caused by gravity is essential. The floating occurs because the spacecraft and its contents are

Figure 1
Canadian astronaut Chris Hadfield appears to be floating. What is really happening to create this effect?