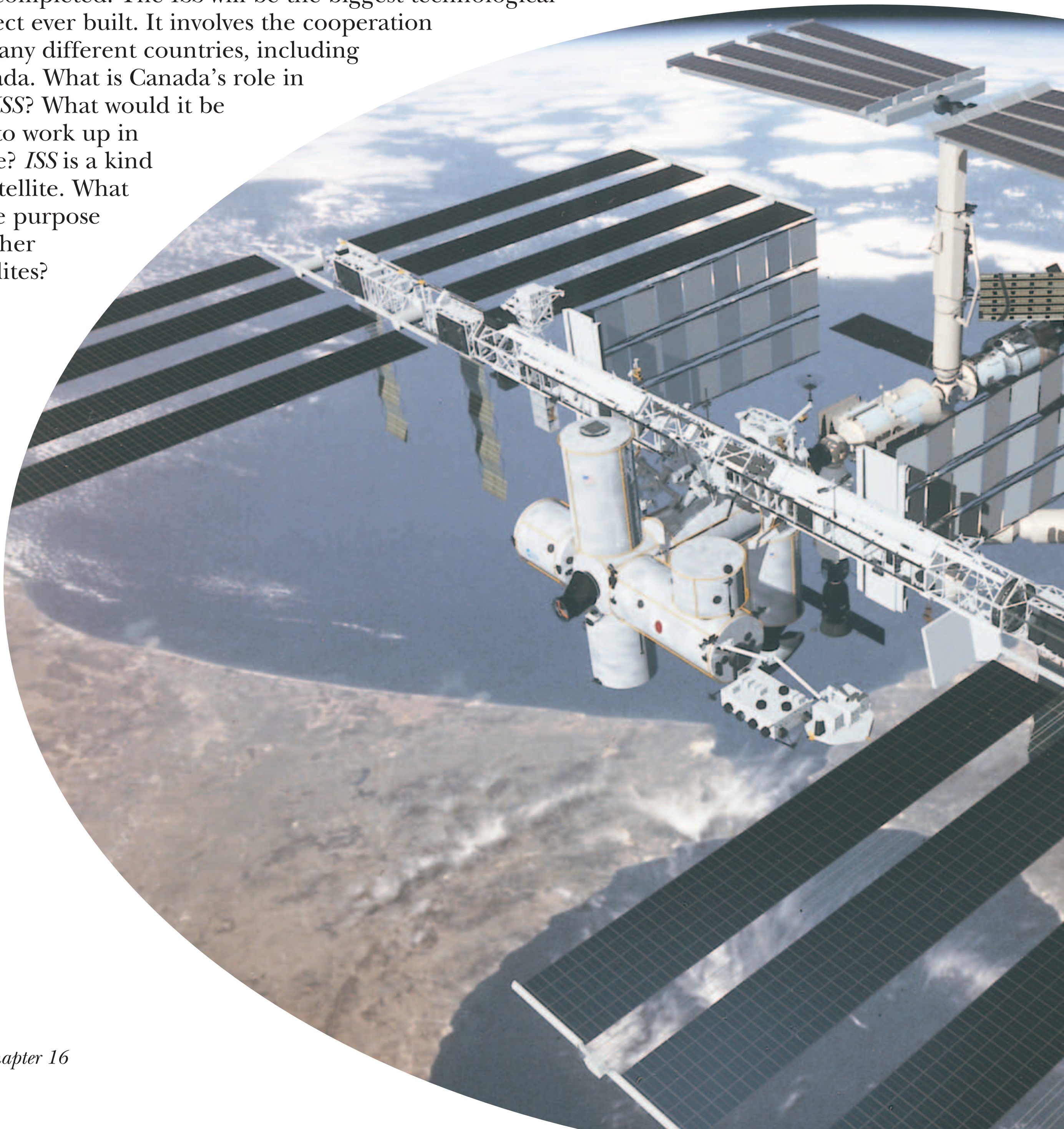
CHAPTER

16 Space Research and Exploration

Getting Started

1 This is what the *International Space Station (ISS)* will look like when it is completed. The *ISS* will be the biggest technological project ever built. It involves the cooperation of many different countries, including Canada. What is Canada's role in the *ISS*? What would it be like to work up in space? *ISS* is a kind of satellite. What is the purpose of other satellites?



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.

16.1

Getting into Space

A basic human characteristic is curiosity—our drive to explore. People have crossed the oceans, climbed Earth's highest mountains, and walked on the Moon. The biggest single frontier left to explore is **outer space**, which is everything outside of Earth's atmosphere. The atmosphere—the air and everything it holds, such as water vapour—extends upward from Earth's surface, gradually becoming less dense until it finally becomes almost nothing at an altitude of about 150 km. This is where "outer space" begins.

Did You Know?

The first artificial satellite, *Sputnik*, was launched into space in 1957 by the Soviet Union. Canada's first satellite, *Alouette 1*, was launched in 1962. Since then, hundreds of satellites have been sent into space to orbit Earth.

Comparing Aircraft and Spacecraft

Can an aircraft travel in outer space? Can a spacecraft travel in Earth's atmosphere with no engines operating, as it can in outer space? The answer to both questions is no. To find out why, we need to consider the characteristics of each type of craft.

An **aircraft** is a vehicle that travels through the air; examples include jet airplanes, propeller airplanes, and helicopters. The engines of these vehicles must operate continuously to keep them above the ground. The engines use oxygen in the air to burn the fuel they need to travel. Most aircraft do not travel higher than about 20 km above Earth's surface. If they go too high, there is not enough oxygen to support the burning of the fuel. Also, air is needed to support the aircraft. Whether it is a helicopter or a plane, air keeps the aircraft aloft. The rotors or wings are curved so that the air pressure below them is greater than that above (**Figure 1**), so they are forced upward. Without the air, an aircraft would plummet toward Earth.

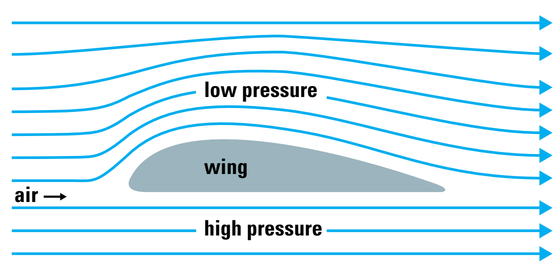


Figure 1

A **spacecraft** is a vehicle designed to travel in the near vacuum of space, usually 200 km or more above Earth's surface (**Figure 2**). Once the spacecraft rises above the atmosphere and is travelling extremely fast parallel to Earth's surface (which tends to make it leave Earth), its forward speed balances the pull of gravity (which tends to make things fall toward Earth). When these two opposing pulls are perfectly balanced, the spacecraft no longer needs to operate its engine full-time in order to travel around Earth. The spacecraft must be above the atmosphere, otherwise air resistance (the friction of the air molecules brushing past the craft) would slow it down.

Try This: Events in Space Exploration

Make an illustrated time line of the major events in space exploration. Use reference books and CD-ROM resources to help you design interesting illustrations. Early events include Konstantin Tsiolkovsky's explanation of rocketry in 1903 and Robert Goddard's first liquid-fuelled rocket launch in 1926.

Although many spacecraft travel in orbits around Earth, some go to the Moon or to other parts of the solar system. A spacecraft must carry its own fuel and source of oxygen, and it must travel fast enough so it doesn't fall back to Earth.

Unpiloted and Piloted Spacecraft

Spacecraft can be piloted (with people on board) or unpiloted (also called robotic spacecraft). Satellites are the most common type of spacecraft. As you've learned, a satellite is an object that travels in an orbit around another object; for example, the Moon is a natural satellite of the Earth. Another important type of spacecraft, called a **space probe**, is one with many instruments on board that is sent to discover more about moons, planets, comets, the Sun, and other parts of the solar system.

The first piloted spacecraft was sent into space in 1961 by the former Soviet Union (Russia and its allies). The cosmonaut aboard was Yuri Gagarin. Piloted craft tend to gain more public attention than unpiloted spacecraft, but the added expense of sending humans into space is a disadvantage. Piloted spacecraft always have to be brought back to Earth, whereas unpiloted craft often do not have to return.

One type of piloted spacecraft is the space station. The first one, *Salyut 1*, was placed into orbit in 1971. A newer station is the *International Space Station (ISS)*, shown on page 486. It is designed to stay in space for many years, allowing people to live and work in space. **Figure 3** shows an example of another piloted spacecraft: the space shuttle built by the United States. One task of the shuttle is to take materials and astronauts to and from the *ISS*.

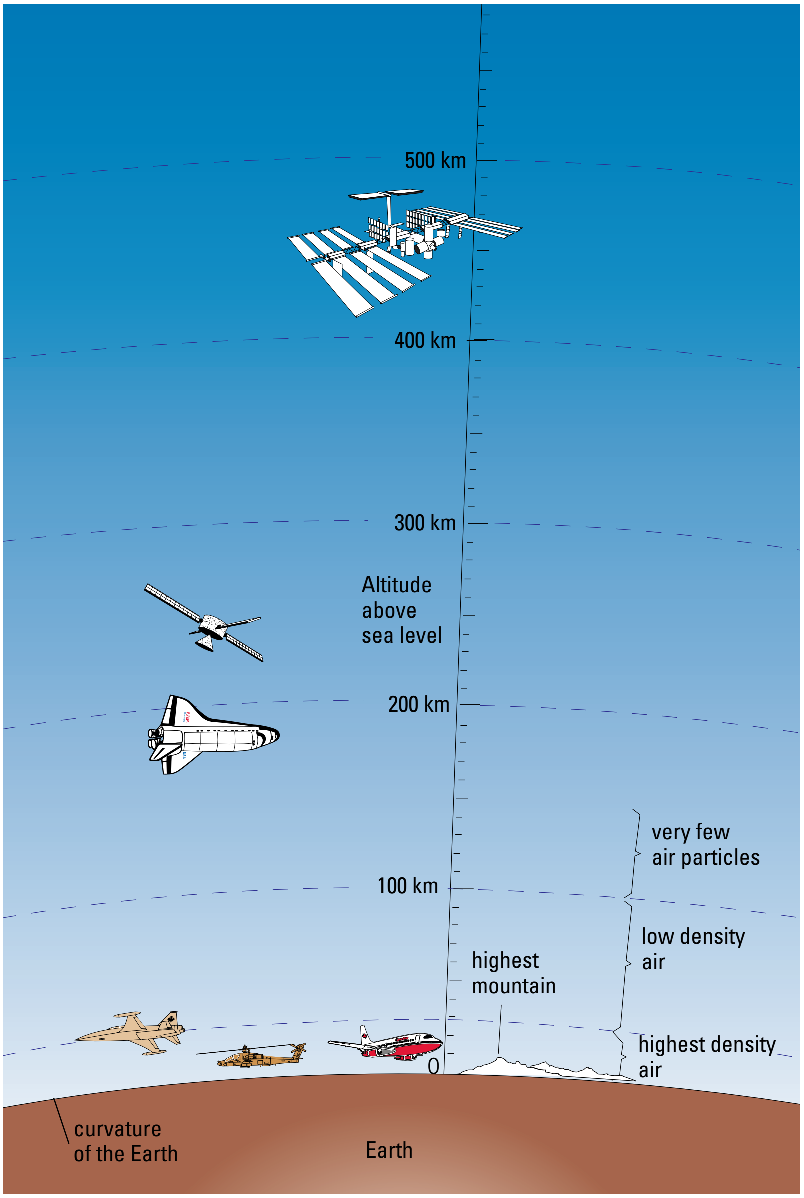


Figure 2
Vehicles in Earth's atmosphere and in outer space beyond

Figure 3
This U.S. space shuttle is about to land. What clues reveal that it is a piloted spacecraft rather than an unpiloted one?

Payloads and Launchers

If you were to throw a ball to a friend, your arm could be called the launcher, and the ball, the payload. In space exploration, a **payload** is any satellite, piloted spacecraft, or cargo launched into space. The **launcher** is the device that carries a payload into space. Its main part is a rocket engine.

What happens if you try to throw a ball straight up? It soon falls back down, pulled by gravity. Large bodies, such as Earth, exert a strong force of gravity on nearby objects. A vehicle can be launched into space only by counteracting Earth's strong force of gravity. The huge force needed to counteract gravity is provided by a powerful rocket engine.

A toy balloon is a simple model that helps explain how a rocket engine works. When the air in an inflated balloon is released, the balloon flies quickly and uncontrollably around the room. As the air under pressure inside the balloon escapes from the open neck, the balloon is forced in the opposite direction. The force that causes an object to move is called **thrust**. In the case of the balloon, the thrust is exerted by the pressure of the gas coming out of the balloon. If the air is escaping to the left, the thrust on the balloon is to the right (**Figure 4**).

Like a balloon, a rocket engine is enclosed except at the nozzle end. Unlike a balloon, a rocket engine operates through the action of two chemicals. **Figure 5** shows that exhaust gases travelling rapidly in one direction cause thrust on the rocket in the opposite direction.

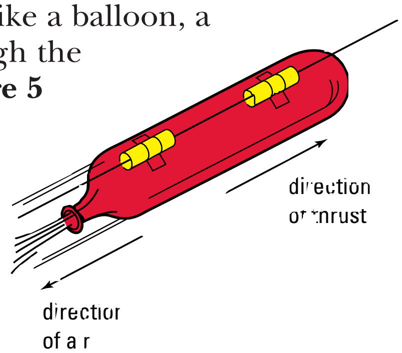


Figure 4

A balloon can demonstrate thrust. To guide the balloon, feed fishing line through two pieces of a drinking straw taped to a blown-up balloon. When the balloon is released, air leaves the open neck rapidly in one direction, creating a thrust on the balloon in the opposite direction.

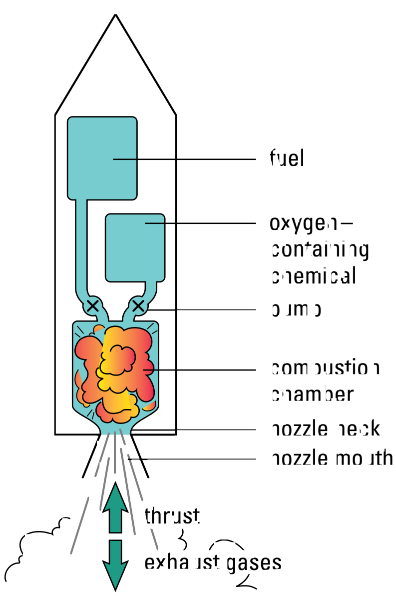


Figure 5

This represents the basic design of a liquid-fuelled rocket engine. The fuel and an oxygen-containing chemical are pumped into the combustion chamber where the fuel burns rapidly, producing gases under high pressure. The gas molecules speed up as they escape through the nozzle neck; then they speed up even faster when they get to the nozzle mouth. These escaping gas molecules exert an upward thrust on the rocket engine.

Understanding Concepts

1. Name the force that must be overcome in order to launch a vehicle into space.
2. Classify each of the following as a payload or a launcher:
   (a) a weather satellite
   (b) a rocket
   (c) an astronaut
3. Describe thrust and how it causes a rocket to move.

Making Connections

4. Why do humans want to explore space? Give reasons to support your views.
5. Suppose you needed raw materials to build a space colony on another planet. What would be some of the advantages of obtaining those materials from the Moon rather than from Earth?

Exploring

6. How could you make a flying balloon into a payload-carrying device? What might an appropriate payload be? With your teacher's approval, try "launching" a rocket balloon (**Figure 4**) with and without the payload. Account for your observations.

SKILLS MENU
- Questioning
- Hypothesizing
- Planning
- Conducting
- Recording
- Analyzing
- Communicating

Launching Water Rockets

A toy water rocket is a safe and easy way to study how rockets work. Although it is powered only by water and air, it works on the same principles as a rocket powered by chemical fuels. Your challenge is to design modifications to make the water rocket go as high as possible.

Materials

- toy water-rocket kit
- instruction manual for the rocket
- clean water
- safety goggles
- astrolabe

Question

1 Ask a question that your experiment will answer. (2A)

Hypothesis

2 Write a hypothesis and predict how each controlled variable will affect the dependent variable.

Experimental Design

3 Examine the water rocket (**Figure 1**) and read the instruction manual. Design a controlled experiment in which you vary one factor—"controlled variable"—at a time. The height reached by the rocket is the "dependent variable."

(a) Make a list of the steps you would take to safely launch the water rocket, including safety precautions, measurement of variables, and recording your data. Ask your teacher to approve the steps.

Figure 1
After adding some water to a water rocket, you can use the pump to increase the air pressure inside the rocket. What factors do you think control how high the rocket will fly? Which of these could become controlled variables?

Procedure

4 Discuss with your group how you will determine the height the rocket reaches. (Think of triangulation, measuring angles, and drawing scale diagrams.)

(a) Record the steps you will take to measure the height. Ask your teacher to approve these steps.

5 After your design has been approved, carry out your investigation outdoors.

(a) Record your observations, measurements, and calculations.

Operate the rocket outdoors only. Do not aim it at anybody. Stand clear of the line of flight. Wear safety goggles.

Analysis and Communication

6 Analyze your observations by answering the following questions:

(a) How did the height of the rocket change as you altered each controlled variable?

(b) How is thrust obtained in a water rocket?

(c) Explain the factors that affect the thrust.

(d) Write up your investigation in a compete lab report.

(e) Do your results support your hypothesis? Explain.

Making Connections

1. Compare the operations of a water rocket and a rocket fuelled by chemicals. Include both similarities and differences.

Exploring

2. If possible, use simulation software to research rocket launching.
3. Find information about a model rocketry club in your area. Invite a member of the club to share ideas about launching rockets and, if possible, demonstrate a model rocket launch.

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.

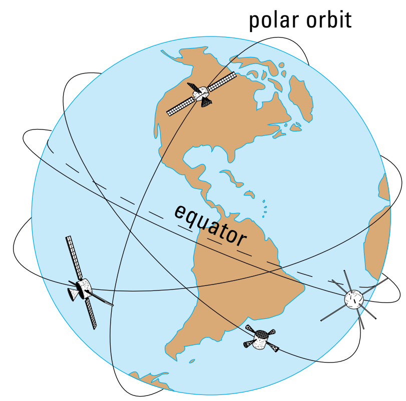


Figure 1
Examples of low Earth orbits may be around the equator, around the poles, or at any angle between the equator and the poles.

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.

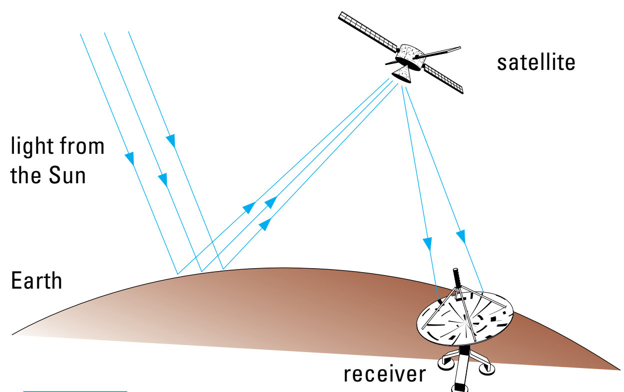


Figure 2
In daylight, visible light from the Sun reflects off Earth's surface or clouds. Digital cameras aboard a satellite capture the reflected light; then antennas on the satellite beam the digital information, using invisible radio waves, to a receiver on Earth.

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.

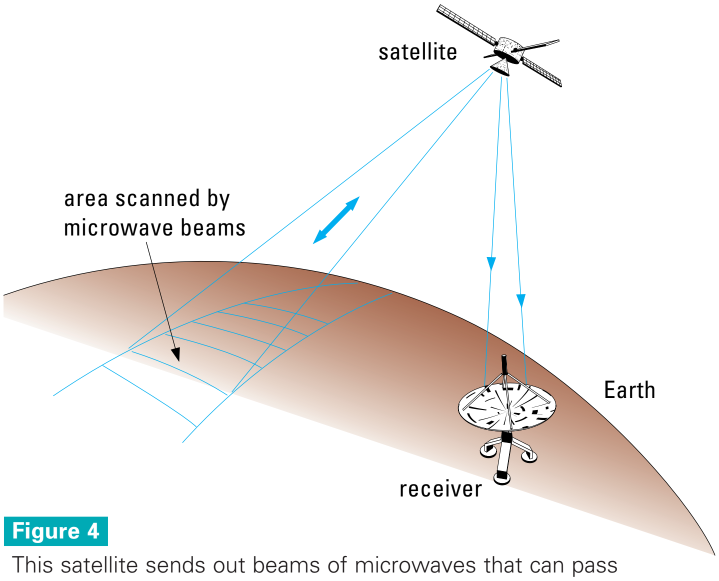


Figure 4
This satellite sends out beams of microwaves that can pass through clouds and reflect off Earth's surface. The satellite receives the reflected waves and converts the information to digital format and beams it back to a receiver on Earth.

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.

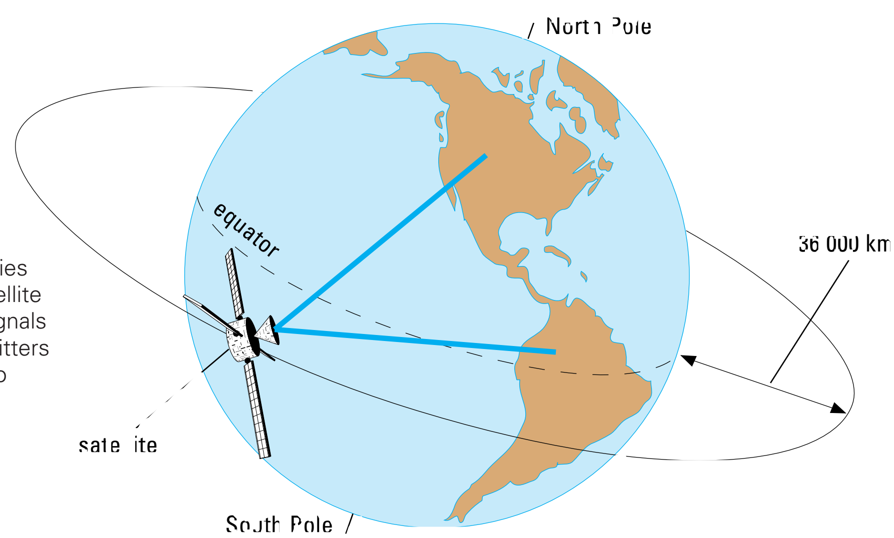


Figure 5
A geosynchronous orbit lies above the equator. A satellite located there receives signals from Earth-based transmitters and sends signals back to Earth-based receivers.

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

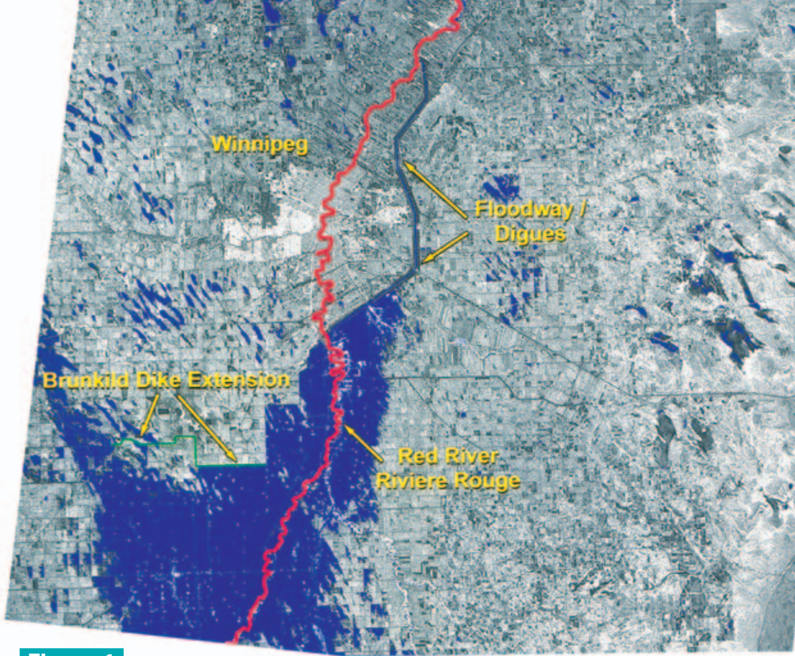


Figure 1
This radar image of part of Manitoba has been computer enhanced, so different features show up as different colours. The red line shows the normal course of the river. The blue area shows the area under floodwaters in 1997.

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.

(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.

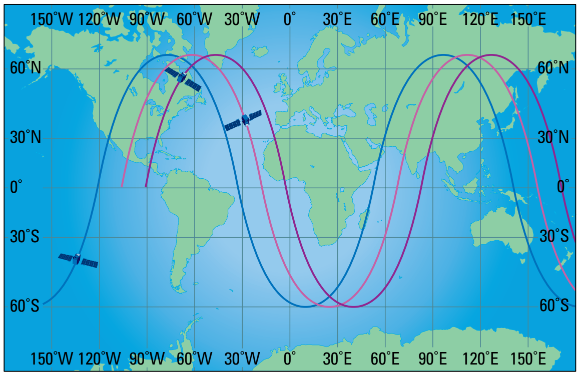


Figure 1
Example of a world map showing paths of satellites

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?

16.6

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.

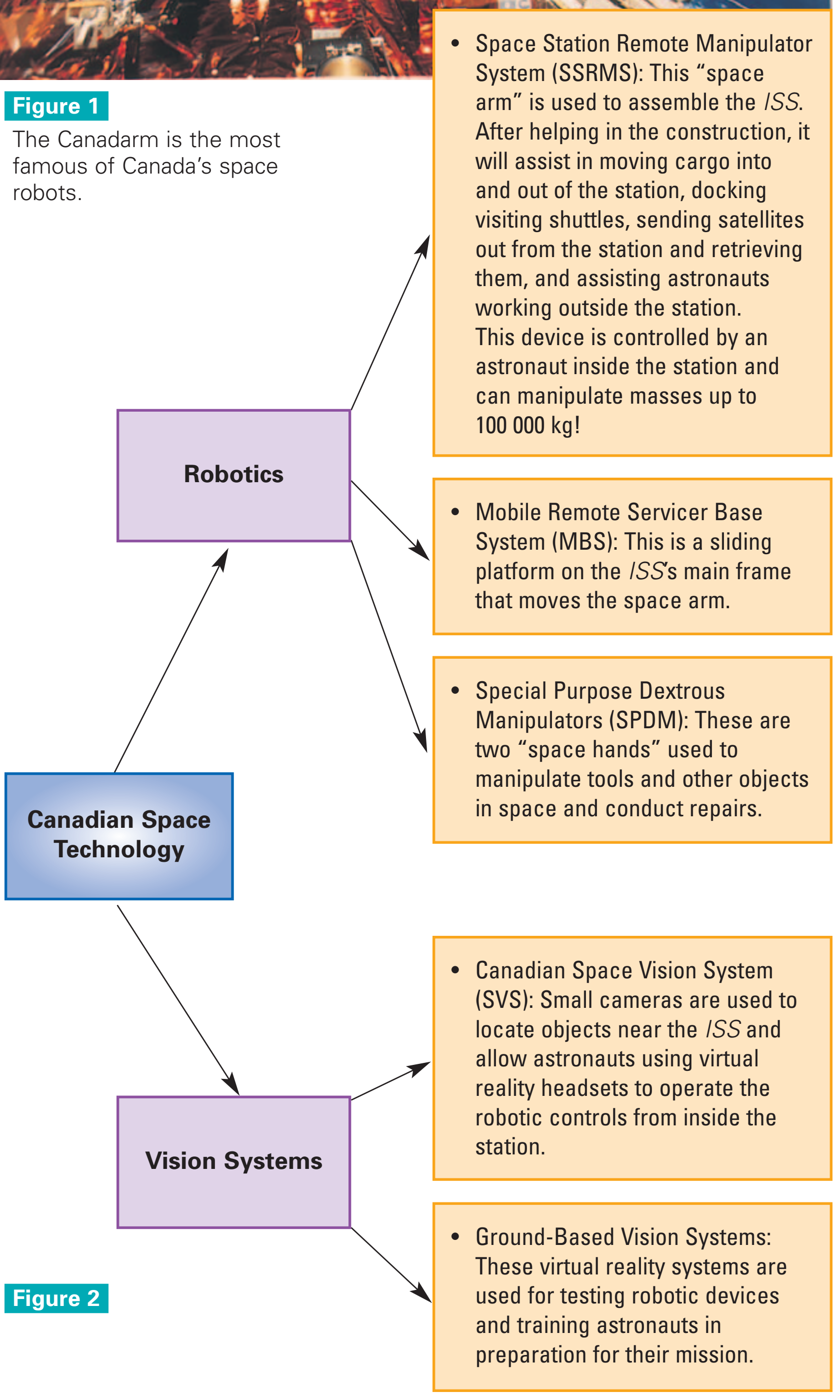


Figure 2

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?

16.7

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.

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*.

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.

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?

continuously falling toward Earth at the same time as they are speeding forward almost fast enough to shoot out into space. This continuous falling is called **free fall**. The result of continuous free fall is that the spacecraft and everything in it remain balanced in orbit (**Figure 2**).

Sometimes the expression "weightless" is used to describe the effect of constant free fall. **Weight** is the force of gravity acting on an object. When an Earthbound object feels heavy, it is because your muscles must exert a large upward force to overcome the downward pull of gravity, whether it is yourself or some other object you are moving. Although the force of gravity pulls you down, your awareness of gravity comes mainly from the upward forces you must exert to oppose it. In an orbiting spacecraft, the craft and everything in it are continuously falling at the same rate, so the astronaut does not have to exert an upward force to hold onto anything in the spacecraft. Thus, astronauts feel as if there is no gravity; they feel weightless. However, as there is gravity, "weightless" is a poor expression to use.

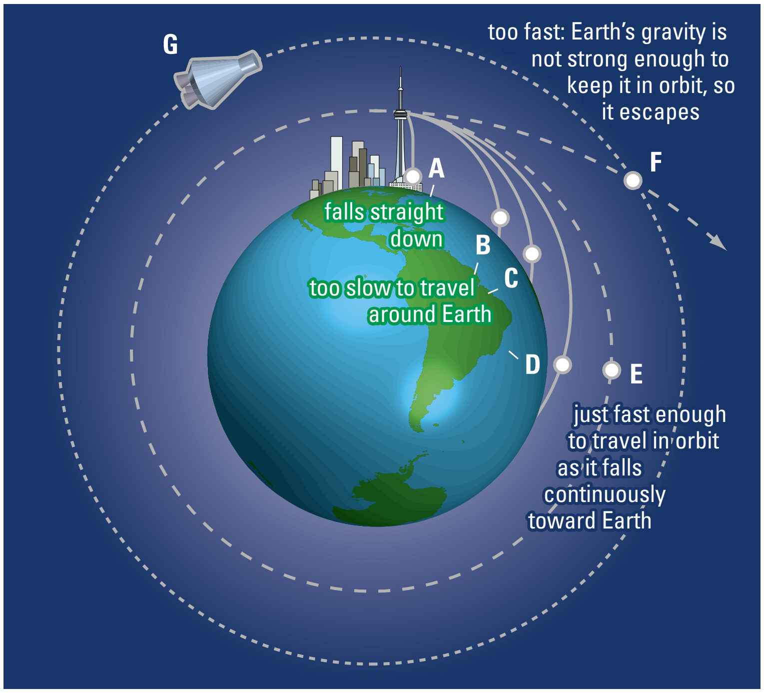


Figure 2

This diagram illustrates constant free fall. Imagine six steel balls that leave a tall tower. Ball A falls straight down while balls B to F get shot outward. Only ball E has the right speed to travel in an orbit around Earth. It follows a curved path just like the spacecraft G, in which astronauts and objects fall together toward Earth as they travel forward at great speed.

Living on the *ISS*

After the shuttle docks with the *ISS,* you enter the station and are greeted by other crew members who have been there for three months. With them, you eat your first space meal, part of which is prepared by adding water to a dry, crumbly mixture in a plastic pouch (**Figure 3**). The other part of the meal consists of fresh vegetables grown on the station as an experiment to help absorb carbon dioxide from the air and provide oxygen for the crew. Water, both hot and cold, is available as a byproduct of the fuel cells that produce some of the energy aboard the station.

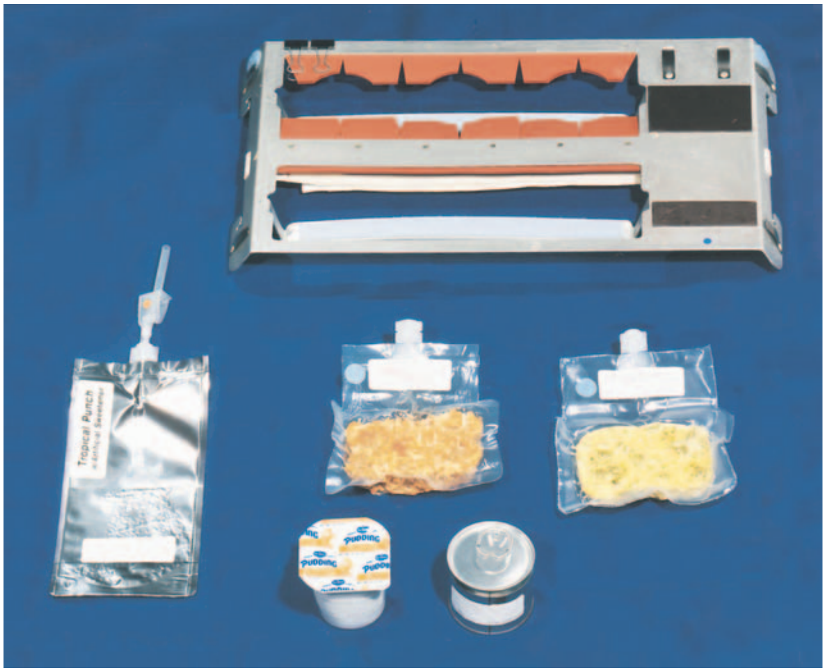


Figure 3

Food in sealed plastic bags is heated in a food warmer.

You do your share of work to help keep the station clean. Sanitation is important in space because microorganisms can grow rapidly in conditions of continuous free fall and an enclosed system like a spacecraft. Allowed to grow unchecked, these microorganisms could cause infections in the astronauts, so the eating equipment, dining area, toilet, and sleeping facilities must be cleaned regularly. Garbage and worn clothing are sealed in airtight bags to be returned to Earth later.

After doing some work at a computer terminal, you talk to your family on Earth and spend a long time exercising on the specially designed treadmills, cycles, and rowing equipment. You must exercise every day to keep your muscles and bones strong and your blood circulating properly. Then, after another meal and relaxation, you fasten yourself into the sleeping hammock tied to one wall.

You spend the next few days working at computers and practising the use of the manipulator arms. You are not allowed to leave the station to carry out your repair tasks until you have been in space at least three days, adapting to continuous free fall.

On the fourth day, you prepare for your first space walk by spending a few hours in a sealed area, breathing pure oxygen, since this is what you will be breathing in your space-walking suit. Breathing pure oxygen means that the air pressure inside your suit can be much lower than in the *ISS*, which allows your joints to be much more manoeuvrable (**Figure 4**) than they would be if your suit pressure was high. Protected by the suit from the vacuum of space and from harmful ultraviolet radiation from the Sun, you go outside the station and attach yourself to the Mobile Remote Servicer Base System (MBS). Using the manipulator system, you grab the satellite that has moved close to the station and pull it close to you. You then replace the satellite's used fuel tank with a fresh one and use the small manipulator arms to replace the damaged part. After testing the satellite, you use the large manipulator arm to push the satellite safely away from the *ISS*.

Did You Know?

You can calculate your own weight by using the equation $F = mg$, where F is the force of gravity, or weight, measured in newtons (N), m is your mass in kilograms (kg), and g is a gravity constant equal to 9.8 N/kg on Earth's surface. On different planets g is different, so your weight would vary! So where would you be truly weightless? Only where you are so far away from all large bodies that the gravity constant, g, is zero. In other words, *way* out in space!

Try This: Artificial Gravity

How can you make "up" into "down"? This model of artificial gravity will show you.

This activity should be done outdoors.

You will need a plastic bucket with a strong handle, a small rubber duck, and water. Half fill the bucket with water. Place the duck in the water. Swing the bucket back and forth until you are ready to swing it in a complete, vertical circle at a fairly high speed. Try not to spill the water as you bring the bucket to a stop.

1. Does the water fall out of the bucket when it is swung quickly in a vertical loop? Explain.
2. From the duck's point of view at the top of the loop, how important is Earth's gravity and which way is down?
3. In what way is this activity a model for "artificial gravity"?
4. How could you apply what you have learned in this activity to a space vehicle that takes humans to and from Mars?

Earth-based controllers then start up the satellite's engines to get it back into its proper orbit.

After three busy months on the *ISS*, you board the shuttle for your trip back to Earth. When the shuttle lands, you may need assistance as you step out and try to walk under the influence of gravity. You feel very heavy at first, but soon you get used to being back on Earth.

Did You Know

The extravehicular maneuvering unit (EMU) has two aluminum tanks with enough nitrogen to last for six hours of activity. It and the entire spacesuit must be well insulated against temperature extremes, which can range from 120°C down to –150°C.

Figure 4

Space-walking astronauts move around with the help of a backpack called an Extravehicular Maneuvering Unit (EMU). The unit contains compressed nitrogen gas, which can be released through a nozzle. How does the EMU resemble the balloon rocket model or the rocket engine model in Section 16.1, Figures 4 and 5?

Understanding Concepts

1. In your own words, describe why astronauts appear to be floating in the *ISS* or a space shuttle in orbit around Earth, even though gravity is pulling on them.
2. Neither weightlessness nor microgravity are accurate ways to describe the conditions experienced by astronauts. Explain why. What is a more accurate term?
3. Draw a diagram to show how an astronaut who is working outside the *ISS* can use a backpack maneuvering unit (the EMU) to move from left to right.
4. Compare a day of living on *ISS* with a day on Earth. What are the similarities and differences?

Exploring

5. Design an amusement park ride that produces artificial gravity.
6. Research one of the following Canadian astronauts' qualifications, background, interests, and contributions to the space program: Roberta Bondar; Marc Garneau; Chris Hadfield; Steve MacLean; Julie Payette; Robert Thirsk; Bjarni Tryggvason; Dave Williams.
7. Compose an application letter to join the CSA's astronaut-in-training program. Indicate why you want to become an astronaut, what you can add to the space program, and other details.

Challenge

Humans have designed special features and products to survive in spacecraft. What features and products do you need to consider for the space colony challenge?

SKILLS MENU
- ○ Questioning
- ● Hypothesizing
- ● Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Communicating

Gravity and Free Fall

Have you ever been on an amusement park ride that lets you fall straight downward? If so, you were in free fall. Astronauts on space shuttles or the *International Space Station* experience free fall continuously.

Part 1: Weight and "Weightlessness"

Question

What do the astronauts feel and why?

Hypothesis

1 Write a hypothesis about the relationship between mass and weight of an astronaut in orbit.

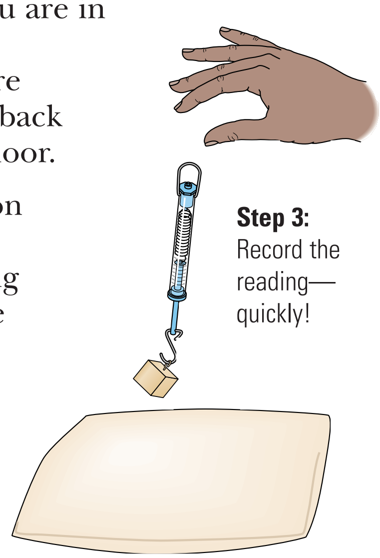
Materials

- spring scale that measures weight in newtons (N)
- a hanging mass that registers about halfway on the spring scale
- pillow

Procedure

2 Squat down, then jump up vertically as high off the floor as you can.

(a) Describe what you feel in your leg muscles
 (i) as your legs are pushing off the floor;
 (ii) when you are in the air;
 (iii) as you are landing back on the floor.



3 Hang the mass on the hook at the base of the spring scale. Determine the apparent weight of the mass (as registered on the spring scale) when
 (i) the mass is resting on the floor;
 (ii) the mass is jerked gently upward;
 (iii) the mass is suspended in midair;
 (iv) the mass and spring scale are allowed to fall freely toward a pillow on the floor.

(a) Record the four readings you observed.

4 Repeat step 3 twice.

(a) Average your readings for the three trials.

Analysis and Communication

5 Analyze your observations by answering the following questions:

(a) When, in step 2, did
 (i) your weight feel normal?
 (ii) you feel heavier than normal?
 (iii) you feel lighter than normal?

(b) What are the differences between mass and weight?

6 Relate your measurements in steps 3 and 4 to the sensations you felt in step 2.

Part 2: What Affects Free Fall?

Question

What factors affect how fast something falls from a person's raised hand to the floor?

Hypothesis

7 Write a hypothesis to answer the question.

Experimental Design

8 (4B) Design an experiment to test your hypothesis.

(a) Identify the factors you will investigate and describe how you think each will affect the motion of the falling objects.

(b) List the materials you will need.

(c) Write out your procedure. Include any useful diagrams.

SKILLS HANDBOOK: 4B Designing a Procedure

Procedure

9 After your teacher has approved your procedural steps and materials list, carry out the steps.

(a) Record what you observe.

Analysis and Communication

10 What can you conclude from your observations?

11 A 500-g ball and a 200-g ball are allowed to fall freely from the same height to the floor. Predict how their motions compare.

12 A piece of paper and a marble are allowed to fall toward the floor from the same height. Compare the motions of the two objects if
  (i) the paper is flat;
  (ii) the paper is crumpled into a ball.

Part 3: Falling While Moving in a Path

Question

What effect does horizontal motion have on the "falling time" of an object?

Hypothesis

13 Write a hypothesis and predict what will happen when you launch one coin horizontally, compared with what will happen when you allow a coin to fall freely downward.

Materials

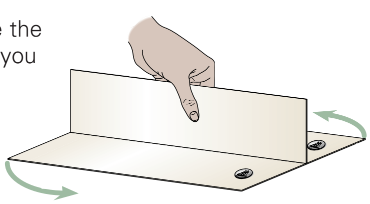
- coin-launching apparatus (shown in **Figure 1**)
- 2 coins

Experimental Design

14 (4B) Design an experiment that uses a coin-launching apparatus to test your hypothesis.

Figure 1

Fold the cardboard and place the coins on it as shown. When you flip the launcher sideways, can you tell which coin will fall straight downward and which will fly sideways? Which coin do you think will land first?



Procedure

15 Make the coin-launching apparatus.

16 After your teacher approves your design, conduct your investigation.

Do not aim the coins at anybody. Launch them only where they will land safely.

(a) Record your observations.

Analysis and Communication

17 Does the sideways motion of a falling object affect its downward falling? Explain.

18 (8A) Write a lab report describing and giving reasons for the different types of motion you observed.

Understanding Concepts

1. As the *ISS* travels in its path around Earth, it is always undergoing free fall. Astronauts inside the station are also experiencing free fall. How does this relate to what you observe about astronauts' motion in the station?
2. Imagine you are in an elevator that is falling freely. You hold out a pen and let it drop. How will its motion compare with yours?
3. Under what circumstances would an astronaut truly be weightless?

Exploring

4. When astronauts train, they experience free fall by going up in a special airplane that falls toward Earth for several seconds at a time. Sometimes the astronauts suffer from motion sickness on this airplane.
   (a) Research information about this airplane and share what you discover with the rest of your class.
   (b) Find out how the actors in the movie *Apollo 13* experienced free fall to make their flight look authentic.

Challenge

What is "artificial gravity" and how might it be applied for long-term space flights? What considerations related to gravity do you have to consider for Challenge 2?

(8A) Reporting Your Work

Spinoffs from the Space Industry

How do the hard plastics used for in-line skates, safety helmets, and many other products, relate to space technology? Hard plastics were first designed by the space program to fulfill a specific need, then applied to the products we use (**Figure 1**). This is just one of many examples of a **spinoff**—an extra benefit from technology originally developed for another purpose.

How important will space science be in the 21st century? People who oppose spending on space missions argue that the money would be better spent cleaning up the environment and reducing poverty on Earth. People who promote space exploration argue that the money spent on space missions is only a small portion (under 2%) of any nation's budget. Furthermore, they point out, society benefits from space exploration (**Table 1**).

Procedure

1. Choose a recently developed product, and research how its development began with the space program (see **Table 1** for examples).
2. Design a poster or give an oral presentation tracking your product's research and development, evaluating the product, and giving your opinion on whether to invest in the spinoff.

Figure 1

Figure 2

Table 1 Types and Examples of Spinoffs

Area of Research	Examples
microelectronics	digital watches, home computers, pacemakers, hand-held calculators
new materials	nylon strips used to fasten clothing and objects, nonstick coating, flame-resistant materials (**Figure 2**)
metal alloys	dental braces
hard plastics	safety helmets, in-line skates
robotics	mining, industry, and offshore oil exploration where the conditions are too dangerous or the tasks too precise or repetitive for humans
vehicle controllers	controller for those with disabilities
safety devices	smoke detectors
recycling processes	water recycling
energy storage	solar cells, chemical batteries
food	freeze-dried convenience foods
pharmaceutics	antinausea medication to overcome the effects of motion sickness or the side effects of other drugs
pump therapy	method to provide insulin continuously to diabetes patients
scanning	medical scanning using imaging techniques developed for satellites
space vision technology	satellite data applied to improving the efficiency of agricultural spraying
lasers	improved laser surgery

Understanding Concepts

1. What is meant by the term "spinoff"?
2. Which spinoffs listed in this section are most likely linked to Canada's contribution to space science and technology?

Making Connections

3. List some space spinoffs that are now part of your daily life, both at school and at home.
4. What can we learn in space that would benefit the elderly?

Career Profile

Aerospace Engineer

Amyn Samji is not your typical engineer, but he was the one on NASA's graveyard shift monitoring Canada's famous robot, the Canadarm. He had to help remedy the problem of icicle growth on the shuttle.

"It's a long way from Overlea Secondary School to sitting at a console at NASA's Johnson Space Centre," he quietly muses.

> "Becoming a team player, learning to solve problems, and working hard are important to success in the space business."

Amyn Samji was born in Tanzania, Africa and came to Toronto with his family when he was eight years old. At first he struggled with mathematics, but things changed in high school. "I began to understand relationships and patterns." He joined the mathematics club and a special geometry class.

At the University of Waterloo, Samji took a co-op course in Applied Mathematics and Engineering, followed by a Masters degree in Aerospace Science at the University of Toronto Institute for Aerospace Studies.

Samji's research on robots began when he joined Spar Aerospace, developing computer models for the assembly of *International Space Station* (ISS). Spar engineers were developing the Space Station Remote Manipulator System (SSRMS). Samji developed computer simulations to show how astronauts would exchange parts of the SSRMS.

Later, at NASA's Johnson Space Center, Samji assumed flight support duties, monitoring the Canadarm during missions and solving operation problems. "At 4:00 a.m. on one shift the SSRMS break slip (alarm) went off during a thruster firing. NASA was trying to shake loose an icicle on the orbiter. It was tense. We solved it. It was O.K.," he smiles.

Samji then became the manager of the Mobile Servicing System (MSS) program, Canada's proud contribution to the *International Space Station*.

Exploring

1. If you were designing a space robot, how would you deal with the harsh conditions it would encounter in outer space?
2. Identify several important characteristics that make a successful project manager.
3. Research post-secondary institutions in your area providing programs that could lead to a career in the space field.

16.10

Space Medicine

Human health is an important issue. The study of human health in space—space medicine—is not only fascinating, it is also a great benefit because it helps us learn more about human health on Earth.

Three of Canada's astronauts, Roberta Bondar, Robert Thirsk, and Dave Williams, are medical doctors working in the field of space medicine. Dr. Williams is director of NASA's Space and Life Sciences program.

Space Sickness

An immediate and annoying problem for a human body in orbit is space sickness, a type of motion sickness. During constant free fall, signals from the eyes, skin, joints, muscles, and the balance organs get rearranged. The conflicting clues lead to signs and symptoms of space sickness, such as dizziness, nausea, and vomiting. **Figure 1** explains how the balance organ, located in the inner ear, functions.

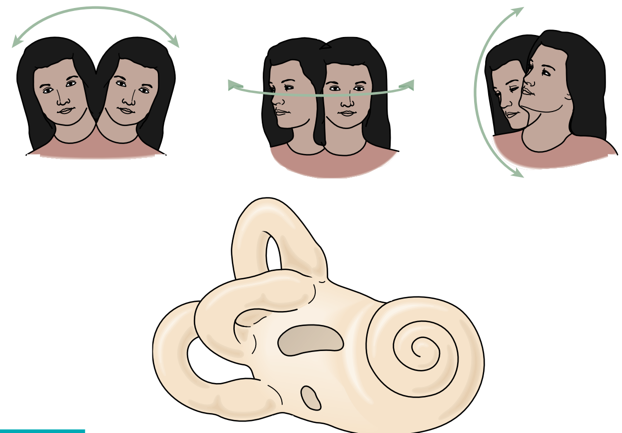


Figure 1
The drawing shows the structure of the inner ear of a human. The three fluid-filled tubes, called the semicircular canals, are responsible for balance. The fluid moves when the head moves: side to side, spinning around, or up and down.

Try This — Your Sense of Balance

Here are two simple activities you can use to test your sense of balance. How does your sense of balance compare with that of other students?

1. Stand on one leg with your eyes open. Then close both eyes and try to maintain your balance.
2. Stand on one leg facing a striped sheet or blanket held by two students. Try to maintain your balance as the blanket is moved sideways, as shown in **Figure 2**.

Have two spotters nearby in case you lose your balance.

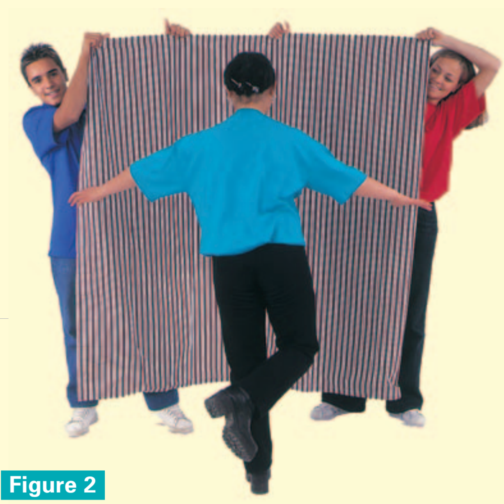


Figure 2
The moving stripes may fool your brain into thinking that you are moving, so your muscles compensate, and you fall over!

Other Effects of Space Flight

Imagine you have had a full-length cast on one leg for three months. The broken bones have healed, and your doctor removes the cast. But your leg still doesn't work normally: although the bones have healed, the muscles have weakened and shrunk from lack of use. It will probably take weeks or even months for you to regain the normal use of your muscles.

Similar problems occur when astronauts are in constant free fall while orbiting Earth. On Earth, your *awareness* of gravity comes mainly from the upward forces needed to oppose it. But in free fall, astronauts are not aware of this gravitational pull. They *feel* weightless, just like the hanging mass that fell with the scale in Investigation 16.8. The lack of forces against the body causes the muscles to become smaller and the bones to lose calcium and become brittle. It seems as though the normal aging process is vastly speeded up. This process can be slowed with a vigorous exercise program during the space flight, but it is not yet known whether this process can be stopped entirely. The data collected during space missions is used in research into the normal aging process. Scientists would like to reduce the deterioration that occurs during both processes.

Another possibly dangerous side effect of space travel involves body fluids. Because of constant free fall, about two extra litres of blood remain in the upper half of the body, swelling the heart and the blood vessels and making the astronauts' faces look puffy and their legs look thinner. More importantly, this condition alters the fluid balance of the body and, in turn, affects the kidneys and causes excess urination. Much is yet to be learned about long-term effects, and research is ongoing.

Astronauts are also exposed to more cosmic radiation on a single trip than they would experience in several years on Earth. We do not yet know whether this exposure is harmful because any effects might not show up for several years. Thus, scientists continue to check the health of space travellers carefully. Space medicine is still a young science, and much remains to be learned about the effects of space travel on the human body.

Did You Know?

When 77-year-old John Glenn went on a space shuttle flight in 1998 to perform experiments on aging, some of the experiments were designed by Canadian scientists. One study related to osteoporosis, a condition of the bones. This was Glenn's second space flight: in 1962 he was the first American to orbit Earth.

Understanding Concepts

1. Describe the effects of constant free fall on the human body. Why do these effects occur?
2. Astronauts must spend a long time exercising each day. Why?

Making Connections

3. How do you think an exercise program in space might be applied to design an exercise program for seniors on Earth?
4. Choose one of the health problems described. How does the research related to it affect the lives of other people not involved in space flight?

Exploring

5. Research the invention of the antigravity suit by Canadian, Dr. W. R. Franks in 1940. Write your own short story about it.
6. Make up an exercise program for astronauts either while aboard the *ISS* or when they return to Earth.

Challenge

Check the NASA web site to obtain more information about NASA's Space and Life Science program. Which contributions have Canadians made to this program?

16.11 Investigation

SKILLS MENU
- Questioning
- Hypothesizing
- Planning
- Conducting
- Recording
- Analyzing
- Communicating

Experimenting in Free-Fall Conditions

Did you know that you are slightly taller when you get up in the morning than when you go to bed? In the daytime, when you are upright, the force of gravity pulls on your spinal column, causing it to crush together. When you are lying down, this crushing is reduced, so the bones spread apart a bit.

This same thing happens to astronauts in constant free fall: they become several centimetres taller. What is more, their bones lose mass, and their muscles weaken because they don't have to work against gravity. Many of their experiments involve finding out what happens to human bodies in space and why. Knowing the answers will help future space exploration as well as the treatment of aging problems on Earth.

In this investigation, you will design an experiment suitable for astronauts to perform on the *ISS* or for the Canadian Space Agency (CSA) to send on a space probe mission.

Question

1 Choose one area of research from **Table 1** that interests you. Plan how you will find out more about that area.

2 Find the information, then choose one topic on which you will base an experiment that will prove useful either to future space flight or to life here on Earth.

(a) Write out the question your experiment will attempt to answer.

Table 1 Canada's Specialties in Space Science

Area of Research	Examples of Topics Researched
Space Life Sciences	bone and muscle loss, neurobiology, early development, radiation, heart and circulation system research
Science in Constant Free Fall	crystals, including protein crystals, metals research, fluids research, materials for semi-conductors and fibre optics
Atmospheric Sciences	global warming, Arctic-region research, ozone depletion, middle/upper atmosphere science
Space Astronomy	research using various parts of the electromagnetic spectrum
Solar-Terrestrial Relations	Earth's ionosphere and magnetosphere, the ionosphere on Mars, solar wind, space plasma, aurora research

Hypothesis

3 Write a hypothesis to answer the question.

4 Predict what results you would expect from your experiment.

(a) Write out your prediction, including the controlled and dependent variables.

Experimental Design

5 Design a controlled experiment to answer your question. List the materials needed, the procedural steps, and any safety considerations. Also mention how you would analyze the results.

(a) Write out your experimental design and have it approved by your teacher.

Procedure

6 Conduct your experiment.

Analysis and Communication

7 Create a proposal that would persuade a space agency to conduct your experiment, then submit your proposal.

8 How does performing experiments in space differ from performing experiments on Earth?

Making Connections

1. How do you think your proposed experiment could benefit people or things on Earth?

Exploring

2. Write a short letter, including a relevant question, to a Canadian astronaut on the *ISS*.

Our Future in Space

If space stations are successful, the next stages of space travel may be exploration of Earth's Moon, and the planet Mars and its small moons, Phobos and Deimos. These objects could be mined and the materials used to build structures in space. Eventually, human colonies may be established on the Moon and on Mars.

Many problems must be overcome before we can travel to, and live on, Mars. One of the biggest problems is the reaction of the human body to constant free fall. To reduce the effects on long space trips, a feature of any piloted trip to Mars will probably be artificial gravity, created by rotating the spacecraft (**Figure 1**). Once on Mars, the astronauts will find a gravitational force only 38% of that on Earth. This may also cause problems for the human body over long periods of time.

Visitors to Mars will require water, food, oxygen, and warm shelter. Oxygen and small amounts of water could be extracted from the low-density atmosphere, which consists mostly of carbon dioxide. Water could also be extracted from the permafrost on Mars and from the recycling of plant and human wastes. Large greenhouses could be used to grow fruits and vegetables. Even though Mars is farther from the Sun than Earth is, the Sun's radiation is far more harmful there because the atmosphere on Mars has no ozone to offer protection. As a result, living quarters would have to be buried beneath the Martian soil to protect humans from harmful solar radiation.

Some scientists predict that by the time humans have settled on Mars, we will have propulsion systems powerful enough to allow spacecraft to reach extremely high speeds. Perhaps such a craft, if unpiloted, would be sent to explore neighbouring stars in our galaxy.

Figure 1
Artist's concept of a spacecraft travelling to Mars

Issue: Space Exploration

People in favour of space exploration give many good reasons why it will benefit the human race. People opposing space exploration feel strongly that there are drawbacks that outweigh the benefits. Working in a group, choose either a supporting or an opposing position on space exploration. 9C

- Brainstorm a list of reasons that support your group's viewpoint. Consider economics, ethics, environmental issues, politics, and available technology as you brainstorm.
- Discuss these as a group and carry out further research where necessary.
- Prepare a 5-min presentation, putting forth your position.

Challenge

What situations should you consider for sustained survival when designing a space colony?

SKILLS HANDBOOK: 9C Working Together

Chapter 16 Review

Key Expectations

Throughout the chapter, you have had opportunities to do the following things:

- Describe and explain the effects of continuous free fall (microgravity) on organisms and other contents of orbiting spacecraft. (16.8, 16.9, 16.11, 16.12)
- Investigate questions related to sending satellites and humans into space, and organize, record, analyze, and communicate results. (16.2, 16.4, 16.6, 16.7, 16.9, 16.10, 16.12)
- Formulate and research questions related to space exploration, and communicate results. (all sections)
- Describe, evaluate, and communicate the impact of research and achievements in space on other fields of endeavour. (16.3, 16.4, 16.5, 16.9, 16.10, 16.11, 16.12)
- Identify the purpose and accomplishments of space initiatives such as satellites, space probes, and the *International Space Station*. (16.1, 16.3, 16.4, 16.5, 16.6, 16.7, 16.13)
- Investigate and provide examples of ways in which Canada participates in space research and international space programs. (16.3, 16.5, 16.7, 16.11)
- Explore careers related to space exploration. (Career Profile)

KEY TERMS

aircraft	outer space
free fall (microgravity)	radar
geosynchronous orbit	remote sensing
Global Positioning System	space probe
International Space Station	spacecraft
launcher	spinoff
low Earth orbit	thrust
payload	weight

Reflecting

- "Space exploration and the related technology contribute to our understanding of Earth and the universe and provide many useful applications for life on Earth." Reflect on this idea. How does it connect with what you've done in this chapter? (To review, check the sections indicated above.)
- Revise your answers to the questions raised in Getting Started. How has your thinking changed?
- What new questions do you have? How will you answer them?

Understanding Concepts

1. Make a concept map to summarize the material that you have studied in this chapter. Start with the words "space exploration."

2. What are the purposes of space stations?

3. During blast-off, an astronaut feels heavier than usual; later, lighter than usual. Explain why.

4. What is "artificial gravity"? How might it be created on a spacecraft?

5. List benefits of studying space medicine.

6. Classify each of the following vehicles as Earth-based, atmosphere-based, low Earth orbit, or geosynchronous orbit: the *International Space Station*; a space shuttle; a helicopter; a sailboat; a TV satellite; a remote-sensing satellite.

7. State the purpose or function of: remote sensing satellites, RADARSAT, GPS satellites, and an orbiting observatory.

8. Compare an aircraft engine and a rocket engine, explaining why an aircraft cannot fly in space.

9. Describe situations in which you have experienced free fall.

10. Why are robotics and vision systems important on the *International Space Station*?

11. What would happen to a spacecraft in orbit around Earth if its speed becomes too slow? Explain.

12. Can a human be a payload? Explain your answer.

13. Which electromagnetic waves, infrared or radar, would be better for viewing the heights of mountains and craters on the moons of planets? Why?

14. Why are remote sensing satellites that use radar not used to predict daily weather patterns?

15. (a) Why is the expression "zero gravity" misleading for an astronaut inside a spacecraft in an Earth orbit?
    (b) Under what condition(s) would the expression "zero gravity" not be misleading?

16. During the last few days, identify ways you have benefited from space exploration. (Include both direct benefits and spinoffs.)

17. If you were standing on your head, your blood distribution would change. Relate this change to what an astronaut experiences in orbit around Earth.

18. At the same instant, one car drives horizontally off a cliff at a high speed and another falls straight down.
    (a) Compare the times the cars take to land.
    (b) Relate your answer to space vehicles that travel around Earth.

19. A sports event takes place in Australia, and at almost the same time you are able to watch that event on television. Describe how this form of telecommunication works.

20. Space probes are sent to explore asteroids and comets. How does this exploration help in the study of the origin of the solar system?

21. Why are we more protected from the Sun's harmful radiation on Earth than astronauts are in space?

22. The air pressure in an *ISS* suit is less than atmospheric pressure. Find out why, and what advantages and disadvantages this brings.

Applying Skills

23. If a satellite takes 90 min to travel once around the world, for about how long will it be in view, each orbit? Show your calculations.

24. Describe what conditions would allow you to observe a satellite or the *ISS* travelling across the sky. Draw a diagram to illustrate your answer.

25. Find the results of a Canadian research project, involving students growing seeds that had been in space.

26. Select a career in the field of astronomy or space science, and find out what aptitudes and qualifications you would need to enter this career. If possible, interview someone in this career and prepare an audio report on the person's professional life.

27. Write a short science fiction story about space exploration using as many of the key terms as you can.

28. Describe what steps you would take to discover what fuels are used to launch a space shuttle.

29. Describe how to access information on the Internet about RADARSAT.

30. Assume you are an astronaut on the Moon carrying out an investigation to determine the factors affecting how fast objects fall. Describe in detail the steps you would take. Show that you understand what a controlled experiment is.

31. Draw a graph to predict how the speed of a balloon (vertical axis) depends on the air pressure inside the balloon.

Making Connections

32. Create a chart of Canadian contributions to the study of the universe, giving the Canadians' names and outlining their work.

33. List two or three careers in the space industry that require a background in (a) engineering and (b) technical studies.

34. Choose five interesting space spinoffs and for each, name at least one possible career associated with it.

35. To find out more about how the human body reacts in space, investigate Dr. Dave Williams' research on flight STS-90.

36. Defend or oppose one of the following statements:
    (a) Space exploration benefits the human race.
    (b) Money spent on space exploration would be better spent cleaning up the global environment.

Challenge

Bringing Your Ideas Together

Scientists and technologists share ideas in many ways. They may design simulations to understand concepts and to predict future events. They may develop technologies that improve our lives or that can be used to make further scientific investigation possible. They may conduct research and record and communicate what they discover. You can choose one of these approaches in the challenges described below:

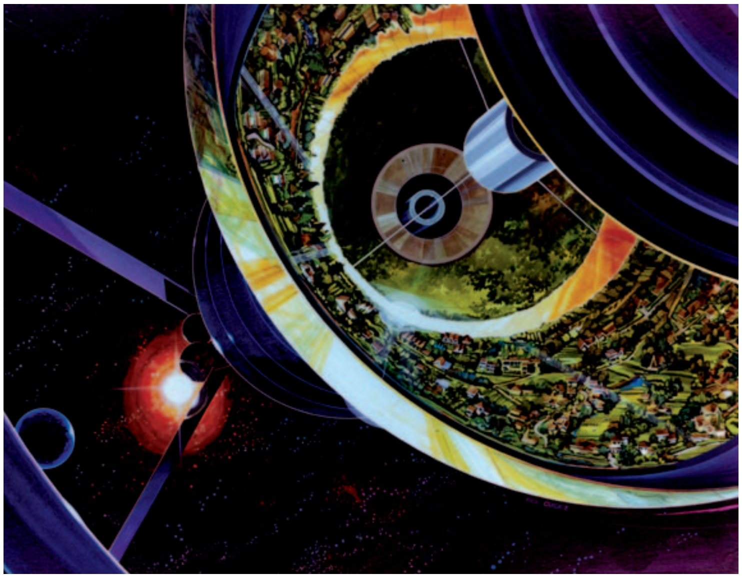
1 Planetarium Shows

A planetarium is a structure in which people can learn more about astronomy. The night sky is simulated using a projection of points of light representing stars and other objects onto the inside of a dome. By moving the projector, the appearance of the night sky at any time and any date can be represented. Planetariums usually offer a variety of shows designed for different purposes and audiences.

Your job is to design and prepare three shows that could be used in a planetarium. One show should be designed to teach grade 6 students about the solar system. The other two shows should be designed for the general public. You must include a script for each show and be prepared to present one of them.

Your simulations should include:

- models or other representations of year-round constellations, seasonal constellations, planets, comets, and other natural objects discussed in this unit
- representations of human-made objects such as satellites and space probes
- a model that demonstrates the motions of as many of the objects as possible
- design features that take into consideration the size, construction, and layout of a large planetarium



2 A Space Research Colony

You are part of a company that has designed a colony that would conduct research in outer space. The company is preparing to display its plans at the International Space Conference, in the hope of attracting investors for the project.

Design and create a display depicting a sustainable space research colony suitable for permanent human habitation.

Your display should include:
- a representation of the destination of your choice in outer space
- a demonstration of how the colony will be adapted to the environment of the destination chosen
- a plan that outlines how colonists will achieve self-sufficiency in both the short and long terms
- evidence of how knowledge gained from existing space explorations and space technology will be used
- proposals for the type of research that would be best suited for the destination you chose
- models and diagrams of relevant components

3 A Space Technology Information Package

Vast amounts of money are spent on technology related to space exploration. The merits of this expenditure are frequently debated in public. Your company has been commissioned by the Canadian Space Agency to develop an information package about the usefulness of space technology. You are to demonstrate how the use of space technology contributes to our understanding of the universe and how applications of that technology benefit us in our everyday lives. The package is designed for distribution to the general public.

Design an information package that outlines the diverse tools used both in space exploration and the study of astronomy and the influence they have had on our lives.

Your information package should include:
- an organizational tool for accessing the information
- examples of the uses of space technology
- links to Canada's role in the development of space technology
- illustrations of what we have learned about the universe using the technology
- examples of applications of the technology that positively affect our daily lives

Assessment

Your completed challenge will be assessed according to how well you:

Process
- understand the specific challenge
- develop a plan
- choose and safely use appropriate tools, equipment, and materials when necessary
- conduct the plan applying technical skills and procedures when necessary
- analyze the results

Communication
- prepare an appropriate presentation of the task
- use correct terms, symbols, and SI units
- incorporate information technology

Product
- meet established criteria
- show understanding of concepts, principles, laws, and theories
- show effective use of materials
- address the identified situation/problem

Unit 4 Review

Understanding Concepts

1. In your notebook, write the letters (a) to (k), then indicate the word(s) needed to complete each statement below.

(a) The ___?___ is everything that exists, including all the matter and energy everywhere.

(b) The four planets closest to the Sun can be called the ___?___ planets or the ___?___ planets.

(c) ___?___ was the first scientist to use a telescope to obtain evidence that stars were much farther away than planets.

(d) The ___?___ is a broad band of energies that can travel in a vacuum.

(e) The process used by stars to produce energy is called ___?___ .

(f) Stars start and end their lives as clouds of dust and gas called ___?___ .

(g) ___?___ is the force of attraction between all objects that have mass.

(h) A payload is to a ___?___ as an arrow is to a ___?___ .

(i) A satellite in ___?___ orbit appears to remain stationary when viewed from Earth.

(j) ___?___ is the force of gravity acting on an object. In the metric system its unit is the ___?___ .

(k) A ___?___ is a benefit that comes from space science and technology research.

2. Indicate whether each of statements (a) to (o) is TRUE or FALSE. If you think the statement is FALSE, rewrite it to make it true.

(a) Our Sun is the only star that has planets orbiting around it.

(b) An object that is 30 astronomical units from the Sun could be either a gas giant or a comet.

(c) The light-year is a unit of time.

(d) A comet's tail is visible only when the comet's path is close to the Sun.

(e) When using triangles to measure distances to objects in the sky, the longest baseline possible to observers on Earth is Earth's diameter at the equator.

(f) The speed of electromagnetic waves in a vacuum is 3×10^5 km/s.

(g) Auroras are caused by light pollution.

(h) Most stars are bigger than the Sun.

(i) The Sun is in the galaxy called the Milky Way.

(j) In the lives of stars, a red supergiant results from stars that have a smaller mass than the Sun.

(k) Both stars and planets form from nebulas.

(l) Evidence of an expanding universe comes from red shift of the spectra of stars and galaxies.

(m) Space probes have been sent to explore stars nearest to the solar system in our galaxy.

(n) RADARSAT uses waves that belong to the invisible part of the electromagnetic spectrum.

(o) The problems of increased body length and harmful radiation disappear after astronauts have been in orbit for a week or more.

3. Describe the similarities and/or differences between each pair of objects listed below:

(a) star constellation; star cluster

(b) Earth's rotation; Earth's revolution

(c) asteroid; comet

(d) galaxy; star cluster

(e) interplanetary distance; intergalactic distance

(f) solar flare; solar prominence

(g) apparent magnitude; absolute magnitude

(h) neutron star; black hole

(i) aircraft; spacecraft

(j) vacuum; atmosphere

(k) natural satellite; artificial satellite

(l) space shuttle; space station

(m) geosynchronous orbit; low Earth orbit

For Questions 4 to 10, choose the best answer and write the full statement in your notebook.

4. Pointer stars:

(a) can be used to locate planets in the night sky

(b) are found only in the year-round constellations
(c) can be used to locate constellations and other stars
(d) appear to be pointed
(e) all of the above

5. Compared with the terrestrial planets, the gas giants tend to:
(a) be hotter, rotate faster, and have a lower density
(b) be colder, rotate faster, and have a lower density
(c) be colder, rotate slower, and have a lower density
(d) be colder, rotate slower, and have a higher density
(e) be hotter, rotate faster, and have a higher density

6. Which does not belong in this list?
(a) radio waves
(b) visible light
(c) X rays
(d) sound waves
(e) infrared radiation

7. The order of stars from coolest to hottest is
(a) blue, yellow, red
(b) red, blue, yellow
(c) yellow, red, blue
(d) blue, red, yellow
(e) red, yellow, blue

8. A possible order of events in the evolution of stars is
(a) nebula, energy produced through fusion, core collapse
(b) core collapse, energy produced through fusion, nebula
(c) nebula, core collapse, energy produced through fusion
(d) energy produced through fusion, core collapse, nebula
(e) energy produced through fusion, nebula, core collapse

9. The force caused by expanding gases leaving a rocket engine is called
(a) chemical energy
(b) gravity
(c) thrust
(d) friction
(e) air resistance

10. The best explanation of why orbiting astronauts appear to be floating is that they are experiencing
(a) microgravity
(b) weightlessness
(c) no gravity
(d) continuous free fall
(e) none of the above

11. Which planets are the most likely targets for exploring by robotic rovers in the near future? Give reasons for your choices.

12. Some planets cannot be explored by robotic rovers. What ways can be used to study these planets at close range?

13. Which planets tend to have the greatest number of moons? Explain why this situation occurred as the solar system developed.

14. (a) What are sunspots?
(b) How can they be safely observed?
(c) What evidence do they provide of the Sun's rotation?

15. Stars move at great speeds. Why did people long ago believe that stars were fixed in place?

16. Can two stars with the same luminosity have different apparent magnitudes? Explain.

17. How are the temperatures and colours of stars related? Give examples.

18. Which types of stars tend to become supernovas? What happens after that stage?

19. The inner planets and gas giants formed at about the same time. Which stages of their formation were similar, and which were different? Explain why there was a difference.

20. According to the present theory, what are the main stages of the evolution of the universe?

21. What happens to low Earth orbit satellites if their orbits become too low? Why?

22. (a) Describe the conditions needed for you to feel you are weightless for a short period of time.
(b) Relate your answer in (a) to what astronauts experience in orbiting spacecraft.

23. (a) As you observe the night sky in the Northern Hemisphere, which star appears not to move?
(b) Why does it appear not to move?
(c) How long do constellations take to appear to travel once around that star?

24. You are conducting an investigation to compare the motions of planets and constellations seen in the night sky.
(a) How would the motions compare if you made observations three hours apart?
(b) How would the motions compare if you made observations three weeks apart?
(c) Explain the difference between observations (a) and (b) above.

25. What is the Hubble Deep Field? Why is it important?

26. If you see two stars through a telescope and one looks bluish, the other yellowish, what can you say about the difference between the stars?

27. What is the relationship between the speed of a satellite and the height of its orbit?

Applying Skills

28. In observing the night sky, it is important to judge the differences between stars and planets. Describe the main ways you have learned to distinguish stars and planets.

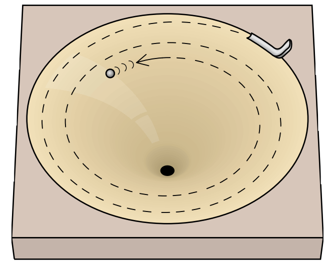
29. A student records these observations in a log book: "The constellation was 3 fists to the right of south, and 4 fists up from the horizon." Describe what these observations mean.

30. A certain comet, visible tonight, has a period of 185 years.
(a) Draw a diagram showing the basic orbit of the comet around the Sun. Include Earth in your diagram as well as the comet's tail at a few locations.
(b) Predict when the comet will again be visible.

31. Write these measurements out in long form
(a) 3.4×10^6 km
(b) 7.9×10^{12} kg

32. Describe a safe way to make observations of the Sun when it is high in the sky.

33. The figure below shows a device in which a rolling ball moves faster and faster, finally getting gobbled into the centre. How is this a model of a black hole? In what ways is the model not realistic?



34. Describe briefly how each of the following devices helps in the exploration of the universe:
(a) an orbiting observatory
(b) a ground-based observatory
(c) a radio telescope

35. Describe how any or all of the following have helped you understand ideas in this unit:
(a) modelling
(b) performing student-designed investigations
(c) drawing scale diagrams
(d) graphing
(e) operating computer simulations
(f) researching information on the Internet

36. **Table 1** indicates the speed, orbital radius (from the centre of Earth), and period of revolution of four types of artificial satellites and the Moon.
(a) Determine the information needed to complete the table.
(b) What patterns do you observe in your completed table?
(c) For the artificial satellites, plot a line graph of period of revolution (vertical axis)

Table 1

Satellite	Orbital Radius	Period of Revolution	Average Speed
remote sensing	6.67×10^3 km	1.5 h	?
Iridium	7.18×10^3 km	2.8 h	?
GPS	2.67×10^4 km	12 h	?
geosynchronous	4.24×10^4 km	24 h	?
the Moon	3.84×10^5 km	656 h	?

against the orbital radius. Use the line on the graph to determine (i) the period of a satellite with an orbital radius of 3.5×10^4 km and (ii) the orbital radius of a planet with a period of 10 h.

(d) For each satellite, including the Moon, calculate the ratio of radius^3 to period^2. What do you discover?

37. Make a list of three important questions you would like answered to help you understand more about (a) astronomy and (b) space exploration.

Making Connections

38. What were some skills achieved by astronomers in ancient times?

39. What is the evidence that astronomy is a very old science?

40. (a) What are observatories used for?

(b) Does Canada operate or help operate any observatories outside the country? If so, where?

41. Professional astronomers rely on amateur astronomers to find objects such as comets in the sky. Why?

42. Give examples in which Canadians have participated in discoveries and/or research in astronomy.

43. Many devices you use in your daily life are digital, just like devices used in astronomy and space exploration. Give examples of digital devices and describe why they are called "digital."

44. How has Canada's space technology helped in each of these endeavours?

(a) robotics

(b) resource management

(c) navigation

(d) telecommunications

45. In what ways will future space probes help increase our understanding of the universe?

46. List three general areas that involve careers in space technology. Within each area, name one specific career, some of its aspects, and the education required for it.

47. Explain the advantages of using robotics rather than piloted probes to explore the planets and other bodies in the solar system.

48. Explain this statement: "Visual systems and robotics often operate together."

49. Choose an area of scientific research carried out by astronauts aboard the *International Space Station*. Describe what you know about that research.

50. You are the leader of a team of scientists, engineers, and technologists who are developing spinoffs of the space industry. Make a list of five problems you would like the team to work on.

51. Robotic rovers designed to roam across the irregular surface of Mars will have to be "smart"; in other words, they will have to make their own decisions about whether it is safe to move forward. Explain why such rovers could not be adequately controlled by Earth-based controllers.

52. Research the latest developments in communications systems that make use of geosynchronous satellites. How are they improvements on older systems?

53. Find out about one of the many traditional religions or cultures that base their calendar on the movements of the Sun and Moon. Create a display showing how the dates of various celebrations are fixed.

54. Do spacecraft have to be aerodynamic in shape? Explain.

55. Many satellites are powered by electricity converted by big shiny panels from solar energy. Investigate the advantages and disadvantages of this source of energy, and suggest what design challenges the spacecraft engineers face and how they might overcome these challenges.

56. Research into the specialized areas of science (such as fluid physics, or crystal growth) that make use of the free fall conditions in an orbiting laboratory.

57. What probes are in outer space this year? Research their purpose, and find out what kinds of data they are sending to Earth. How are these data changing our ideas about space?

58. Investigate the "What's New" page of the Canadian Space Agency's web site to check on the progress of the *ISS*. Prepare periodic verbal reports for your class, focussing on Canada's contribution.