8.1 Exploring Space

Key Terms
electromagnetic radiation
refracting telescope
reflecting telescope
satellite
ethics

Throughout human history, curiosity and the need to understand the world around us have driven people to explore. People also explore to find new resources, such as minerals, and places to live. People started exploring on land. Then various civilizations built boats and ships to explore the world further. Next came exploration of the North and South Poles and the oceans. In the mid-20th century, humans ventured into space. On July 20, 1969, American astronaut Neil Armstrong was the first human to step onto the Moon, followed by Edwin (Buzz) Aldrin, who is shown in **Figure 8.1**. The third member of the *Apollo 11* crew, Michael Collins, stayed in orbit around the Moon in another vehicle while Armstrong and Aldrin explored the surface for two hours.

Challenges of Space Travel

It is very difficult and costly to send humans into space because everything is so far away. Humans need enough food and air for long trips. Other challenges include protecting them from the extreme cold of space, and trying to ensure that the spacecraft do not break down and leave humans stranded in space. One alternative to sending humans into space is exploring space from Earth using telescopes and other instruments. Another alternative is sending instruments, such as planetary orbiters, landers, and satellites, instead of people. Instruments are expensive, but sending them is less expensive and less risky than sending humans because, for example, instruments do not need food and companionship.

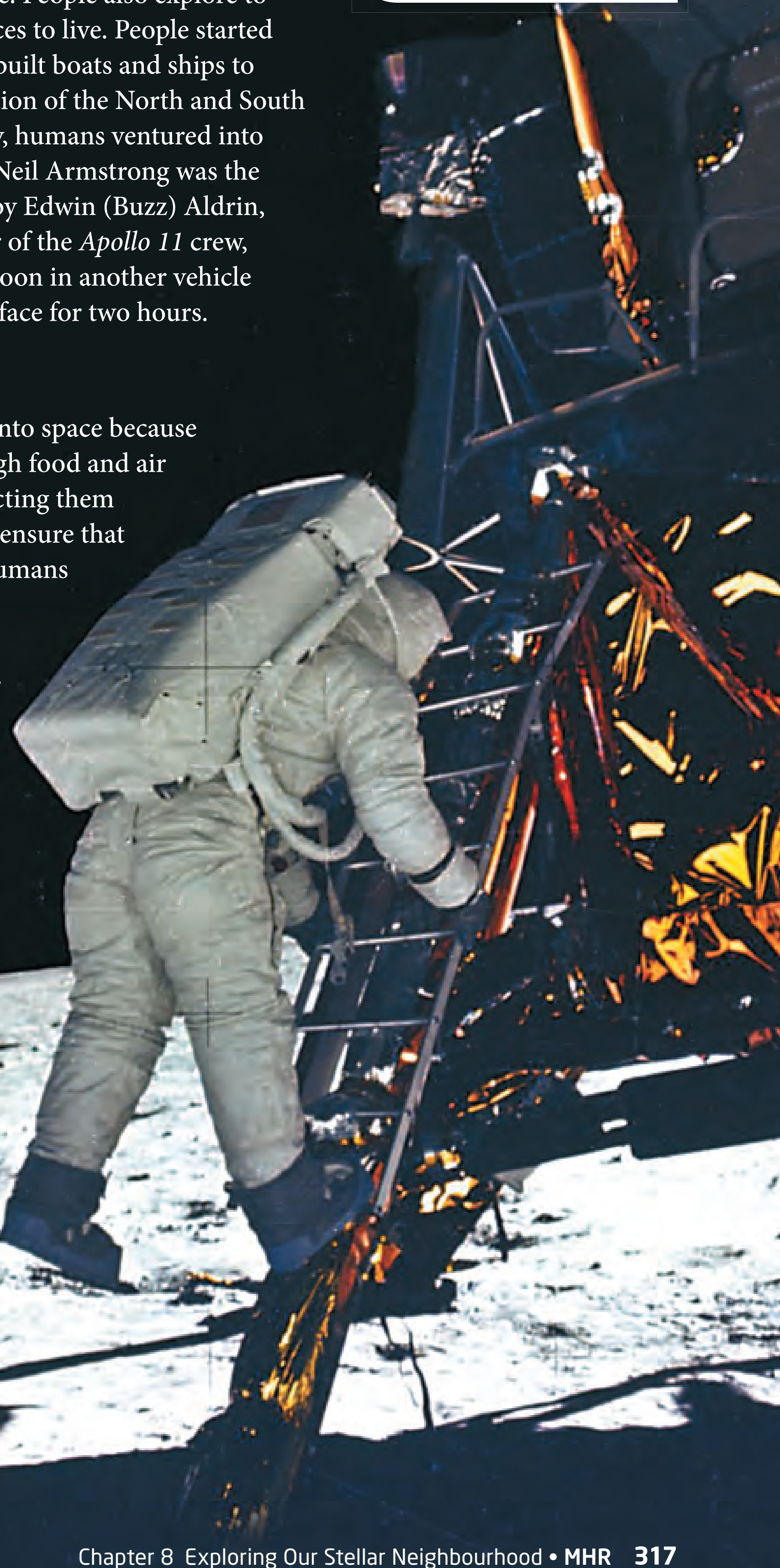


Figure 8.1 In this image, American astronaut Buzz Aldrin is about to step onto the Moon's surface.

Exploring Space with Telescopes

As you learned in Chapter 7, people began exploring space simply by watching the sky. As new technologies, such as telescopes, were invented, people began using the technologies to explore space further. Galileo Galilei (1564–1642) was one of the first to turn the telescope to the sky. Today, there are many types of telescopes and other instruments used to explore space.

The telescopes that astronomers use to study space all detect electromagnetic radiation. **Electromagnetic radiation** is varying types of energy waves. The electromagnetic spectrum, shown in **Figure 8.2**, is the range of all forms of electromagnetic radiation. Visible light is a form of electromagnetic radiation, as are X rays, microwaves, and radio waves. Cellphone signals are radio waves. All forms of electromagnetic radiation travel at the speed of light (3.00×10^8 m/s).

electromagnetic radiation radiation consisting of electromagnetic waves that travel at the speed of light (such as visible light, radio waves, and X rays)

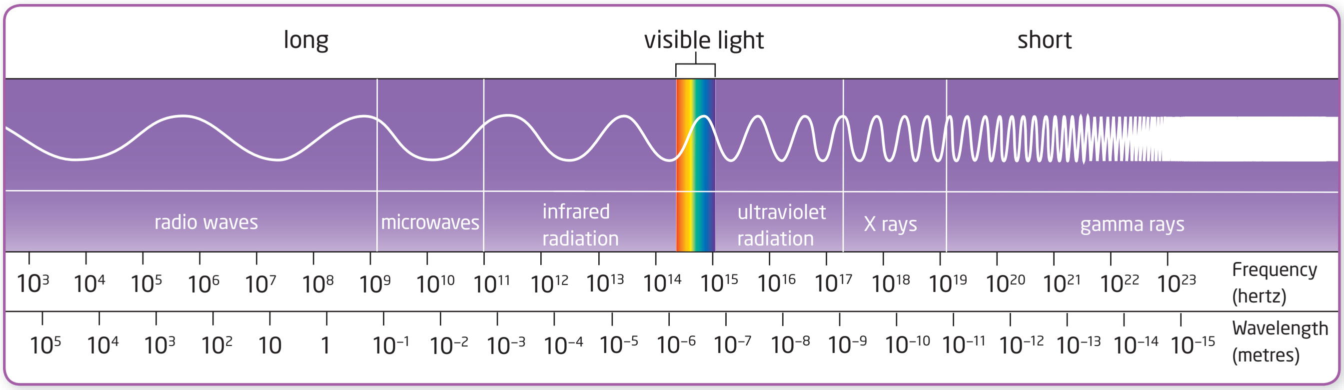


Figure 8.2 Radiation with shorter wavelengths is associated with higher energy. In optics (the science of light), the term *wavelength* is associated with the word colour.

Activity 8-2

An Astronomer's View

You might think that exploring space with a telescope is easy because the stars seem so bright and space is dark. However, Earth's atmosphere changes incoming starlight and prevents the formation of perfect images. How can you model looking through Earth's atmosphere? In this activity, you will model looking through Earth's atmosphere by using plastic wrap.

Materials

- piece of plastic wrap, about 15 cm long

Procedure

1. Place an opened book in front of you and observe how clear the text is from a distance of 1.0 m.
2. Hold the piece of plastic wrap in both hands, close to your eyes. Keep it taut.
3. Look at the same text from step 1 through the plastic wrap at the same distance.
4. Fold the plastic wrap in half, and look at the text again through both layers at the same distance.

Questions

1. In a sentence or two, compare reading text through plastic wrap to an astronomer viewing stars through Earth's atmosphere.
2. How many times do you think you would have to fold the plastic wrap before the wrap becomes opaque? (Remember that each fold doubles the number of layers of plastic wrap.)
3. Find the relationship between layers of plastic and distance from the text needed to read the text.

Optical Telescopes

An optical telescope is a telescope that detects visible light. There are two main types of optical telescopes. **Refracting telescopes**, shown in **Figure 8.3**, use a lens to collect light. **Reflecting telescopes**, also shown in **Figure 8.3**, use a curved mirror to collect light.

refracting telescope a telescope that uses a lens to collect the light from an object

reflecting telescope a telescope that uses a mirror to collect the light from an object

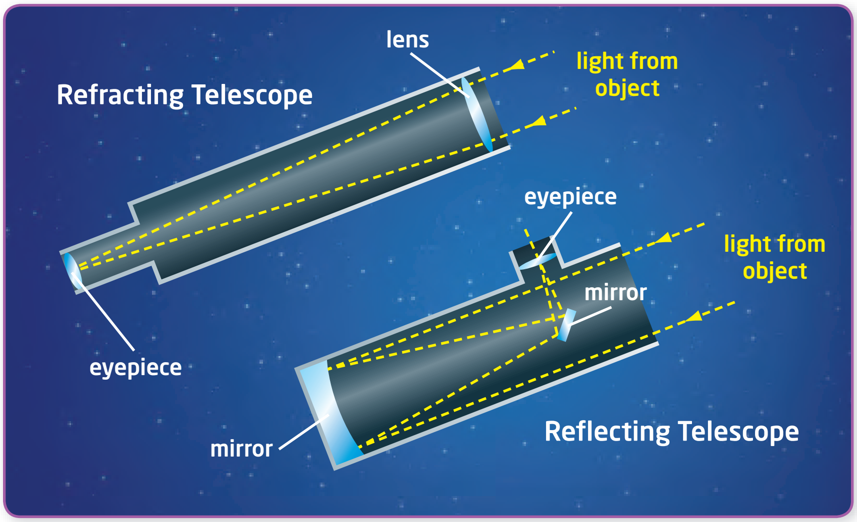


Figure 8.3 When using an optical telescope, the observer views the image of the object through the eyepiece, which is a lens that magnifies the image.

Non-optical Telescopes

There are other types of telescopes that detect non-visible radiation. One example is a radio telescope, shown in **Figure 8.4**. A radio telescope detects radio waves. Radio waves can penetrate clouds, so an advantage of using radio telescopes over using optical telescopes is that radio telescopes can be used on cloudy days. Another advantage is that they can also be used at night.

Radio telescopes are large receivers, similar to the satellite dishes attached to some homes. Radio waves coming from a distant object are collected and focussed on the receiver. An organization called the SETI (Search for Extraterrestrial Intelligence) Institute uses a group of radio telescopes to search for signs of intelligent life on other planets.

Figure 8.4 This 26 m radio telescope is part of the Dominion Radio Astrophysical Observatory near Penticton, British Columbia. The observatory is owned and operated by Canada's National Research Council.

Telescopes in Space

Much of the radiation that reaches Earth from space is absorbed by Earth's atmosphere and does not reach Earth's surface. As illustrated in **Figure 8.5**, for example, infrared radiation with a wavelength of 1 mm is absorbed about 50 km above Earth's surface. Therefore, in order to explore space in more detail, some telescopes need to be placed above Earth's atmosphere. There are several telescopes in space. Some examples are the Chandra X-ray Observatory, the Spitzer Space Telescope (which detects infrared radiation), and the Hubble Space Telescope (HST). The HST has provided many of the beautiful images in this unit.

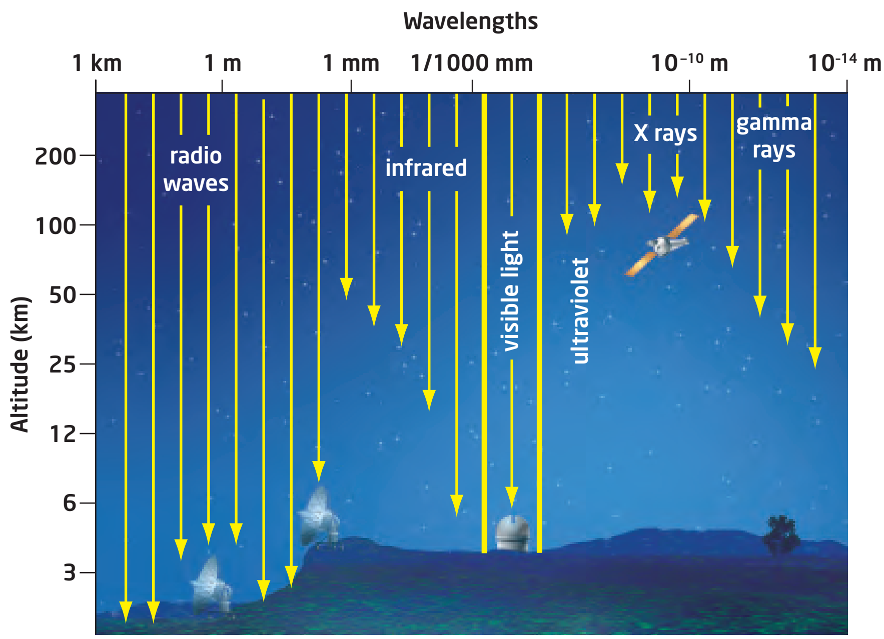


Figure 8.5 Only small portions of the electromagnetic spectrum from space reach Earth's surface. Therefore, telescopes need to be above Earth's atmosphere to detect the portions that do not reach Earth's surface.

The advantages and disadvantages of placing telescopes in space compared with Earth-based telescopes are summarized in **Table 8.1**.

Table 8.1 Advantages and Disadvantages of Placing Telescopes in Space

Advantages	Disadvantages
• They are above Earth's atmosphere, so they can detect parts of the electromagnetic spectrum that do not reach Earth's surface. • They can take long exposures of certain parts of the sky without being affected by daylight and bad weather. This allows the telescopes to detect faint astronomical objects not otherwise detectable on the ground.	• Launching telescopes into space is very expensive. • Telescopes in space are subjected to extremes of hot and cold. Such extremes cause the metals used in the instruments to expand and contract. Over time, the materials weaken. Once in space, telescopes are difficult or impossible to repair and upgrade. • Without a solid base, telescopes in space are difficult to point accurately and to keep pointing in any direction. Earth-based telescopes are anchored to the ground. • Compared with Earth-based telescopes, the working lives of space telescopes are very short, sometimes lasting only a few years.

MOST: Canada's "Humble" Space Telescope

MOST (Microvariability and Oscillations of STars) is Canada's first space telescope. It is pictured in **Figure 8.6** beside its older cousin, the HST. **Table 8.2** compares the HST and MOST. MOST was designed and built by the University of British Columbia, Dynacon Inc., and the University of Toronto Institute for Aerospace Studies, Space Flight Lab. The $10 million in funding was provided by the Canadian Space Agency (CSA). MOST's purpose is to study stars that are similar to the Sun, one star at a time for about eight weeks per star. To keep it pointing in one direction for that length of time, MOST uses Dynacon's reaction wheels, which were mentioned with the NEOSSat satellite in Chapter 7. MOST was expected to study 10 stars and last one year. It has provided data on over 1500 stars and is now expected to last until 2015.

Another telescope in space, called SOHO (SOlar Heliospheric Observatory), gathers data on the Sun. Astronomers have learned much about the Sun and other stars from SOHO and other technologies, such as spectroscopy. You will learn more about spectroscopy, the Sun, and other stars in Sections 8.2 and 8.3.

Table 8.2 A Comparison of the HST and MOST

	Hubble Space Telescope	MOST
Cost and year of launch	$10 billion; 1990	$10 million; 2003
Dimensions and mass	13.2 m × 4.2 m (about the size of a large school bus); 11 110 kg	65 × 65 × 30 cm (about the size of a suitcase); 60 kg
Instruments	7 science instruments; diameter of the primary optical mirror: 2.4 m	telescope mirror diameter: 15 cm
Altitude above Earth	600 km	820 km
Power	solar energy	solar energy

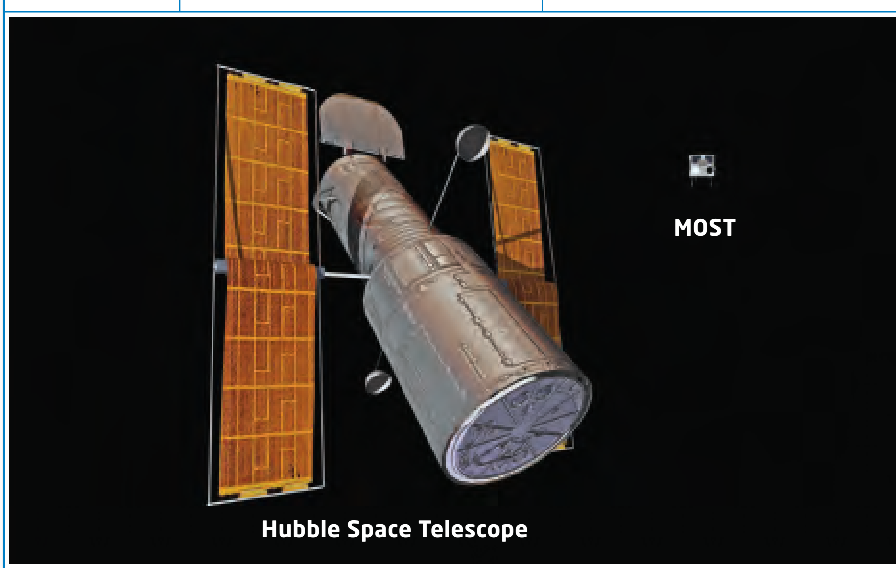


Figure 8.6 The tiny MOST satellite is so successful that it received the Alouette Award in 2008 for its outstanding contributions to space technology and research. (Alouette was Canada's first satellite, launched in 1962.)

Studying Objects in Different Wavelengths

A range of telescopes can reveal different types of information about an object. For example, **Figure 8.7** shows the planet Saturn in four different wavelengths. A comparison of Saturn in visible light, shown in **Figure 8.7A**, with Saturn in ultraviolet radiation, **Figure 8.7B**, reveals that Saturn has auroras (the glowing areas at the poles), like Earth. The view in infrared, **Figure 8.7C**, shows detailed features in Saturn's atmosphere. The different colours represent different heights and compositions of Saturn's clouds. The radio wave image in **Figure 8.7D** indicates that the planet emits (gives off) radio waves (the red) and that the rings (the blue) absorb this radiation.

Study Toolkit

Making Study Notes A T-chart such as the one on page 316 could be used to organize the information in the first paragraph on this page. A T-chart is helpful because it shows the main idea and supporting details.

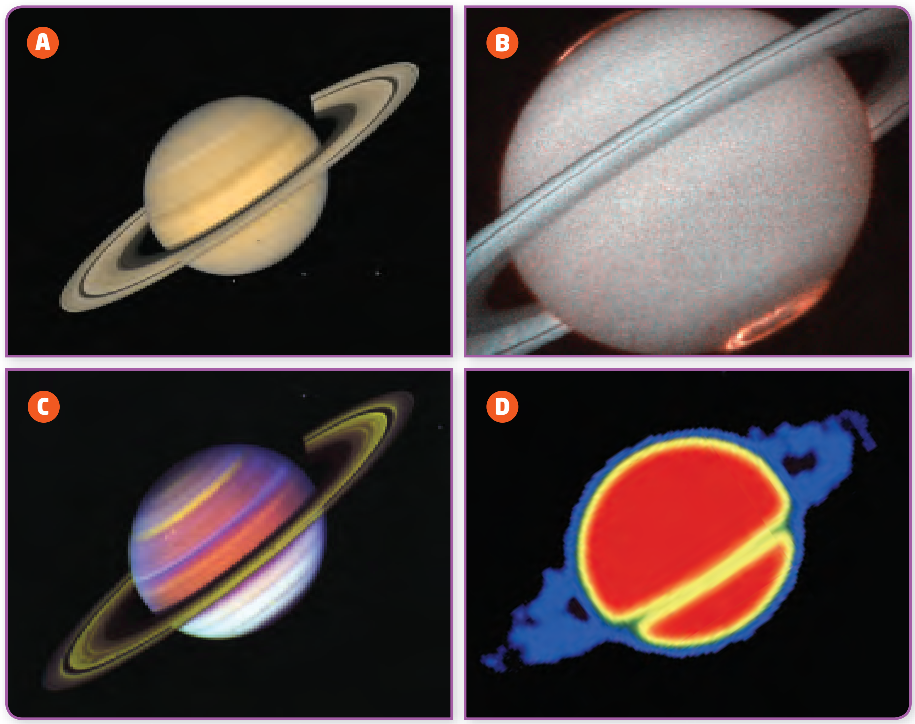


Figure 8.7 **A** is Saturn in visible light, **B** is Saturn in ultraviolet, **C** is Saturn in infrared, and **D** is Saturn in radio wavelengths. The colours in **B**, **C**, and **D** are false. Astronomers add the colours to show different features.

Learning Check

1. Why is it risky to send humans into space?
2. Compare and contrast space telescopes and Earth-based telescopes.
3. How do telescopes that detect non-optical radiation contribute to our understanding of space? Review **Figure 8.7**.
4. Neil Armstrong's first words on the Moon were, "That's one small step for [a] man, one giant leap for mankind." What do you think his words mean?

Planetary Orbiters and Landers

Orbiters are observatories that orbit other planets. They are equipped with digital cameras that provide high-resolution images not obtainable from Earth. Orbiters have fairly short operational life expectancies, such as 2 or 3 years, but some have lasted as long as 10 years. One example of an orbiter is *MESSENGER* (MErcury Surface, Space ENvironment, GEochemistry, and Ranging), shown in **Figure 8.8**. NASA launched *MESSENGER* in 2004 to explore Mercury.

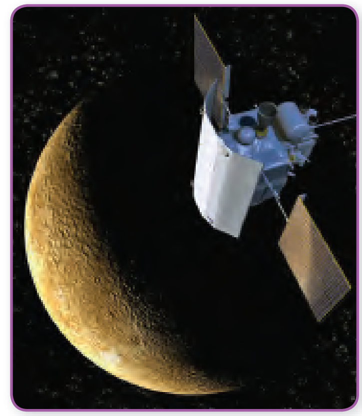


Figure 8.8 In January 2008, the spacecraft *MESSENGER* was close enough to Mercury to start sending back images of Mercury's heavily cratered surface.

The *Mars Climate Orbiter*

Sending instruments into space has some risks. In December 1998, NASA launched an orbiter to Mars called the *Mars Climate Orbiter* (MCO). The MCO was supposed to go into orbit around Mars. Once in orbit, the MCO was to act as a Martian weather satellite and communicate with the *Mars Polar Lander.* A *lander* is a spacecraft designed to land on a planet. The *Mars Polar Lander* was launched in January 1999 and was scheduled to land on Mars in December 1999. In September 1999, as the MCO approached Mars to go into orbit, NASA engineers lost communication with it, and never heard from it again.

Look at **Figure 8.9**. The blue line is the MCO's intended orbit, and the red line is the actual path that the MCO followed. A team of engineers at NASA's Jet Propulsion Laboratory (JPL) was responsible for monitoring the MCO's orbit. The JPL team used metric units, such as kilometres, for their data. The contractor for the MCO, Lockheed Martin, sent data to JPL in imperial units, such as miles. As a result, the MCO went into an orbit that was too low, and it burned up in the atmosphere of Mars. The *Mars Polar Lander* also failed: it crash-landed on Mars. The total cost of the MCO mission was U.S. $327.6 million, and the total cost of the Mars Polar Lander mission was U.S. $120 million.

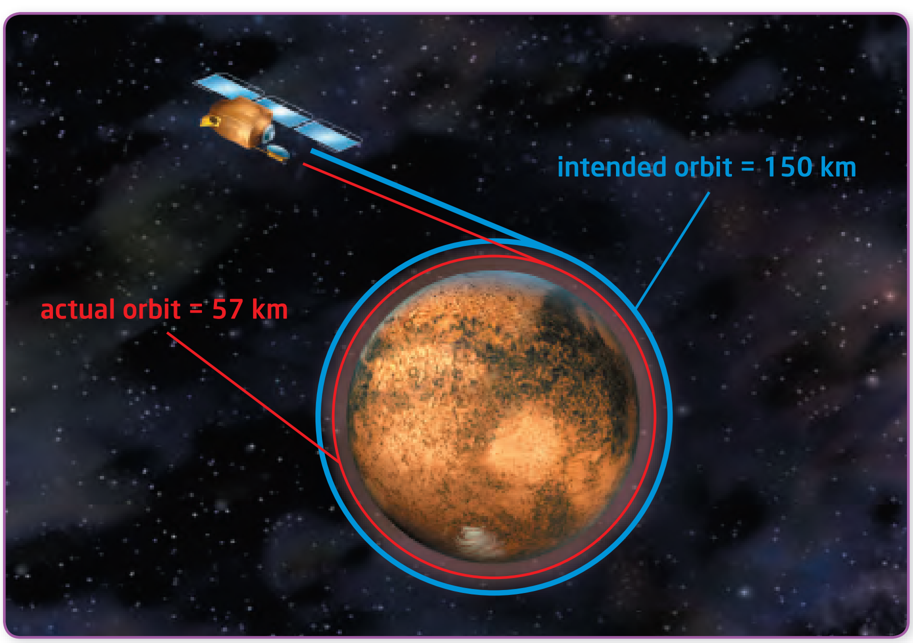


Figure 8.9 As a result of an error in communication, NASA lost the *Mars Climate Orbiter*. (This image is not to scale.)

Landers

Landers cannot move around. Therefore, they can sample only a fraction of the environment on the planet being explored. NASA's *Phoenix Lander* is shown in **Figure 8.10**. Most landers are designed to last for a few months, although in exceptional cases they have been known to last many months longer than what they were designed for. Landers, like orbiters, are expensive. They must be able to land safely on a surface. This added complexity contributes significantly to the cost of the project. As you read on the previous page, sometimes landers do not land safely.

Go to **scienceontario** to find out more

One of the sets of instruments that *Phoenix* took is a weather station that was designed and built by a team from York University (Toronto), Dalhousie University (Halifax), Optech Inc. (Vaughan), the University of Alberta (Edmonton), and the CSA. The weather station collected data on clouds, fog, and dust in the Martian atmosphere—giving a weather report from Mars! In November 2008, winter began on Mars. The amount of sunlight reaching the northern polar cap began to decline, so the weather station stopped working. *Phoenix* required sunlight to power its computers and run its instruments.

The Lidar Instrument

One of the instruments in the weather station is called lidar, which stands for Light Detection and Ranging. The lidar instrument, which is about the size of a shoebox, uses laser technology. The thin, green vertical line in **Figure 8.10** is the lidar's laser beam. The laser shot quick pulses of light into the Martian atmosphere, and the light bounced off clouds and dust particles. The laser light then returned to an optical telescope in the instrument. The Canadian science team ran the laser for 15 min, four times a day. The data that the team collected gave information on the movement, size, and composition of Martian clouds and dust particles above the weather station.

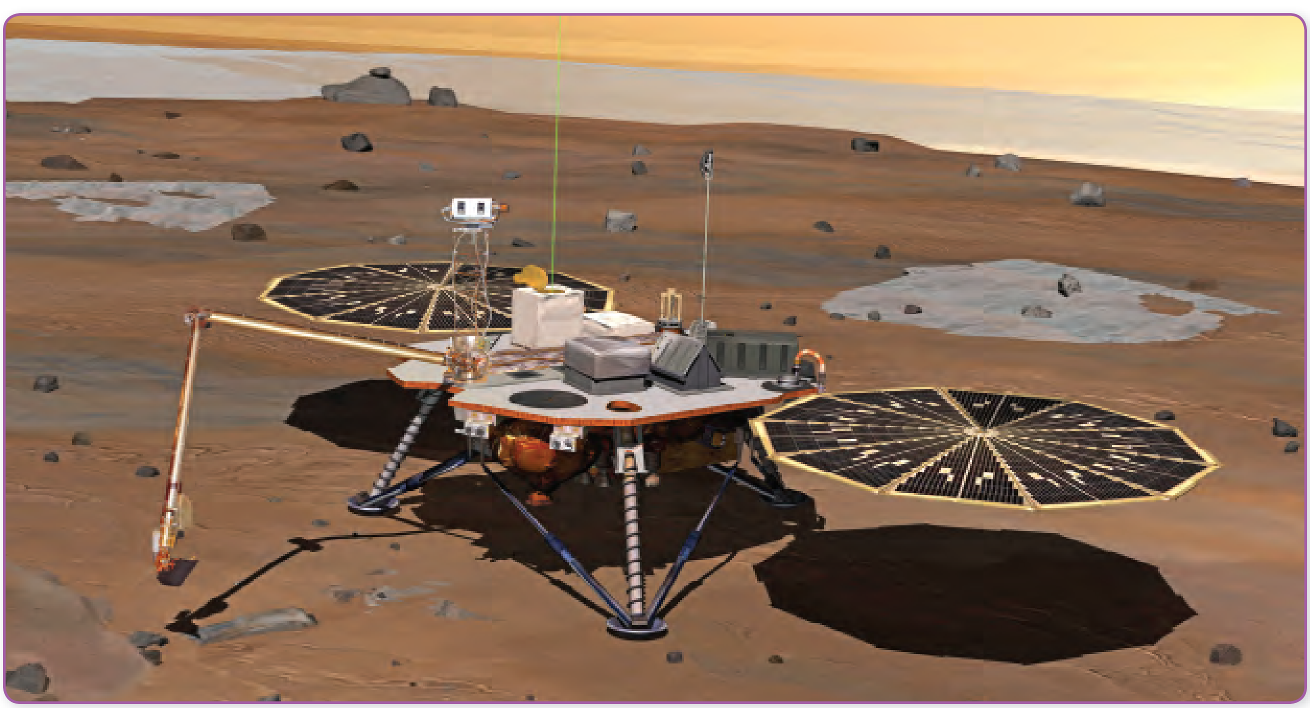


Figure 8.10 The *Phoenix Lander* was the first spacecraft to land in the northern polar region of Mars. The CSA invested $37 million in the weather station. This picture is an artist's conception of *Phoenix* on Mars.

Satellites

A **satellite** is a human-made object or vehicle that orbits Earth, the Moon, or other celestial bodies. Satellites are an important part of your daily life. The weather reports on television, the Internet, and the radio use data from weather satellites. When you watch television, telephone a friend, and use the Internet, communications satellites are likely playing a role (see **Figure 8.11**). Communications satellites transmit television, telephone, and radio signals around the world. Canada has been part of the communications satellite industry since 1972, when it launched its first communications satellite, *Anik 1*. Canada is an extremely large country, with its towns and cities spread far apart. Communications satellites are important to unite the country.

satellite an artificial (human-made) object or vehicle that orbits Earth, the Moon, or other celestial bodies; also, a celestial body that orbits another of larger size (for example, the Moon is Earth's natural satellite)

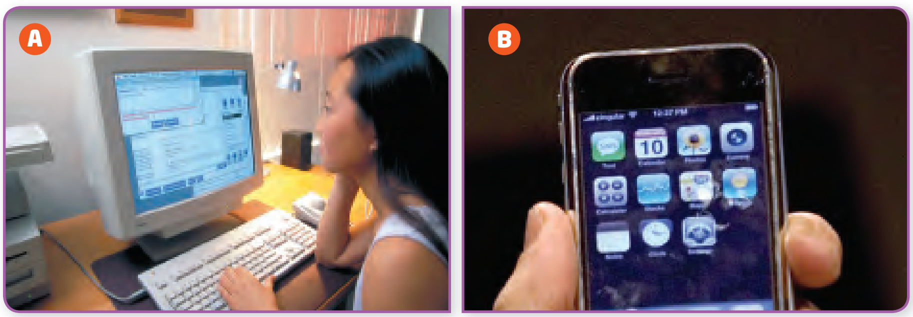


Figure 8.11 Without satellite technology, both **A** computers and **B** cellphones could not access the Internet to the extent possible today.

Global Positioning System (GPS) Satellites

Satellites also provide services for search and rescue. Using a small, hand-held GPS unit, as shown in **Figure 8.12**, you can use satellite technology to find out where you are on Earth. More than two dozen GPS satellites (called NAVSTAR, for navigation satellite tracking and ranging) are now spread out in orbit around Earth, about 20 200 km above Earth's surface. As a result, there are always at least three above the horizon, wherever you are in the world, whatever the time of day.

GPS technology is now commonly used in all kinds of vehicles, even in farmers' combines (large tractors). The GPS unit in a farmer's combine monitors the farmer's field at evenly spaced time intervals, for example, every 10 min. The unit gives information on factors such as soil needs, differences in types of soil, and soil moisture. Such data allow the farmer to fine-tune the fertilizing and watering needs for the whole farm.

Figure 8.12 You need never get lost again. Hand-held GPS units are becoming more and more popular with hikers.

Remote-sensing Satellites

Satellites that are generally less than 700 km above Earth's surface are called low-Earth-orbit satellites. They take about 90 min to complete a single orbit. They can survey Earth quickly and cover a lot of surface. This is very useful for the sciences of meteorology (study of weather), climatology (study of climates), oceanography (study of oceans), and hydrology (study of water). The process of gathering data about Earth using instruments mounted on satellites is called *remote sensing*.

Sense of **scale**

It is estimated that about 8000 satellites have been launched. About 3000 of those have fallen out of orbit and burned up in the atmosphere.

ENVISAT

ENVISAT (ENVIronmental SATellite) is a remote-sensing satellite launched in 2002 by the European Space Agency (ESA). The CSA and several Canadian companies contributed to the funding, design, and construction of ENVISAT.

For example, EMS Technologies, in Sainte-Anne de Bellevue, Québec, designed and manufactured one of ENVISAT's remote-sensing instruments. The instruments can capture data even through cloud cover and during the long, dark winters at the poles. Scientists now have a better understanding of shrinking Arctic sea ice and Antarctic ice shelves. **Figure 8.13** shows changes in the Arctic ice in 2008. Scientists also use ENVISAT data to monitor the heights of oceans, land surfaces, and major lakes and rivers.

Additional Uses of ENVISAT Data

Scientists use ENVISAT data to help manage resources and prevent disasters. For example, the ESA maintains a World Fire Atlas, which makes fire maps available on-line in near-real time. The atlas uses ENVISAT data. The maps are used for assessing damage and the risk of fires, and deciding how to fight fires efficiently.

ENVISAT data have even helped in a race to the North Magnetic Pole. When 16 teams skied 500 km from Resolute Bay to the North Magnetic Pole in the 2005 Scott Dunn Polar Challenge, they used ENVISAT maps that showed the extent and types of ice.

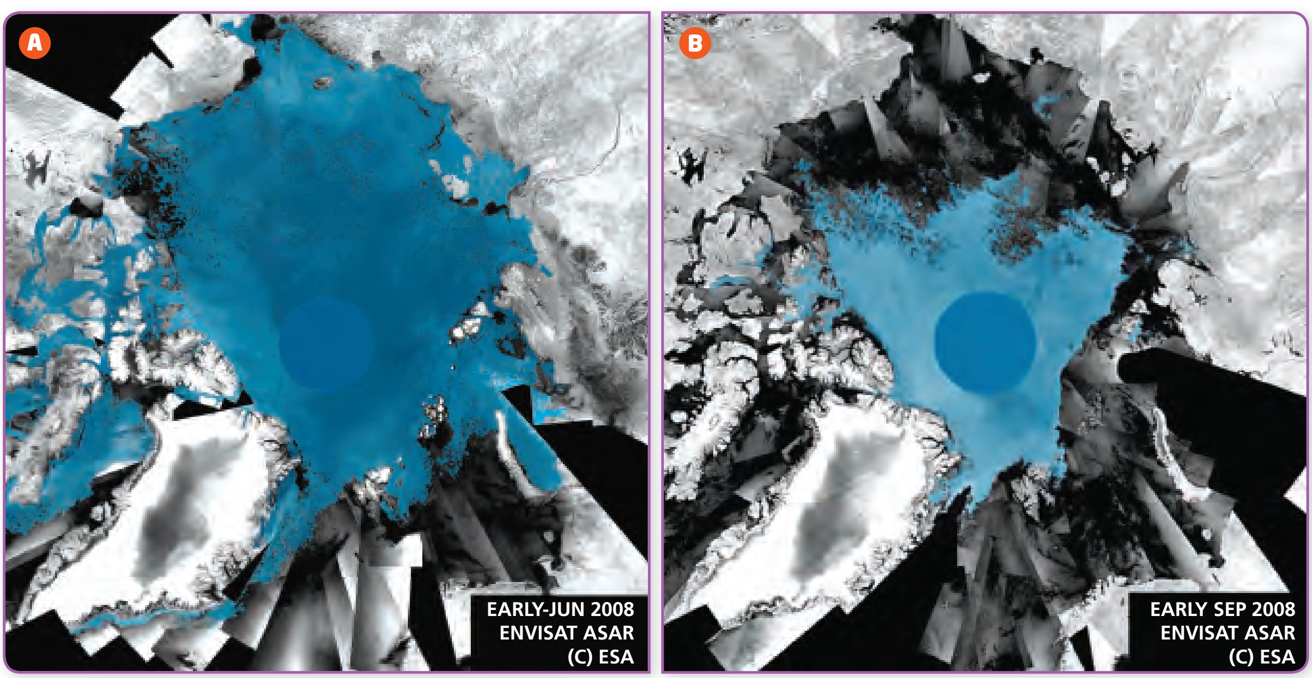


Figure 8.13 These ENVISAT images show the changes in ice cover between June, in part **A**, and September, in part **B**, in 2008. The blue represents areas covered with ice, and the grey represents areas with no ice.

Geosynchronous Satellites

Geosynchronous satellites orbit Earth in an eastward direction at an altitude of 35 800 km above the equator. At this altitude, it takes 24 hours for a geosynchronous satellite to complete one orbit. Since Earth also turns in an eastward direction and makes one rotation in 24 hours, the satellite appears to stay over a single location above the equator. As a result, these satellites are also called "geostationary" satellites (*geo* means Earth). The rotation of Earth combined with the orbital motion of the satellite creates the illusion that the satellite is stationary in the sky. The advantage is that the receivers on the ground do not have to move to track the satellite. The best-known geosynchronous satellites are the ones that broadcast television programs and satellite radio.

Learning Check

5. Compare the altitudes and purposes of remote-sensing, GPS, and geosynchronous satellites.
6. List three alternatives to sending humans into space.
7. Compare the advantages and disadvantages of using a lander over using an orbiter.
8. The CSA invested $37 million in the weather station on Mars. Do you think it was worth the investment? Explain your answer.

The International Space Station

Since the late 20th century, more countries have begun to partner in space exploration to share the costs. Numerous partnerships between private businesses and governments, including Canada, have been formed to complete the International Space Station (ISS).

Construction of the ISS began in 1993. It is being built piece by piece from components delivered by NASA's space shuttle and rockets from Russia. Its orbit is about 360 km above Earth. **Figure 8.14A** shows the ISS, and **Figure 8.14B** shows the altitude of the ISS compared with the altitudes of other spacecraft.

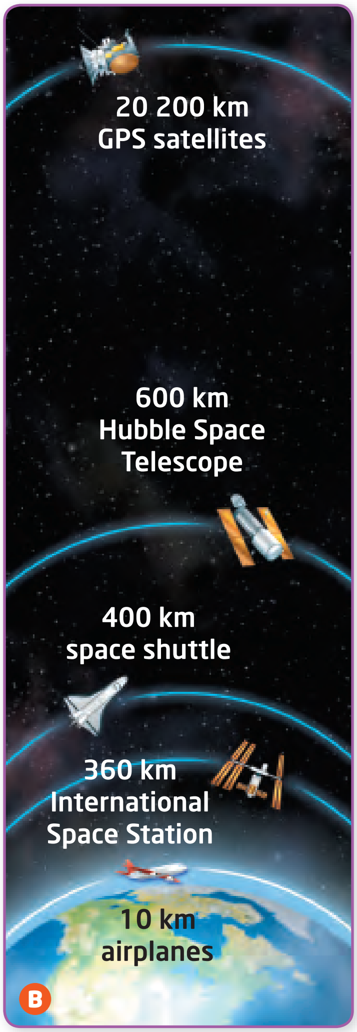


Figure 8.14 **A** Travelling at more than 27 000 km/h, the ISS circles Earth in about 90 min. Part **B** shows the altitudes of the ISS and other spacecraft.

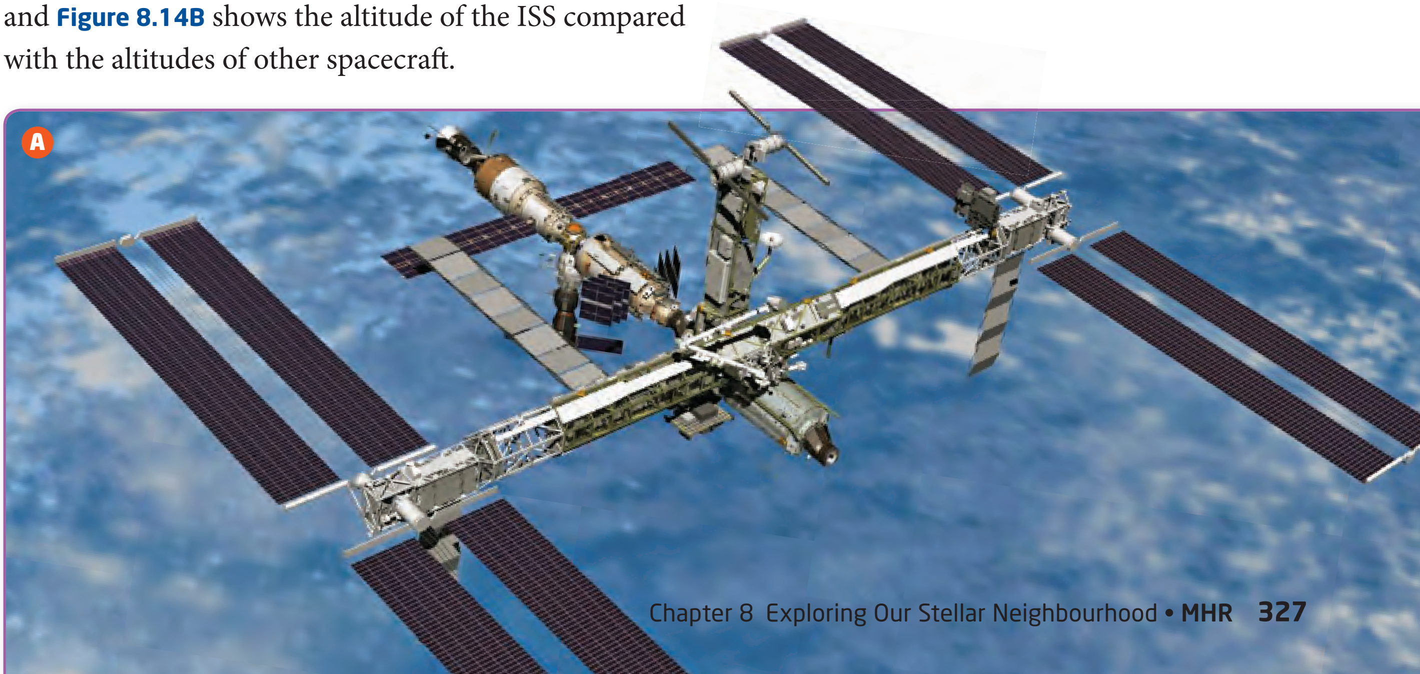


Figure 8.16 As of 2009, Canada has three active astronauts: Chris Hadfield (top), Julie Payette (middle), and Robert Thirsk (bottom).

A Laboratory in Space

The ISS is a space-based laboratory. It provides many opportunities for research in the microgravity environment. Microgravity is the condition of weightlessness experienced by all objects in space, including people and spacecraft. Scientists at the CSA are known around the world for their work in microgravity research.

The crew members who stay on the ISS conduct experiments, such as growing protein crystals. Research on growing protein crystals will help scientists determine protein structure and function. Pharmaceutical companies may be able to use this research to develop treatments for diseases.

Canadian Contributions to the ISS

One of the largest successes in the U.S. space program has been the robotic fixtures that were designed and built in Canada: Canadarm, Canadarm2, and Dextre, shown in **Figure 8.15**. The Canadarms are used on NASA's space shuttles to help with the construction of the ISS.

Canada's robotic technology has resulted in benefits on Earth, too. For example, MD Robotics, the company that built the Canadarms, has used this technology in another arm—the Light Duty Utility Arm. This robotic arm handles radioactive waste in underground storage tanks.

Canada's Astronauts

As of this book's printing, Canada has three active astronauts: Chris Hadfield, Julie Payette, and Robert Thirsk, shown in **Figure 8.16**. Hadfield has been an astronaut since 1992, and he was the first Canadian to operate the Canadarm in orbit. Payette has also been an astronaut since 1992 and was the first Canadian to travel to the ISS. Thirsk has been an astronaut since 1983. He studies the effects of space conditions on animal and plant life. Canada's retired astronauts are Roberta Bondar, Marc Garneau, Steve MacLean (now president of the CSA), Bjarni Tryggvason, and Dave Williams.

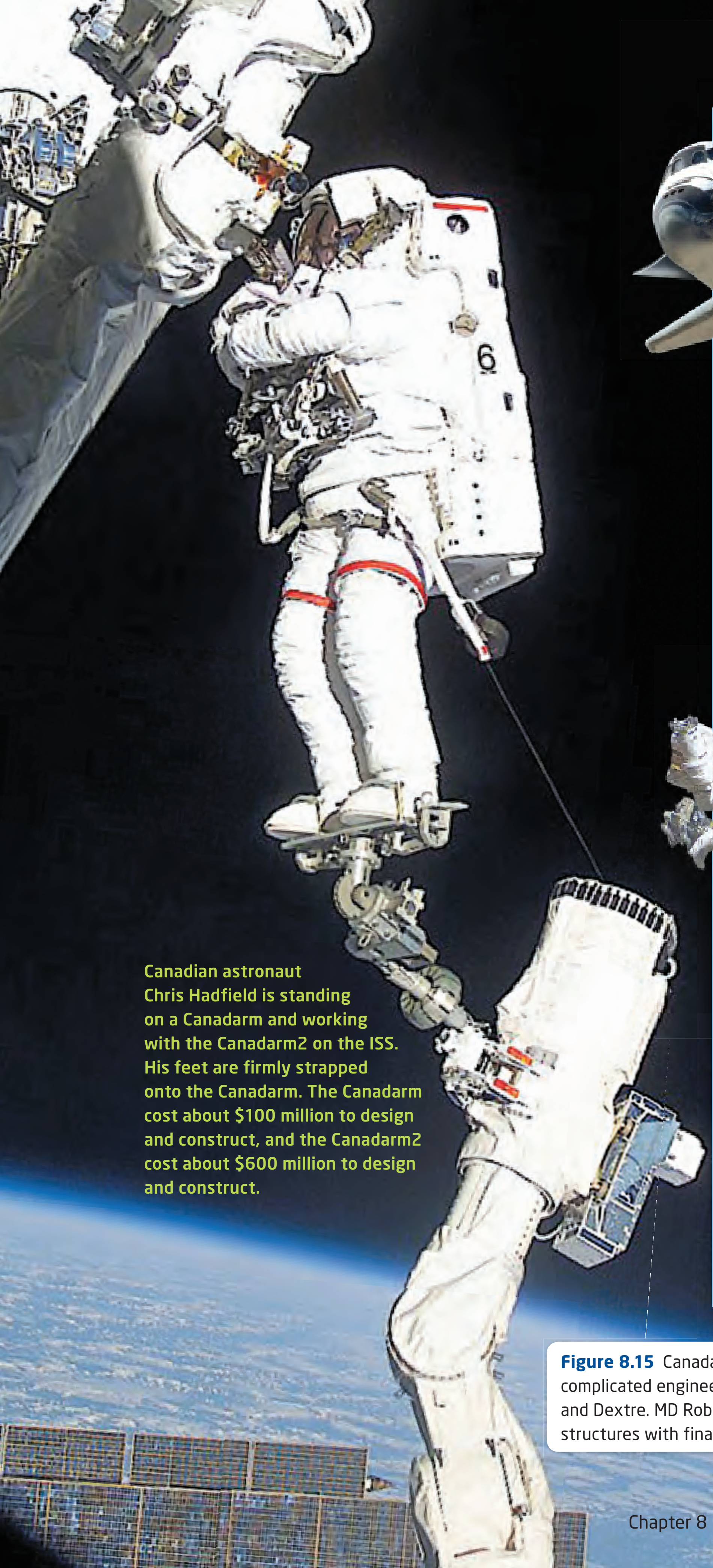
Making a Difference

Roberta Bondar fulfilled a childhood dream after she boarded the space shuttle *Discovery* in 1992. She also became Canada's first female astronaut and the first neurologist in space.

Roberta spent eight days conducting experiments and researching connections between how the human body recovers after being in space and neurological conditions, such as Parkinson's disease and stroke.

Roberta has studied agriculture and zoology at the University of Guelph and neurobiology at the University of Western Ontario and the University of Toronto. She earned a medical degree from McMaster University with a specialty in neurology.

Roberta is an inspiring role model for students all across Canada. Which Canadian role model has made the biggest impact on you and your dreams for the future?



In 2003, the space shuttle *Columbia* was destroyed when it was re-entering Earth's atmosphere, killing all seven members of the crew. Some protective tiles on the shuttle were damaged during its launch. To prevent an accident like this from happening again, MD Robotics developed an extension to the Canadarm. The extension includes a laser camera and is used to inspect the whole space shuttle for damage before the shuttle returns to Earth.

Dextre (Special Purpose Dexterous Manipulator) is a two-armed robot that attaches to the end of Canadarm2. Dextre has special grippers that include a light and a camera. Dextre helps with station maintenance, such as replacing batteries and small computers. Having Dextre help with such tasks frees the astronauts, who can then spend more time on experiments. Dextre's name was suggested and chosen by Canadian students in a national contest.

Canadian astronaut Chris Hadfield is standing on a Canadarm and working with the Canadarm2 on the ISS. His feet are firmly strapped onto the Canadarm. The Canadarm cost about $100 million to design and construct, and the Canadarm2 cost about $600 million to design and construct.

Figure 8.15 Canada is a leader in robotic technology, producing such complicated engineering structures as the Canadarm, the Canadarm2, and Dextre. MD Robotics, in Brampton, Ontario, developed these three structures with financial support from the CSA.

The Costs of Space Exploration

Sense of Value

NASA's budget in 2008 was just over U.S. $17 billion, most of which went to salaries. How does this compare with the budget of the city or town you live in?

It takes years of designing and testing the equipment, spacesuits, and computer software needed to send people and vehicles into space. As a result, space exploration is very expensive. Sending humans into space is also extremely risky. Tragic accidents have occurred. For example, the first Apollo mission—*Apollo 1*—did not even get off the ground. In 1967, there was a fire in the spacecraft on the ground during a test three weeks before launch, leading to the deaths of all three astronauts inside. In another accident, the Russian cosmonaut (the Russian equivalent of an astronaut) Vladimir Komarov died when his spacecraft crashed when returning to Earth, also in 1967.

The Ethics of Space Exploration

ethics the set of moral principles and values that guide a person's activities and help him or her decide what is right and what is wrong

The term **ethics** means the set of moral principles and values that guide a person's activities and help him or her decide what is right and what is wrong. When discussing space exploration and the use of space resources, such as rock samples from the Moon and other celestial bodies, it is important to consider the ethical issues related to space exploration. Closely tied to ethical issues are environmental and political issues.

STSE Case Study

Space Junk

Earth is not the only place where humans have dumped their garbage–we have also created a garbage problem in space. There are now millions of pieces of garbage, called space junk, orbiting our planet.

In January 1997, a piece of space junk fell and grazed Lottie Williams' shoulder.

Most pieces of space junk are very small, but they move at speeds of up to 8 km/s. At these extremely high speeds, a collision with even a very small piece of junk can cause a lot of damage. Mission controllers have sometimes had to change the flight paths of space shuttles to avoid dangerous collisions. But scientists cannot track the millions of pieces of junk all the time, and the risk of a collision with a piece of this debris is now the biggest threat to space shuttle missions. Space junk can also cause costly damage to functioning satellites.

According to NASA, about one piece of space junk returns to Earth every day, and there is a one-in-a-trillion chance a person will be hit by falling junk. There have been no reported cases of people being killed by space junk, but there have been reports of large pieces of junk falling to Earth.

Reducing Space Junk

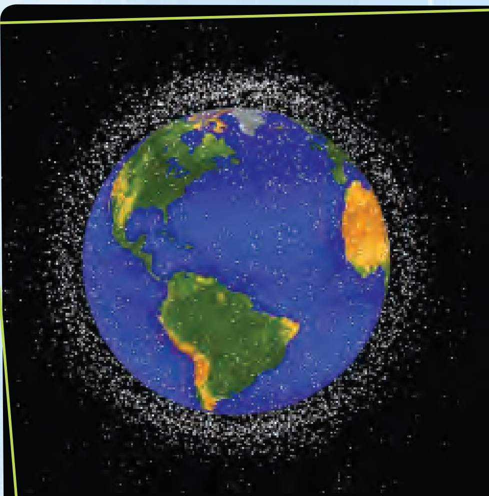
Space agency scientists are researching ways to clean up and reduce the amount of space junk. One solution for reducing the amount of space junk is to send spacecraft into orbit to try to collect it. Another solution is to slow the orbit of a piece of space junk using lasers, so that it will fall back to Earth. Unfortunately, these strategies are too expensive or technically difficult to put into practice. Until we find a way to get rid of the orbiting junk, sending astronauts and equipment into space will become riskier.

Issues to Consider

Table 8.3 outlines some of the questions that we must consider if we are to prevent the unethical use of space and its resources in the future.

Table 8.3 Issues Related to Space Exploration

Ethical	• How do we ensure that space resources will be used to help all humankind, rather than just to provide an advantage for one country or another? • Do humans have the right to explore other environments around the solar system? • Do humans have the right to take materials from other bodies in the solar system?
Environmental	• How will space exploration affect Earth's natural systems? • Who is responsible for policing environmental impacts? • Who is responsible for cleaning up any damage or debris caused by space exploration and development?
Political	• Who owns space resources? • Should countries share technology and resources? • Who should decide how space resources will be used?



Earth is surrounded by a halo of space junk.

Sources of Space Junk

- Millions of small bits and pieces, such as paint chips, nuts and bolts, and other tiny fragments, have broken off telescopes, satellites, and spacecraft.
- An American astronaut's extra glove floated off during the first U.S. spacewalk in 1965, and in 2008 an astronaut lost a tool kit.
- Some countries have intentionally exploded their own satellites. For example, in 2007, China tested its anti-satellite capabilities by destroying one of its own satellites, creating hundreds of new pieces of garbage.
- New pieces of space junk form when objects already in orbit collide with each other.
- Old satellites and other equipment, such as rocket stages, have remained in orbit but are no longer functioning.

Your Turn

1. What is space junk, and why is it such a problem?
2. Some people think that space junk is similar to pollution and other environmental problems on Earth. Create a Venn diagram to illustrate the similarities and differences between space junk and pollution on Earth.
3. You are a reporter for a local newspaper who has been assigned to write about a large piece of space junk that has landed in a field outside of town. Write a newspaper article that describes what happened and why space junk is dangerous.

Section 8.1 Review

Section Summary

- There are two basic types of optical telescopes. Refracting telescopes collect light using a lens, and reflecting telescopes collect light using mirrors.
- There are also telescopes that detect non-visible radiation.
- Alternatives to human exploration of space are telescopes, planetary orbiters, landers, and satellites.
- There are hazards, risks, benefits, and ethical issues related to exploring space and developing space technology.
- The Canadian government, Canadian companies, and individual Canadians have contributed to the exploration of space in many different ways.

Review Questions

K/U **1.** List two reasons why astronomers collect electromagnetic radiation from objects in space using telescopes instead of visiting the objects.

C **2.** In a graphic organizer, show the advantages and disadvantages of using robots and satellites instead of humans to explore space.

K/U **3.** List two risks of space exploration.

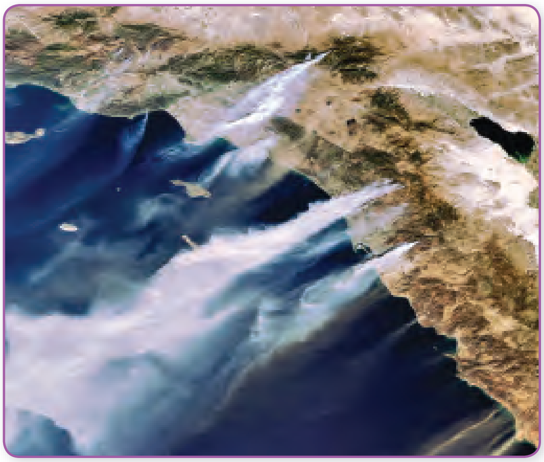
K/U **4.** Canadian individuals, Canadian companies, and the Canadian government are active in space research.

a. List three Canadian contributions to space exploration.

b. List three Canadian individuals who have contributed to space exploration.

K/U **5.** How have Canadians contributed to the development and use of satellite technology? Include an example in your answer.

A **6.** The image on the right was taken by ENVISAT in late 2007. The coastline is southern California. What is the image showing, and how is this helpful?



The ENVISAT satellite took this image of southern California in October 2007.

C **7.** The term *geostationary satellite* is not really accurate. Argue why this is so.

T/I **8.** Study **Figure 8.5** on page 320. Predict what this drawing would look like if Earth's atmosphere were replaced with the atmosphere of Mars. Include a sketch. How would this affect the design of a space suit?

T/I **9.** In **Table 8.3** on page 331, nine questions are posed. In your opinion, which three questions are the most difficult to answer? Explain your choices.