Space Exploration

Technological developments over the past century have helped us explore outer space and push the boundaries of the known Universe. In the past five decades, humans have expanded their presence from our planet to the edge of the Solar System and beyond. We have built scientific laboratories in space (Figure 1), and spacecraft have landed on other planets, moons, and asteroids. We place instruments into space that gather information we would not be able to access from our planet's surface. Can you think of any objects or materials in everyday life that may have been developed as a result of space exploration?

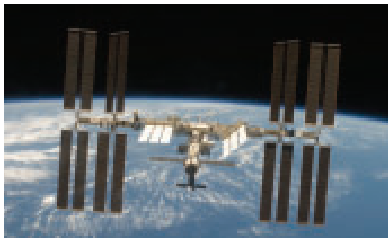


Figure 1 The International Space Station (ISS) is a research facility in Low Earth Orbit.

Exploring Space from Earth

The science of astronomy is different from many other sciences. Scientists cannot directly experiment on the objects they study because they are so far away. They must use many different types of instruments and devices to make accurate observations and predictions about celestial objects.

Telescopes are instruments that detect and collect different types of electromagnetic (EM) radiation. Large telescopes are housed in observatories. In the past, all observatories were large buildings on the ground. During the last few decades, a growing number of telescopes and observatories have been launched into orbit around Earth. One example of such a telescope is the Spitzer Space Telescope, which detects the radiation given off by young stars that are difficult to see because they are usually hidden in clouds of dust and gas (Figure 2). Another telescope, the XMM-Newton Observatory (Figure 3), examines the X-ray radiation emitted by objects such as black holes.

DID YOU KNOW?

International Year of Astronomy

The year 2009 was declared the International Year of Astronomy by the United Nations because it marked the 400th anniversary of Galileo's telescope. All over the world, people attended "star parties," where they could look through telescopes and observe real images of distant celestial objects.

GO TO NELSON SCIENCE

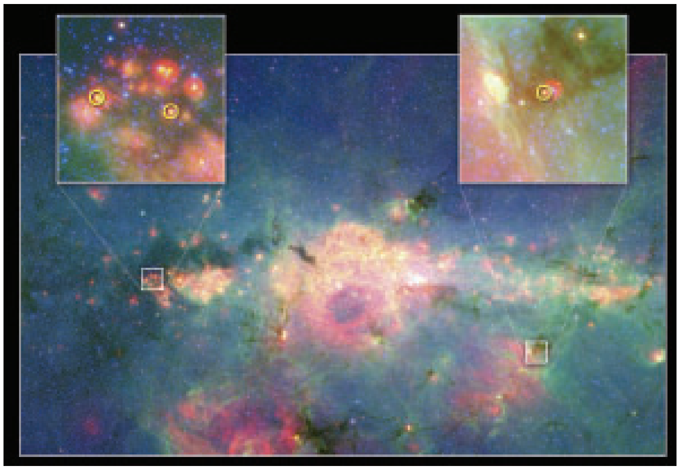


Figure 2 This Spitzer Space Telescope image shows three new stars in the Milky Way galaxy (circled in yellow). These stars were previously undetected because they are obscured by dust, but the Spitzer can detect them by monitoring infrared radiation.

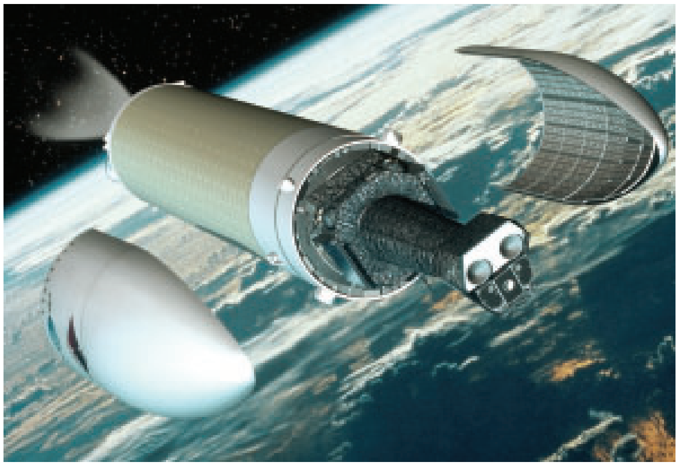


Figure 3 The XMM-Newton, the European Space Agency's largest astronomical satellite, is being released from its *Ariane 5* launch vehicle.

Early Telescopes

The first telescope was invented in 1608 in the Netherlands by glassmaker Hans Lippershey. The following year, astronomer Galileo Galilei refined the design. Merchants and sailors used Galileo's telescopes to look out to sea and spot distant ships coming to land, but Galileo used his own telescope to explore the night sky. Using the telescope's magnification and resolving power, Galileo revolutionized our view of the Universe.

refracting telescope an optical telescope that uses glass lenses to gather and focus light

reflecting telescope an optical telescope that uses mirrors to gather and focus light

The first optical telescopes used curved lenses to collect beams of light. This type of telescope, called a **refracting telescope**, gathers and focuses light from the visible light spectrum to form an image (Figure 4(a)).

In 1668, Sir Isaac Newton built the first astronomical telescope with mirrors. Known as a **reflecting telescope**, it uses a series of mirrors instead of glass lenses to collect and focus light from celestial objects (Figure 4(b)).

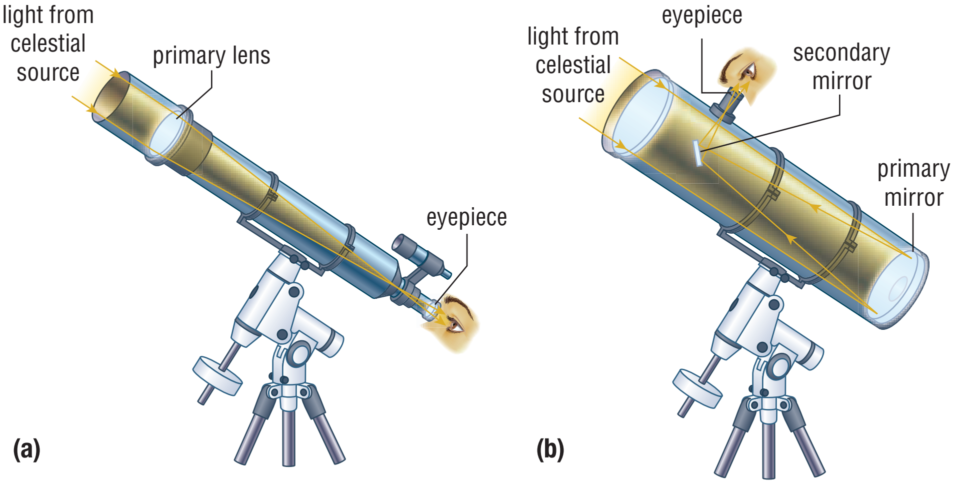


Figure 4 Stargazers still use (a) refracting and (b) reflecting telescopes to get a closer, clearer, and brighter image of stars and planets in the night sky.

Ground and Orbital Observation

Within the last century, astronomers have developed new technologies to build different types of telescopes. These new telescopes specialize in looking at various parts of the EM spectrum outside the range of visible light, such as radio waves, X-rays, and gamma rays.

RADIO TELESCOPES

Radio waves are easy to detect, are unaffected by weather, and can pass through concrete structures. Astronomers use radio telescopes to collect radio waves emitted from distant stars and galaxies. Similar to tuning a radio to different stations, astronomers can tune to different radio frequencies and "listen" to the stars and galaxies. Most radio telescopes look like a large curved satellite dish made of wire and metal (Figure 5). They collect radio waves from space and focus them on the telescope's receiver (Figure 6). The receiver amplifies the signal and transmits it to a computer for analysis.

DID YOU KNOW?

Square Kilometre Array Telescope

Canada is one of 20 countries working together to build the world's largest telescope to be completed by 2012. Called the Square Kilometre Array, this radio telescope will be 100 times larger and 10 000 times more powerful than the largest observatory today. Consisting of thousands of radio dish antennas, it will be able to "listen" to radio waves travelling from the edge of the Universe and the beginning of time.

Figure 5 The Arecibo radio telescope is the largest single radio telescope in the world. It is situated in a natural valley in Puerto Rico.

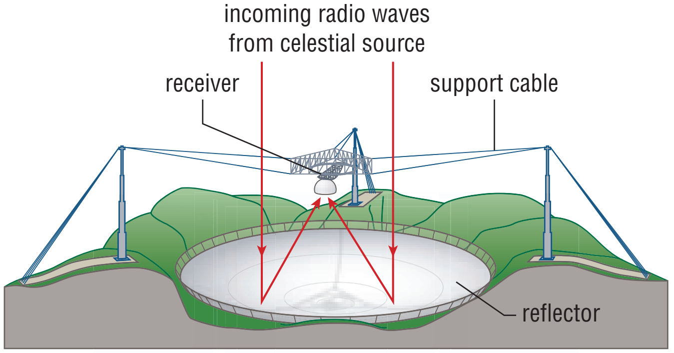


Figure 6 The receiver of the Arecibo radio telescope is suspended above the reflector.

X-RAY TELESCOPES

Some types of EM radiation emitted by distant celestial objects, such as X-rays, are not detectable from the surface of Earth because they are filtered out by our atmosphere. X-rays are emitted from remnants of massive dying stars, such as neutron stars and black holes. To intercept the X-rays, astronomers place telescopes equipped with X-ray detectors into orbit around Earth. One such telescope, the Chandra X-ray telescope, has four long, smooth mirrors made of a hard, silver-like metal called iridium. This telescope can detect extremely hot, invisible objects in space.

GAMMA RAY TELESCOPES

Gamma ray observatories, such as Europe's INTEGRAL space telescope and the United States' Swift space telescope, track intense surges of gamma ray radiation from distant regions in the Universe. Astronomers think that these mysterious bursts of gamma rays may be caused by pairs of black holes or neutron stars colliding billions of light years away.

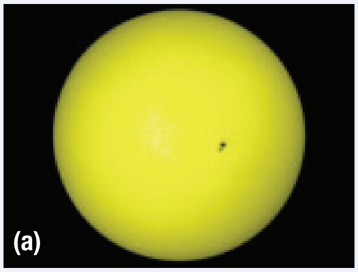
HUBBLE SPACE TELESCOPE

The Hubble Space Telescope (HST) was named after the famous astronomer Edwin Hubble. The HST orbits Earth (Figure 7), which allows astronomers to view objects at distances far greater than they could from telescopes on the ground. Hubble's spectral range extends from the ultraviolet through the visible, and into the near-infrared. The HST has a variety of telescopes and instruments on board.

DID YOU KNOW?

Looking into Space

Astronomers have learned more about celestial objects by comparing images of them using different telescopes. These images of the Sun were taken using (a) optical and (b) X-ray telescopes.


(a)

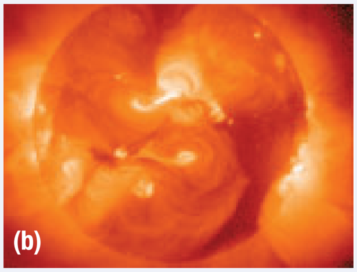

(b)

Figure 7 The HST has revolutionized astronomy by providing unprecedented deep and clear views of the Universe. Many of the images in this unit were taken by the HST.

Human Space Exploration

A **spacecraft** is a vehicle designed for travel in space. It can be operated directly by humans, or it can be a robotic vehicle that is propelled into space and operated from an Earth-based control centre. Spacecraft are made up of various parts. One part—the rocket body or launch vehicle—overcomes the force of gravity on Earth and launches the object toward its destination. On most human-occupied missions, astronauts sit in another area where they pilot the spacecraft. Another part of the spacecraft is designed to carry cargo of scientific equipment, supplies, and sometimes even other spacecraft, such as lunar or planetary landers and rovers.

spacecraft a human-occupied or robotic vehicle used to explore space or celestial objects

Until the 1980s, spacecraft were designed to be used only once. The *Apollo* missions that sent humans to the Moon used a multistage launch vehicle called *Saturn V.* These giant rockets carried the human crew, the lunar lander, and the command module toward the Moon. After the *Apollo* program ended, the United States began to develop and build a partially reusable spacecraft called a space shuttle. Although the external tank of a space shuttle is expendable, the two solid rocket boosters and the orbiter are reusable. The Space Transportation System (STS), also called the Space Shuttle program, launched with the Space Shuttle *Columbia* (STS-1) in April 1981.

To learn more about being a design engineer for spacecraft or robotics,

GO TO NELSON SCIENCE

Since Marc Garneau became the first Canadian in space in 1984, Canadian astronauts have flown on more than a dozen space shuttle missions. In 1999, the space shuttle *Discovery* lifted off with Canadian Space Agency (CSA) astronaut and mission specialist Julie Payette (Figure 8). In 2009, Payette once again went into space aboard space shuttle *Endeavour* on a mission to continue building the International Space Station (ISS). This was the 127th space shuttle mission.

Figure 8 In 2009, Julie Payette, who is an electrical and computer engineer, manoeuvred three robotic arms to help build a "porch" on the ISS.

READING TIP

Changing Your Perspective

When synthesizing a text, look for clues relating to what you already know about the topic. For example, if the text gives information about how long the space shuttles have been in operation and how many accidents there have been, you may draw on your knowledge of the dangers of space flight, such as being hit by space debris, and conclude that the space shuttle has a good track record.

Working and Living in Space

The International Space Station (ISS) is the ninth space research facility to be built in orbit (Figure 9). Since its launch in 1998, more than 16 countries have participated in its construction and scientific use. The ISS, weighing 245 735 kg, is the largest human-made object to orbit Earth. It travels at an average speed of 27 700 km/h and completes 15.7 orbits per day at an altitude of 350 km.

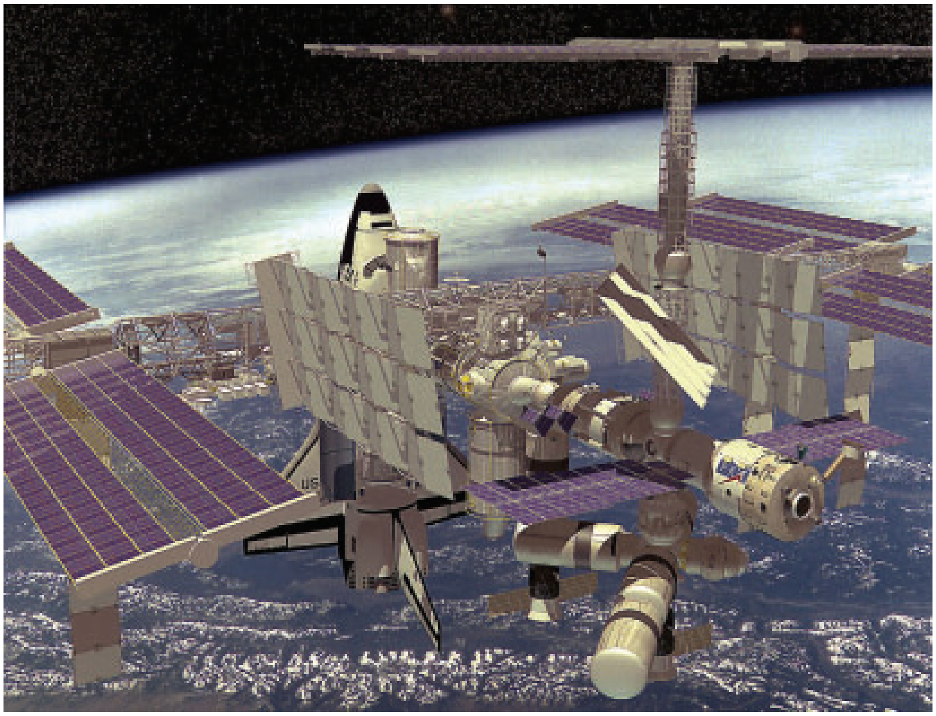


Figure 9 The ISS as it will appear in 2010 after construction is complete

Approximately 50 space shuttle missions and more than 150 space walks (when astronauts put on spacesuits and leave the spacecraft) will be needed to complete the construction of the ISS. When completed in 2010, it will be as big as a football field. The station can be seen with the unaided eye. It looks like a bright star gliding across the night sky.

Two astronauts at a time began living on the ISS in the year 2000, staying aboard the station for up to six months. In 2009, six crew members lived on board together for the first time, one of which was Canadian veteran astronaut Robert Thirsk (Figure 10). There have also been visits by six space tourists for week-long stays.

Astronauts face daily challenges when living in space. Water is a precious resource in space, and there is a limited supply available. Every drop of water—from water vapour that astronauts exhale, to urine they produce—is put through a water-purifying unit to be recycled. This process produces cleaner water than many municipal water treatment plants on Earth. To keep clean, astronauts use special kinds of soap and shampoo that do not need water to rinse.

Crews of astronauts and scientists from various countries are conducting experiments on the ISS and in space to study a variety of medical, chemical, and physical science questions. The ISS provides a unique location for conducting long-term science experiments under effective low-gravity conditions. Canadian experiments on the station include studying the physics and chemistry of how different liquids undergo mixing, which will enable the oil industry to operate more efficiently. Other experiments investigate how blood pressure and fainting can affect both space travellers and people back on Earth.

The 16 countries who contributed $100 billion to build the space station are committed to keeping the station going until 2015 and possibly extending its life to 2020 to conduct more research. This project encourages international cooperation and understanding among countries.

Figure 10 In 2009, Robert Thirsk became the first Canadian to participate in a long-duration stay as part of a six-person crew onboard the ISS.

RESEARCH THIS SEE THE SPACE STATION

SKILLS: Researching, Evaluating

SKILLS HANDBOOK 4.A., 4.B.

As the ISS increases in size with the addition of new solar panels and laboratory modules, it becomes more visible from Earth. When completed, the ISS may become the third-brightest point of light in the sky—brighter than all celestial objects except the Sun and the Moon. The ISS orbits Earth in about 1.5 hours, so it moves fairly quickly and is easily seen without a telescope. In this activity, you will research how, when, and where to observe the International Space Station.

1. Conduct research to discover the exact time of the next overhead pass of the International Space Station for your location.

GO TO NELSON SCIENCE

2. Note the azimuth and altitude of the ISS at an exact time so you know where to look. You might want to sketch the path you expect the ISS to take on a star map and use it to locate nearby constellations for reference.
3. On a clear night, look for the ISS at the appropriate time.

A. Why does the space station shine so brightly? K/U T/I

B. What is the altitude and azimuth of the ISS at the exact time you observed it? T/I

C. As you observe the space station, why does it disappear from view at the horizon? T/I

D. How long would you have to wait to see the ISS at the same spot again? T/I

Space Tools

For three decades, Canada has played an important role in developing robotic tools for use on space shuttle missions and the ISS. The Canadarm, Canadarm2, and DEXTRE are three such tools. Each of these mechanical devices is used in the construction and maintenance of the ISS. During space shuttle missions that bring up new components for the station, these robotic cranes and hands work together to pass loads to one another.

Canadarm

Since 1981, space shuttles have been equipped with the Canadarm, a 15.2 metre–long robotic arm designed and built by Canadians (Figure 11). In the harsh environment of space, this mechanical arm works with the dexterity of a human arm. Its "skin" is made of three types of material—titanium metal, stainless steel, and graphite—and an insulating blanket that protects the internal parts of the arm from the extreme hot and cold temperatures of space. Its "nerves" are copper wiring. Its "bones" are graphite fibre. Its "muscles" are electric motors, and its "brain" is a computer. Canadarm also has six joints: two "shoulders," one "elbow," and three "wrist" rotating joints that allow it to move loads in space. The robotic arm is hollow and would not be able to support its own weight on Earth, but it works very well in space. Attached to a shuttle, the Canadarm is used like a construction crane to lift parts, capture and deploy satellites, and assist astronauts moving in space.

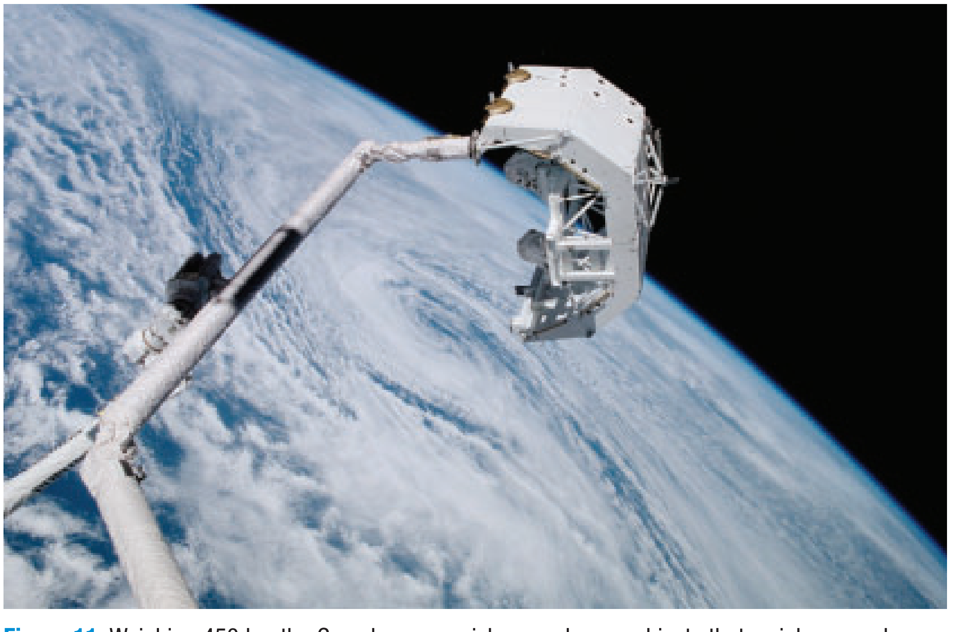


Figure 11 Weighing 450 kg, the Canadarm can pick up and move objects that weigh as much as 29 tonnes. Astronauts use computers within the space shuttle to control this robotic crane.

The first Canadian to operate the Canadarm in space was astronaut Chris Hadfield in 1995. Canadian astronaut Marc Garneau used the Canadarm to deploy and retrieve a satellite on his second space mission in 1996. Four years later, Garneau used the Canadarm to lift solar panels from the space shuttle *Endeavour* to the ISS.

LEARNING TIP

DEXTRE

DEXTRE is short for "Special Purpose Dexterous Manipulator." The word "dexterous" means "careful and skillful use of the hands," and is an appropriate nickname for the ISS's new robotic hand.

READING TIP

Making Connections

Ask yourself what you already know about a topic that relates to the information in a text. For example, you probably have some knowledge of the anatomy of a human arm. You can use this prior knowledge to help you understand the components of the Canadarm and how it works. You might draw a conclusion about how robots are designed to mimic functions that humans perform.

DID YOU KNOW?

Boom Sensor System

During its launch in 2003, the space shuttle *Columbia* suffered damage to one of its wings, causing it to burn up during re-entry. The damage had been suspected, but there was no easy way of checking. Since then, all space shuttles are outfitted with a Canadian-made orbital Boom Sensor System. A special scanner attached to its end can be used to visually check the shuttle exterior for damage. This 15-metre boom with cameras at its end attaches to the Canadarm, effectively doubling its length and giving it the necessary reach to view the wings and the underbelly of the shuttle.

Next-Generation Arm

Canadarm2—a technologically more sophisticated Canadarm—was installed on the ISS in 2001 with the assistance of CSA astronaut Chris Hadfield. It has one more joint than the Canadarm, and neither end is permanently attached to the outside of the ISS. At 18 m in length, the Canadarm2 can manipulate 115 tonnes of equipment and transfer cargo from space shuttles to the ISS. It can crawl along the ISS, capture satellites, and assemble pieces to build and maintain the ISS (Figure 12). It can also work in tandem with the original Canadarm, which is attached to every space shuttle.

To learn more about Canada's contribution to space exploration and the ISS,

GO TO NELSON SCIENCE

Figure 12 Anchored to the foot restraint on the Canadarm, Canadian astronaut Dave Williams spent 6.5 hours replacing a faulty piece of equipment on the ISS.

Canada Lends a Hand

In March 2008, Canada installed a robotic hand onto the International Space Station's Canadarm2. This special purpose dexterous manipulator, known as DEXTRE, is a two-armed robot that is used to do construction and repair work on the outside of the orbiting space station (Figure 13). It can be positioned along various worksites around the station. DEXTRE is outfitted with movable jaws at the ends of its 3.5-metre, multi-joined arms. It also has video cameras and a toolkit around its waist. DEXTRE's main function is to regularly replace 100 kg batteries on the outside walls of the space station, saving astronauts from engaging in dangerous spacewalks.

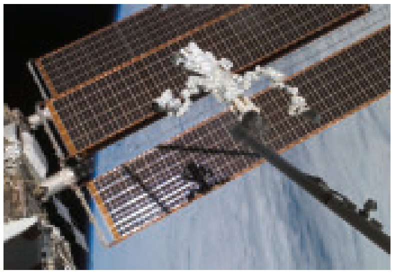


Figure 13 DEXTRE is another of Canada's robotic contributions to the ISS.

Robotic Exploration

Scientists have been able to learn a lot about the planets just by observing them with telescopes on Earth. However, **space probes** have revolutionized our understanding of the Solar System in the last 50 years. These robotic spacecraft, partially controlled by scientists and engineers on the ground, are filled with instruments designed to make close-up observations of objects in the Solar System. Since signals take so long to travel to and from the probes, many of the probes' activities are controlled by onboard computers. The first planets to be explored in this manner were the ones closest to Earth—Mars and Venus.

space probe a robotic spacecraft sent into space to explore celestial objects such as planets, moons, asteroids, and comets

In the 1960s and 1970s, the *Mariner* and the *Viking* series space probes explored Mars by orbiting the planet and landing on its surface. Since then, hundreds of probes have been sent into space to collect information on neighbouring worlds as far as the gas giant planets—Jupiter, Saturn, Uranus, and Neptune (Figure 14).

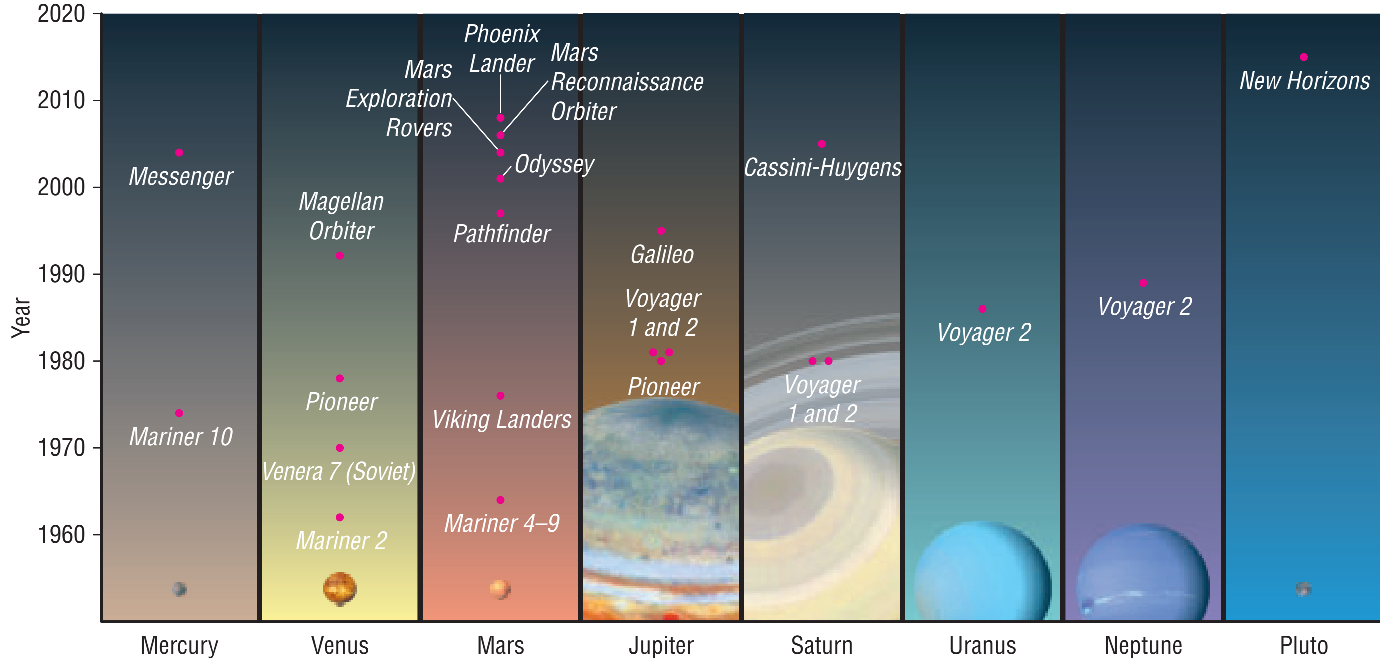


Figure 14 This timeline graph shows when some space probes explored or will explore other planets and the dwarf planet Pluto.

A robotic explorer called *New Horizons* is on its way to the dwarf planet Pluto. Because Pluto is more than 6 billion km away, *New Horizons* will not reach it until 2015. After reaching Pluto, the probe will continue on its journey toward the outer edge of the Solar System.

Mars Exploration

Space agencies in Europe, the United States, Russia, and Japan have been sending spacecraft to fly by, orbit, and land on Mars for five decades. However, not every probe has been successful. Of the 42 missions launched, 22 never sent back any data. In 1997, NASA's *Mars Pathfinder* became the first remote-controlled rover sent to another planet. The tiny robotic car successfully explored the soil and rocks in the landing area for three months.

Two of the most recent successful planetary explorers have been the twin Mars rovers, *Spirit* (Figure 15) and *Opportunity*. They were originally designed to last only three months, but more than five years later, they are still working and sending back data from the surface of the Red Planet.

Landing on opposite sides of Mars, the twin rovers have each travelled more than 8 km. *Spirit* has been exploring volcanic rocks and climbing hills, whereas *Opportunity* has descended into craters and travelled across deserts. Both have found evidence in Martian rocks that more than a billion years ago, the planet was covered by a vast body of salty water.

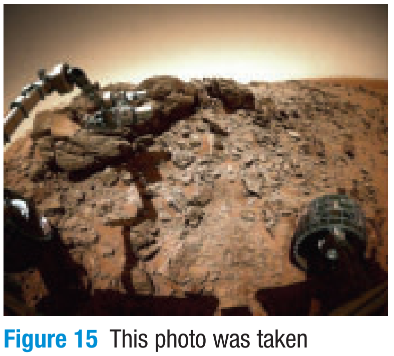


Figure 15 This photo was taken through the "eyes" of the *Spirit* rover. *Spirit's* robotic arm has a small drill and microscope used to inspect Martian rock.

Both rovers recharge their batteries through their solar panels. Over the years, dust storms have covered parts of their solar panels with dust, reducing the amount of power available to the rovers. However, scientists have been surprised to find that small Martian tornadoes, or dust devils, occasionally blow some of the dust off the panels (Figure 16).

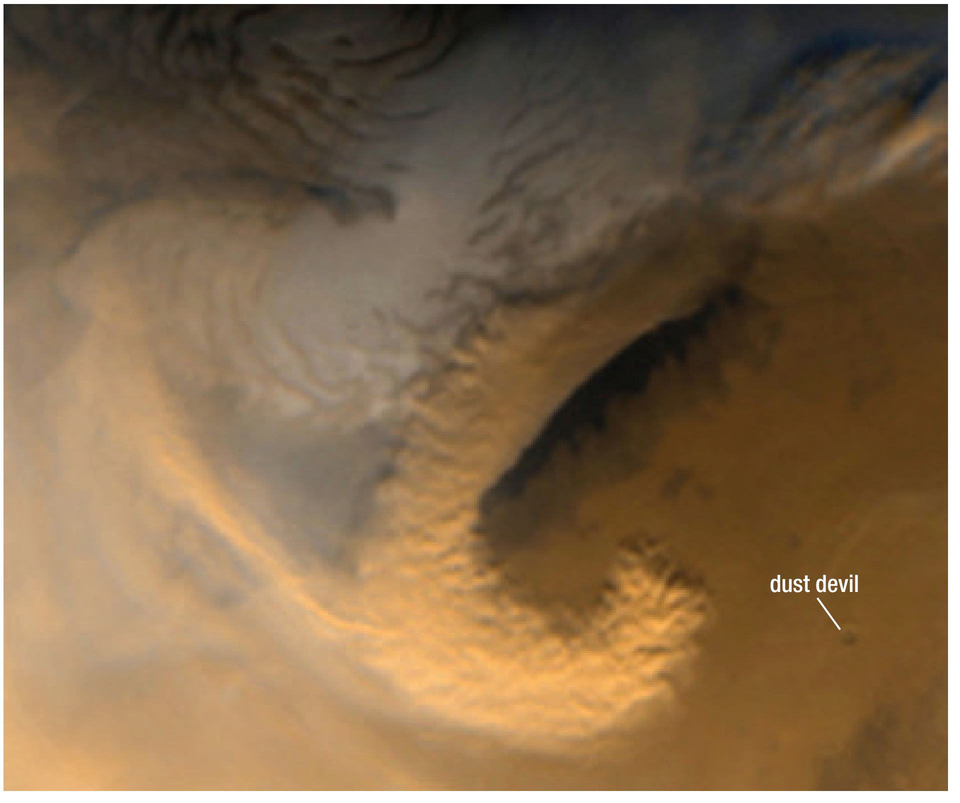


Figure 16 This photo of Mars shows a swirling pink storm at its north pole and dozens of dust devils farther south.

The latest robotic explorer of Mars was the NASA *Phoenix Mars Lander* probe that blasted into space in August 2007. It successfully landed in the Martian Arctic 10 months later, in May 2008. When the probe used its robotic arm equipped with a scoop to examine the soil, it discovered the first visual evidence of water-ice on Mars (Figure 17). This was a significant discovery: the presence of water on Mars suggests that the planet's conditions are (or were) favourable to life. A Canadian-designed meteorological station on board monitored Mars' weather on a daily basis. For the first time in the history of planetary exploration, we had daily weather reports on temperature, cloud cover, humidity, and wind speed on another planet.

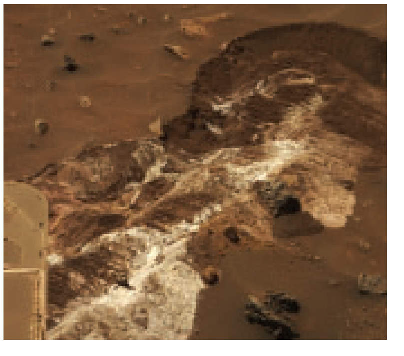


Figure 17 The *Phoenix* lander dug a series of trenches with its robotic arm in the Martian northern Arctic region and discovered a layer of water-ice just a few centimetres below the surface.

Saturn Exploration

Astronomers, engineers, and other scientists from around the world continue to share their expertise and resources to form cooperative space missions. For example, 17 nations collaborated to engineer the space probe *Cassini–Huygens* to explore the distant ringed planet Saturn and its moons. Although the radio signals from this probe travel through space at the speed of light, they still take 68 to 84 minutes to reach Earth, depending on our exact distance.

Figure 18 This side-by-side image shows a Cassini radar image (on the left) of what is the largest body of liquid ever found on Titan's north pole, compared to Lake Superior (on the right). This image offers strong evidence for seas (most likely liquid methane and ethane) on Titan.

Just before *Cassini* went into orbit around Saturn in 2004, it released a probe, *Huygens*, to explore Saturn's moon, Titan. Titan's surface has remained a mystery for decades because it is surrounded by a thick, smog-like atmosphere. The largest moon orbiting Saturn and the second largest in the Solar System, Titan is the only moon with an atmosphere.

The *Huygens* probe snapped photos of dark, river-like channels and bright hills as it floated down to Titan's surface using a parachute system (Figure 18). With batteries lasting only 90 minutes, the *Huygens* probe transmitted pictures of a dark plain with scattered, light-coloured water-ice pebbles.

The main *Cassini* spacecraft continues to orbit Saturn, using its cameras and radar system to study Titan and neighbouring moons. It has discovered that Titan may have lakes of liquid methane, whereas the tiny moon Enceladeus is covered by water-ice and has ice geysers with plumes projecting 400 km into space.

UNIT TASK Bookmark

You can apply what you have learned about telescopes, Canadian contributions, and the challenges and dangers of space travel as you work on the Unit Task described on page 446.

IN SUMMARY

- Telescopes that detect various types of radiation are key tools for astronomers to research celestial objects.
- Robotic spacecraft have been sent throughout the Solar System to explore different objects.
- There have been several successful human space flight missions, including the Apollo and Space Shuttle missions, and expeditions to the ISS.
- Canada has contributed to space exploration with projects such as the Canadarm.
- Saturn and Mars are two planets in the Solar System that are currently being explored by spacecraft.

CHECK YOUR LEARNING

1. Compare the design of refracting telescopes and reflecting telescopes. K/U T/I
2. Name two kinds of EM radiation other than visible light that are used to observe distant objects in the Universe. K/U
3. Why do X-ray telescopes need to orbit Earth beyond the atmosphere to make observations? Name an example of an X-ray telescope. K/U
4. Name three telescopes that are currently collecting data in orbit around Earth. K/U
5. In a paragraph, describe the contributions of one of the Canadian astronauts who has flown in space with the Space Shuttle program. A C
6. Compare and contrast the *Saturn V* rocket with a space shuttle. K/U T/I
7. How many countries participated in the construction of the ISS? K/U
8. Describe how the Canadarm works. In which ways is the Canadarm like a human arm? K/U
9. Describe two experiments currently being performed on the ISS. K/U
10. Describe three ways that Canadians have contributed to space exploration. A
11. What are two planets that humans have explored with space probes? What do scientists hope to learn from these missions? K/U