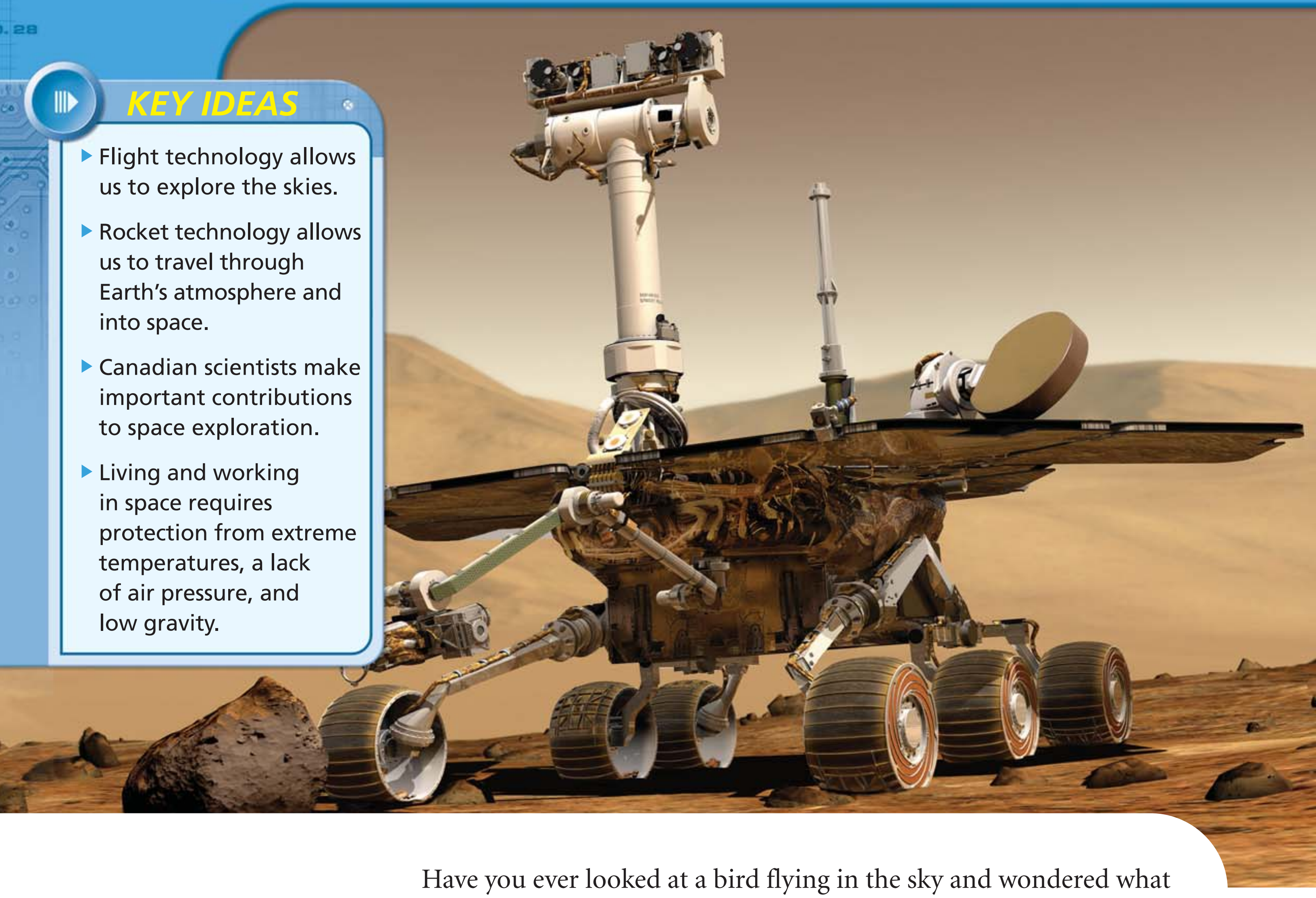
CHAPTER 11

Technology allows us to explore the extreme environment of space.



KEY IDEAS

- Flight technology allows us to explore the skies.
- Rocket technology allows us to travel through Earth's atmosphere and into space.
- Canadian scientists make important contributions to space exploration.
- Living and working in space requires protection from extreme temperatures, a lack of air pressure, and low gravity.

Have you ever looked at a bird flying in the sky and wondered what it would feel like to fly? People have always been fascinated with flying and with exploring the vast space beyond Earth. But it is only in the last 100 years that these dreams have become possible. Today, technology allows us to travel in and explore the skies. We have even been able to use technology to explore other planets, such as Mars, using robotic rovers like the one shown above.

In this chapter, you will learn about the technology of flight and space exploration. You will also discover the important role that Canadian scientists play in exploring space.

Up, Up in the Air 11.1

Since ancient times, humans have dreamed of soaring like birds. Hot-air balloons (**Figure 1**), hydrogen balloons, and gliders got people off the ground. Flight depended on the weather, however, and the pilot could not control where the balloon or glider went.

Everything changed in 1903, when Orville and Wilbur Wright achieved the first controlled flight with the *Flyer* (**Figure 2**). A small gasoline motor, attached to the *Flyer's* propellers, moved the plane forward. The Wrights made a total of four flights in the *Flyer*. The longest flight lasted 59 s and covered 260 m. After the final flight, the *Flyer* was overturned by a gust of wind and destroyed.

Figure 1
In 1793, the Montgolfier brothers made a huge paper balloon and filled it with hot air. Since hot air is lighter than cool air, the balloon rose into the sky.

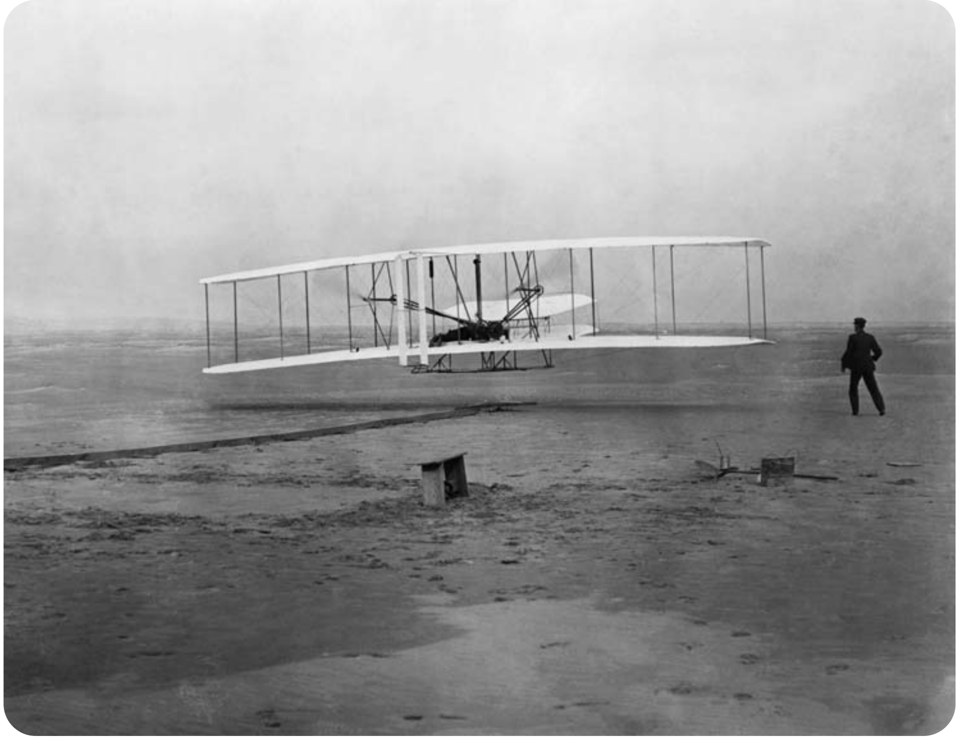


Figure 2
The *Flyer* takes off with Orville Wright at the controls while Wilbur looks on.

After the Wright brothers made their historic flight, different airplane designs made air travel safer and faster. Today, airplanes are made of lightweight metals. They have a streamlined shape and retractable landing gear to reduce air resistance. Millions of people travel the world in high-speed jets. Hot-air balloons and gliders are now used only for recreation.

TRY THIS: HOW DO THE CANS MOVE?

Skills Focus: observing, inferring

Place six straws parallel to each other on a table as shown in **Figure 3**. Space the straws about 2 cm apart. Place two empty aluminum cans on top of the straws. The cans should be about 4 to 6 cm apart. Kneel down so that you are 20 cm from the cans and at eye level with the centre of the cans. Predict what will happen if you blow air in the space between the two cans, using another straw.

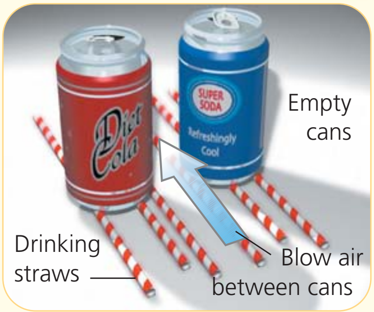


Figure 3

Do not share straws. Each student should use her or his own straw.

1. What happened to the cans? How did they move?
2. Is this what you predicted would happen? Why or why not?
3. Explain why the cans moved the way they did.

Wing Shape and Flight

How does the shape of an airplane's wings help the airplane fly? Imagine that the curve of the aluminum can in the Try This activity is the shape of the top of a wing. Air rushes over the top curve of the wing faster than it moves over the flat bottom surface of the wing. This creates low pressure over the wing, compared with the high pressure under the wing. The high pressure under the wing pushes the wing up and forces the plane upward (**Figure 4**). This is called **lift.** Lift allows people to explore Earth's atmosphere. However, more than lift is needed to get beyond Earth's atmosphere.

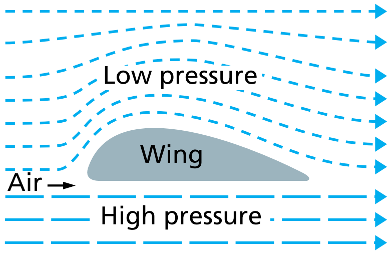


Figure 4
The movement of air over the wings of an airplane produces lift.

LEARNING TIP

After reading "Wing Shape and Flight" on this page, describe to a classmate how wing shape helps an airplane fly. If you have trouble, reread the paragraph and look carefully at **Figure 4** to see how lift is produced.

CHECK YOUR UNDERSTANDING

1. "The Wright brothers' invention of the airplane changed the world." Do you agree or disagree with this statement. Explain.
2. What do you think is happening to the air pressure between the two aluminum cans when you blow air between them?
3. Why are airplane wings curved?
4. What is lift?

Solve a Problem 11.2

Designing a Super Flyer

Scientists and inventors are problem solvers. The Wright brothers were very good problem solvers. To figure out how to fly, they studied flight, built and rebuilt models, or prototypes, of flying machines, tested and retested their ideas, and redesigned their aircraft. The Wright brothers based their 1903 *Flyer* on their 1902 glider (**Figure 1**).

LEARNING TIP

Prototypes are often full-scale working models that help inventors discover what improvements their designs need.

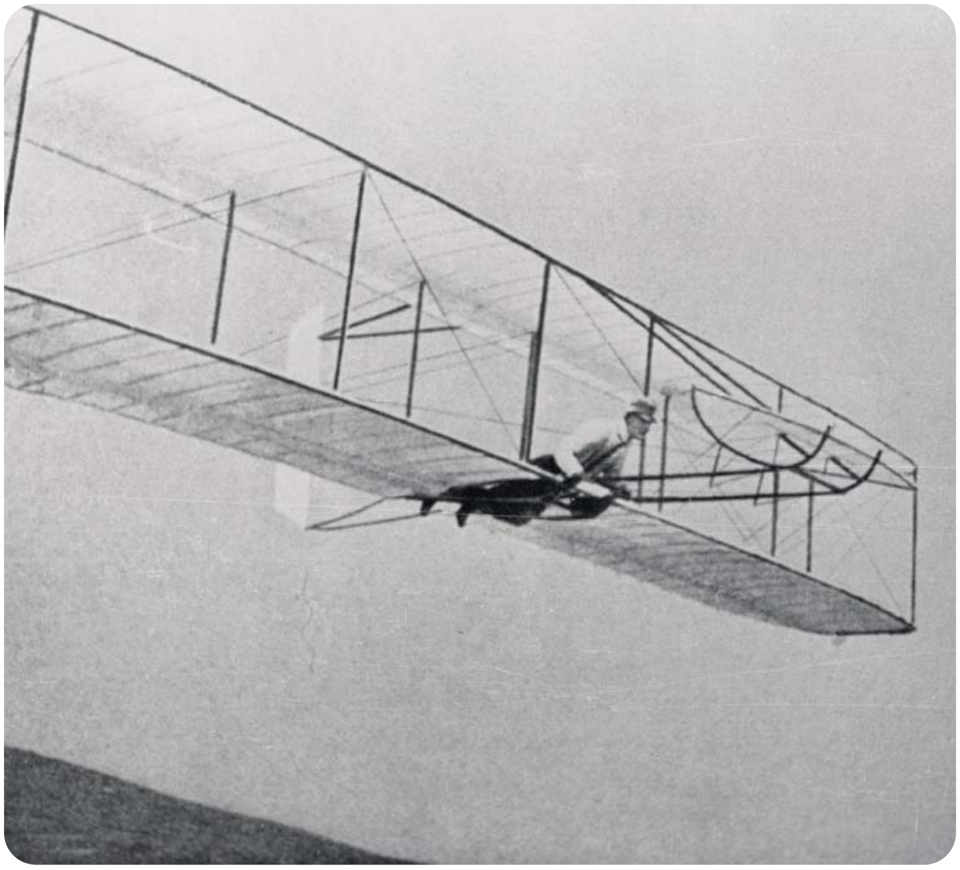


Figure 1
The Wright 1902 glider was the first controllable aircraft that flew.

In this investigation, you will design, build, test, and redesign a Super Flyer paper airplane.

LEARNING TIP

For a review about solving a problem, see the Skills Handbook section "Solving a Problem."

Problem

How can observations from nature help you design a better paper airplane?

Task

Think about how different animals fly through the air. Then think about how different things in nature, such as seeds, move through the air. How are these things designed to fly? Compare the examples in **Figure 2** with the airplanes in **Figure 3**. How can you use your observations of flight in nature to design an improved paper airplane?

Figure 2
Types of flight in nature

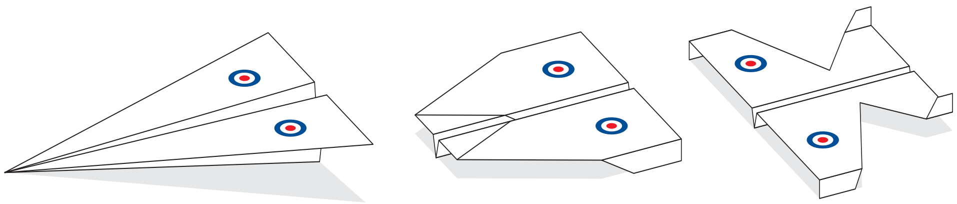


Figure 3
Different designs of paper airplanes

Criteria

To be successful, your final model must

- fly straight for 2 m
- fly at a height of at least 2 m
- be made using the materials you decide upon as a class (e.g., paper, glue, and thin wood)
- incorporate changes based on observations you made when testing and retesting your designs

Plan and Test

1. Work with a partner and design a paper airplane, based on one of the paper airplanes in **Figure 3** or your own ideas. Draw your design.
2. Explain how your airplane will fly. Also explain why you chose to design your airplane the way you did.
3. Prepare a set of instructions for how to build your paper airplane. Use your instructions to build it.
4. Decide how you will test the performance of your paper airplane. For example, consider the following questions:
   - How many times will your repeat your flight tests?
   - What do you plan to observe?
   - What do you plan to measure?
5. Design a table to record your measurements and other observations.
6. Test your paper airplane.

Evaluate

7. How did your airplane do? Based on its performance, design a new airplane that you think will fly farther and straighter. What parts of your design have changed? Why did you change these parts? Modify your diagram and your instructions.
8. Your airplane will participate in a class Paper Airplane Challenge to determine which airplane flies the highest, which airplane flies the farthest, and which airplane flies the straightest.
9. How is your model like a real airplane? How is it different?

Communicate

10. Prepare a labelled diagram, describing how to create your final paper airplane. Include instructions for building your airplane. Give your airplane a catchy name.

CHECK YOUR UNDERSTANDING

1. What is a prototype? Why is it used?
2. What did you learn in your flight tests that helped you design your final airplane?
3. Why was it important to repeat your tests?

11.3 Rocketing into Space with Technology

The invention and development of the airplane meant that people could explore the skies. Travelling beyond Earth's atmosphere, however, was still not possible. Space is a near vacuum, which means that it contains few oxygen or nitrogen molecules. Since airplane engines need oxygen in the air to burn fuel, airplanes could not be used to explore space.

To explore space, a vehicle that could travel in a vacuum was needed. The vehicle also had to carry its own fuel and source of oxygen. As well, it had to be able to travel fast enough to escape Earth's force of gravity, which pulls things down. The development of rockets, like the one shown in **Figure 1**, and other spacecraft made space exploration possible.

Figure 1
In 1926, Dr. Robert Goddard launched the world's first liquid-fuelled rocket from his backyard.

Before sending people into space, scientists sent unpiloted spacecraft, or probes, into space to gather information and to see what dangers lay ahead. The Russians developed the R-7 rocket to launch the first satellite, *Sputnik I*, into space in 1957. One month later, they launched the first space traveller, a dog named Laika. Then, in 1961, they launched the first human space traveller, Yuri Gagarin. Space technology continued to improve and, in 1969, two American astronauts, Neil Armstrong and Edwin "Buzz" Aldrin, became the first humans to land on the Moon.

Eventually, engineers invented a reusable spacecraft—the space shuttle shown in **Figure 2**. The space shuttle is designed to go into space and then re-enter Earth's atmosphere and land safely. The shuttle commander has only one chance to land successfully. There is only enough fuel to get home and not enough to try the landing again. When the space shuttle touches down, a parachute opens to create drag, or resistance, which helps it stop.

Figure 2
The shuttle is a piloted spacecraft that is launched into space using a rocket.

Payloads and Rockets

Anything that is launched into space, such as a satellite or space shuttle, is called a payload. A launcher carries the payload into space. The main part of the launcher is a rocket.

TRY THIS: BLAST OFF!

Skills Focus: creating models, observing, inferring

Blow up a long and skinny balloon, and hold the end closed. Tape a straw along one side of the balloon in a straight line. Feed a piece of fishing line through the straw. Get two assistants to stretch the line across the room and hold the ends tight. Launch the rocket balloon by letting go of the balloon (**Figure 3**).

1. What happens to the balloon? Why does this happen?
2. Compare the rocket balloon with a rocket powered by chemical explosions.

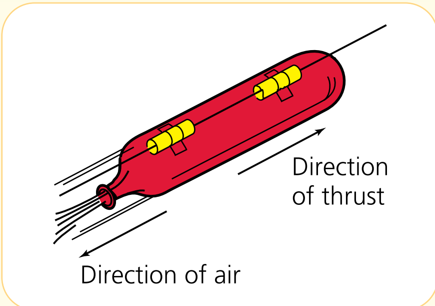


Figure 3

A rocket has an opening at one end, like the balloon in the Try This activity. The force of the air escaping from the open end of the balloon moved the balloon forward. In a rocket, the engine mixes fuel with oxygen and produces exhaust gases. The quick release of these gases downward creates an upward force, or **thrust,** on the rocket (Figure 4).

Figure 4
The force of the exhaust gases shooting out in one direction causes the thrust of the rocket in the other direction, launching the payload into space.

LEARNING TIP

As you read, ask yourself questions to check your understanding: What did I just read? What did it mean? Try to put the information in your own words.

Satellites in Space

Did you know that when you make an overseas phone call, use a cell phone, check the weather forecast, watch TV, or use the Internet, you are using a satellite?

A satellite is an object in space that travels in an orbit around another object. The Moon is a natural satellite of Earth. Human-made satellites are artificial satellites.

Satellites do more than just travel around Earth. Communication satellites receive and transmit television program signals and telephone signals so that you can see and hear about events as they happen, anywhere in the world. For many years, Canada has been an international leader in satellite communication. When the Telesat satellite Anik A1 was launched in 1972, Canada became the first country with its own commercial, domestic communication satellite in orbit. In July 2004, Telesat launched the world's largest commercial communication satellite, Anik F2 (**Figure 5**).

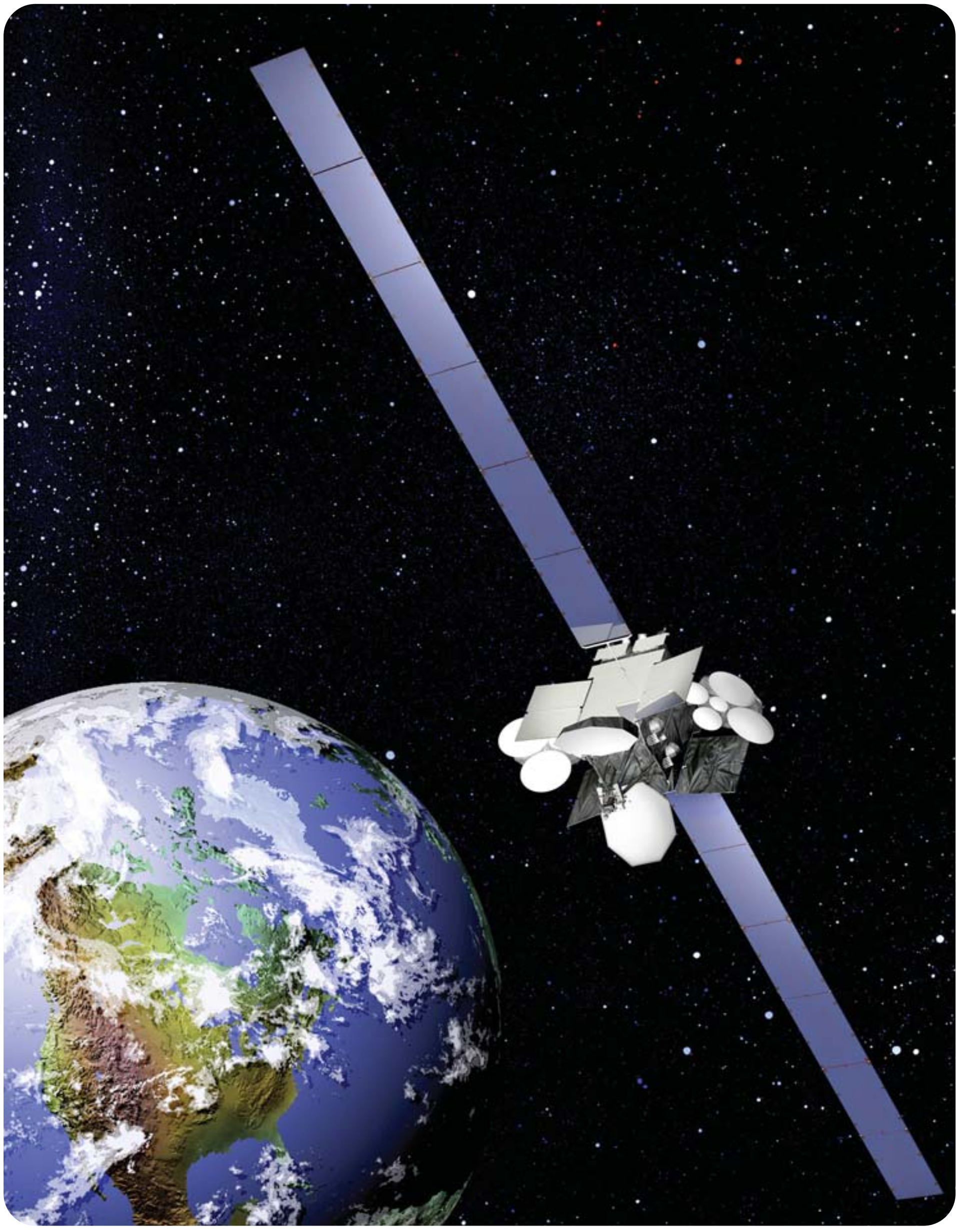


Figure 5
Anik F2 was launched in July 2004. Canada's Telesat communication satellites have all been named Anik, which in the Inuit language means "little brother."

Figure 6
RADARSAT orbits Earth at an altitude of 796 km. It circles Earth 14 times a day. Each orbit takes just over 100 min to complete.

There are many other types of satellites, including navigation, weather, and space research satellites. Some countries even have spy satellites that are used to keep an eye on other countries. Satellites are also used to take pictures of Earth. For example, RADARSAT is a satellite that the Canadian Space Agency developed and operates. RADARSAT provides images of Earth so that scientists can monitor flood damage, soil humidity, forests, and crop conditions, and locate oil spills on the oceans. Images are also used to find surface features that are associated with resources such as oil, water, and minerals. **Figure 6** shows an image of a flooded area of Manitoba, taken using RADARSAT.

Canadian Robots in Space

Canada has made important contributions to space exploration. The Shuttle Remote Manipulator System, commonly known as the **Canadarm,** is a robotic manipulator arm. It was developed by scientists at the Canadian Space Agency and first used on a space shuttle in 1981 (**Figure 7**). An astronaut from inside the space shuttle controls the arm. Over the years, the Canadarm has been changed to adapt to new technology. The Canadarm has been used to send satellites into their proper orbit and retrieve broken satellites for repair, to support space walks by space construction workers, and even to knock ice off the shuttle's wastewater vents.

Figure 7
The Canadarm is 15 m long.

One important job of the Canadarm was the 1993 repair of the Hubble Space Telescope (**Figure 8**). After the Hubble Space Telescope was launched, scientists realized that the photos it took were fuzzy. Using the Canadarm, Hubble was repaired and placed back in orbit to observe the universe.

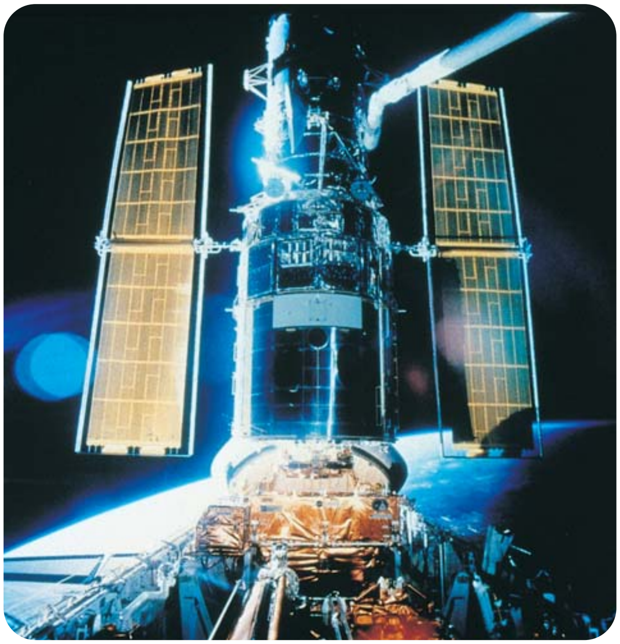


Figure 8
The Hubble Space Telescope takes computerized pictures of space and sends them to astronomers on Earth.

The Canadarm was also used to install the second robotic arm, the Canadarm 2, on the International Space Station in 2001. While helping to install the new robotic arm, Canadian astronaut Chris Hadfield became the first Canadian to walk in space. Hadfield also manipulated the Canadarm from inside the space shuttle to take a piece of equipment from the Canadarm 2 into the space station—a handshake between two Canadian robotic arms!

CHECK YOUR UNDERSTANDING

1. How is thrust created during a rocket launch?
2. Compare an artificial satellite with the Moon. How are they the same? How are they different?
3. What is RADARSAT? What is it used for?
4. Canada has made an important contribution to space exploration through the development of satellites. List two or more things that satellites do for us.
5. What important contribution have Canadian scientists made in robotic space technology? What is this technology used for?

Robots can explore where people can't!

NOMAD, THE DESERT EXPLORER

Deserts can be hot, difficult areas to explore, but not for Nomad! Nomad is a four-wheel-drive roving robot, created by scientists at National Aeronautics and Space Administration (NASA). During the 45 days it spent exploring the rugged Atacama Desert in Chile, Nomad travelled 214 km over rough territory—19 km totally on its own. Nomad even picked up an undiscovered rock from the Jurassic Period.

DANTE II, THE VOLCANO EXPLORER

Dante II is a robot that was built by NASA to explore Mount Spurr, an active volcano in Alaska. Dante II was actually the second robot built to explore volcanoes. The first robot, Dante I, was sent into Mount Erebus in Antarctica. It had only covered a few metres before its cable broke and it fell into the inferno below. Unfortunately, Dante II was also damaged as it explored Mount Spurr. Dante II now tours the United States promoting robotic research.

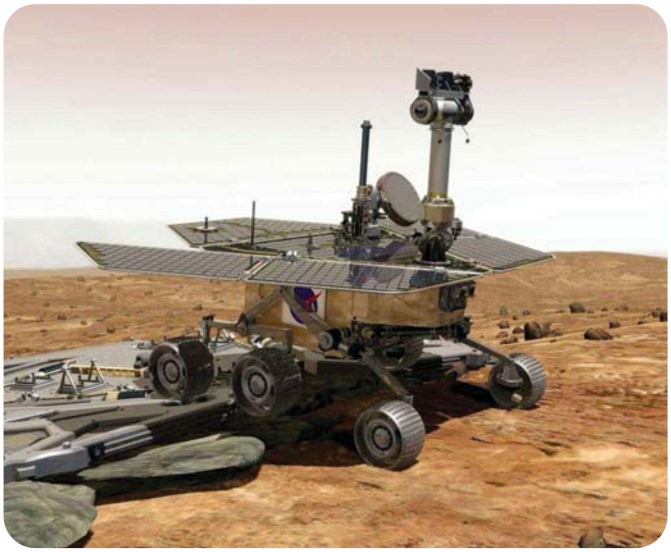
ROPOS AND THE UNDERWATER VOLCANOES

Have you ever wondered what an underwater volcano looks like? ROPOS, which stands for **R**emotely **O**perated **P**latform for **O**cean **S**cience, is a robotic submersible that was developed in Canada. It is used to study submarine volcano systems. It is also used to collect samples and take scientific readings.

ROPOS is placed inside a cage and lowered 5000 m. It is attached to a tether cable and is moved out of the cage to complete the dive. ROPOS uses different tools, such as giant steel jaws, cutters, hooks, and drills, to break off samples from the ocean floor. It uses suction samplers, strainers, and scoops to collect the samples. It has cameras and video and computer recorders to log its underwater explorations. Four people work from the surface ship to direct ROPOS. A scientist directs the dive, a pilot operates the machine, a sample collector operates the tools for collecting the samples, and an event recorder keeps a log of what ROPOS does.

SPIRIT AND OPPORTUNITY ON MARS

In January 2004, two robot geologists—Spirit and Opportunity—landed on the surface of Mars and began to explore their surroundings. Guided from Earth by a team of engineers (in charge of navigating the area) and a team of scientists (in charge of learning about the Martian environment), the rovers travelled across Mars. Spirit took microscopic pictures of an intriguing rock known as Pot-of-Gold. Opportunity moved down into a crater known as Endurance Crater, making observations and using a rock abrasion tool to dig into rocks. Scientists used the computer systems on the two rovers and the computer systems in the laboratory on Earth to analyze soil and rock samples for signs of past life and water on Mars.



11.4 Conduct an Investigation

SKILLS MENU

○ Questioning	● Observing
○ Predicting	● Measuring
○ Hypothesizing	○ Classifying
○ Designing Experiments	● Inferring
● Controlling Variables	● Interpreting Data
○ Creating Models	● Communicating

Rocket Blasters

Young scientists, here is your chance to discover how to achieve the greatest thrust for a canister rocket. You will work as part of a three-member team. Your teacher will assign your team one of the Questions to investigate.

To make sure that your tests are fair and accurate, pay close attention to the procedure and change only one variable at a time. Do at least three trials, and conduct your tests the same way in each trial. Using the results for each variable, you will collaborate with your team to design a new procedure to create a rocket blaster!

Questions

a) Can I create the greatest thrust with my canister rocket using cold water or warm water?

b) Can I create the greatest thrust with my canister rocket using half of an antacid tablet or a whole tablet?

Materials

- apron
- safety goggles
- 2 film canisters, with lids that fit inside the rims
- paper
- tape
- 6 antacid tablets
- beaker of cold water and beaker of warm water (for Question (a))
- beaker of water at room temperature (for Question (b))
- shoebox lid
- tape measure
- stopwatch

Conduct this experiment outside or in a large indoor space. Wear goggles, and make sure that the canister is placed upside down (inverted) during the tests. Everyone should stand well back from the canisters because the rockets can travel up to 7 m.

apron

goggles

film canisters and lids

paper

antacid tablets

tape

beakers of cold and warm water

beaker of water at room temperature

shoebox lid

tape measure

stopwatch

Procedure

1 Make a paper rocket (**Figure 1**). Wrap a piece of paper around the film canister and tape it in place. The lid of the canister should face down. Remember to leave room at the bottom of the canister so you can put the lid back on. Cut a piece of paper into a cone and tape it to the top of the rocket. Draw and cut out four fins for your rocket, and tape them in place.

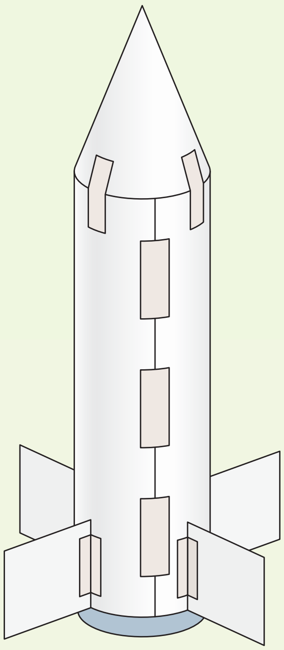


Figure 1

2 Put on your apron and safety goggles. Get six antacid tablets from your teacher. If you are investigating Question (a), you will need a beaker of warm water and a beaker of cold water. If you are investigating Question (b), you will need a beaker of water at room temperature. You will also need to break two antacid tablets in half.

3 Build a launch pad using the shoebox lid. Prop up the lid on an angle. The canister rockets will blast sideways instead of straight up when launched at this angle.

Question (a)

4 Make a table like the one below.

Observations for Question (a)

	Time to blast off (s)			Distance travelled (cm)		
Water	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
hot						
cold						

5 Fill one canister one-third full of warm water. Drop in one tablet, and quickly put the lid on the canister. Place your rocket on the launch pad as shown in **Figure 2**, and stand back. Measure the time the rocket takes to blast off. Record this time in your table. After the rocket lands, measure the distance it travelled. Record your measurements in your table.

Figure 2

6 Repeat step 5, but this time use cold water. Record your measurements in your table.

7 Repeat steps 5 and 6 two more times, for a total of three trials.

Question (b)

8 Make a table like the one below.

Observations for Question (b)

Amount of tablet	Time to blast off (s)			Distance travelled (cm)		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
one tablet						
half of a tablet						

9 Fill both canisters one-third full of water. Put one tablet in one of the canisters. Quickly put the lid on the canister. Place your rocket on the launch pad, and stand back. Measure the time the rocket takes to blast off. After your rocket has launched, measure the distance your rocket travelled. Record your measurements in your table.

10 Repeat step 9 using half a tablet. Record your measurements in your table.

11 Repeat steps 9 and 10 two more times, for a total of three trials.

LEARNING TIP

For help preparing your graph, read "Graphing Data" in the Skills Handbook.

Analyze and Evaluate

1. Find the average time and distance for the three tests.
2. Create a graph to illustrate the results of your test.
3. What conditions created the greatest thrust for your canister rocket?

Apply and Extend

4. As a whole class, discuss the results for Questions (a) and (b). Which conditions do you think will produce the greatest thrust for the canister rockets?
5. What did you do in your investigation to ensure that your results were as accurate as possible?
6. Can you think of other ways to measure the range of your rocket? Are there other variables that you would like to test?

CHECK YOUR UNDERSTANDING

1. Why is it important to follow the procedure the same way in each trial? Why is it important to repeat a test?
2. What variable did you change in your investigation?
3. What made your test a fair test?

The International Space Station

11.5

Space stations are important for space exploration. Before humans can live on places like the Moon or Mars, scientists need to understand how space affects the human body. Scientists research the effects of space in space stations that orbit Earth. The International Space Station, or ISS, is the biggest technological project in space (**Figure 1**). The ISS is so important that space agencies from 16 countries around the world are involved in the project. When it is finished, it will be over 100 m long and will orbit about 320 km above Earth.

Figure 1
The International Space Station (ISS) orbits high above Earth.

The ISS is a laboratory in space. Science experiments on the ISS can last for months. The ISS has a microgravity environment, in which the effects of gravity are very small. Everything appears to be almost weightless. Scientists on the ISS are studying the effects of microgravity on animals and plants.

Scientists on the ISS are also studying the effects of space on human bones. As well, they are studying Earth's climate, learning about the solar system, and developing new technologies that may be used for further space exploration. Canadian scientists are conducting experiments that may lead to the development of new medicines and ways to keep astronauts healthy when they are living and working in space.

Once the ISS is complete, scientists hope that it can also be used as a refuelling station for longer missions. If you look up at night, you may see the ISS passing overhead.

CHECK YOUR UNDERSTANDING

1. Describe some uses of the ISS.
2. Why is it important to research the effects of space on humans and on the growth of plants?

11.6 Living and Working in Space

LEARNING TIP

Set a purpose for your reading of this section. First, read the headings and look at the illustrations in the section. Then make a list of questions that you have about how astronauts live and work in space.

In the International Space Station, the phrase "floating off to sleep" has a totally different meaning. Since the ISS has so little gravity, astronauts must attach their sleeping bags to a wall or seat to prevent them from floating around the cabin as they sleep (**Figure 1**). What other things do you think would be difficult to do in space?

Figure 1
An astronaut zips up for a cozy sleep in space.

Living and working in space is very difficult for astronauts. There are many challenges, such as lack of air in space, extremely low temperatures, and low gravity. Even growing food and getting water are difficult in space.

Breathing in Space

There is no air in space. On the ISS, however, astronauts can breathe easily. This is because of the **life-support systems** on the ISS. The life-support systems provide oxygen for the astronauts to breathe and absorb the carbon dioxide that the astronauts exhale.

Wearing Space Suits for Protection

Space suits are like mini spacecraft, designed to protect astronauts from exposure to space. For example, the normal human body temperature is about 37 °C. When you are hot, your body sweats to cool off. When you are cold, your body warms up by shivering. The temperature of an object in space can drop to −157 °C in the darkness and soar to 121 °C in the sunlight. Astronauts need to wear space suits to protect themselves from these extreme temperatures.

On board the ISS, astronauts wear a T-shirt and shorts as they work and exercise. During a launch or re-entry, however, they wear a partially pressurized suit called a Launch and Entry Space Suit, or LES. An LES can provide enough air pressure to return to Earth during an emergency landing, when cabin pressure in the space shuttle may decrease (**Figure 2**).

Figure 2

The Launch and Entry Space Suit (LES) has batteries for power and radio devices for communication. The LES is also insulated and has an emergency oxygen system, a parachute harness and parachute pack, 2 L of drinking water, and floatation devices.

Figure 3
An astronaut wearing an EMU carries the life-support system in a backpack.

To work in space, an astronaut wears an Extravehicular Mobility Unit, or EMU (**Figure 3**). An EMU has many layers to protect the astronaut from the vacuum of space, extreme temperatures, and the Sun's harmful radiation. A gold visor on the helmet protects the astronaut's eyes from the blinding sunlight. Oxygen tanks provide oxygen for about seven or eight hours. Gloves have heaters to prevent the astronaut's hands from freezing when the astronaut is working in space at night in the cold temperatures. The EMU also contains a small thermostat that can be adjusted if the astronaut becomes too warm while working in space during the day. Tubes coil through special underwear to keep the astronaut at a comfortable temperature. Not surprisingly, the EMU is very heavy. It is made with ball bearings at the joints, which allow the astronaut to bend and twist.

The Manned Maneuvering Unit, or MMU, is a nitrogen-propelled backpack that latches to the EMU and allows the astronaut to move when outside of the spacecraft. An astronaut wearing an MMU can move forward, backward, turn, and even do flips in space.

Falling in Space

If you drop an apple on Earth, it falls to the ground. What happens if an astronaut on the ISS drops an apple? Even though the apple may look like it is floating, just like Chris Hadfield appears to be floating in **Figure 4**, it is actually falling. In fact, the apple, the astronaut, and the ISS are all falling together around Earth. Since they are all falling at the same rate, the apple and the astronaut appear to be weightless inside the ISS. The microgravity condition in the ISS makes them appear to float.

Figure 4
It looks like Canadian astronaut Chris Hadfield is floating. He is actually falling.

TRY THIS: MODEL WEIGHTLESSNESS

Skills Focus: creating models, observing, inferring

The reason that objects feel weightless in space is because they are falling toward Earth's surface. You can make a model to show weightlessness (**Figure 5**). Start by cutting a rubber band. Put one end so that it hangs down into a plastic bottle, while the other end lies across the mouth of the bottle. Screw on the lid to keep the rubber band in place. Note your observations about the rubber band. Unscrew the lid, and put some modelling clay on one end of the rubber band. Put the end with the modelling clay in the bottle. The other end should drape across the mouth of the bottle. Screw the lid on the bottle. Notice the effect of the modelling clay on the rubber band. Hold the bottle about 1 m in the air, and drop it.

1. What do you observe?
2. How do your observations relate to what happens on the ISS?

Figure 5

Because of microgravity, there is a lack of force against the muscles in an astronaut's body. When astronauts are living on the ISS, their muscles become smaller and their bones lose calcium and become weak. The spine and other joints spread apart. This causes the astronauts to stretch up to 5 cm taller. To combat the effects of microgravity on their bodies, astronauts exercise daily on special exercise machines (**Figure 6**). They even race from one end of the ISS to the other to keep in shape!

Figure 6
This astronaut is exercising while on the space shuttle.

Food, Water, and Waste in Space

Survival in space depends on having enough food and water, and on finding ways to dispose of waste. Astronauts get three meals a day. The food must be nutritious and easy to eat in a floating environment (**Figure 7**). The astronauts have more than 100 foods to choose from, including fruits, nuts, peanut butter, chicken, beef, seafood, and candy. Drinks include coffee, tea, orange juice, fruit punch, and lemonade. Drinking straws have clamps that stop the liquid from coming out after the astronaut stops sucking. Some foods are dehydrated [dee-HI-dray-ted], so the astronauts just need to add water. Most foods are precooked, so the astronauts just reheat them in an oven. There are no refrigerators on the ISS.

Figure 7

Astronauts have to be careful that pieces of food do not escape and get into the sensitive instruments.

Did you know that when you exhale, or breathe out, your breath contains water? On the ISS, all water—including water from the astronauts' breath—is recycled and purified so that it can be used again. There is a lot of water on the ISS in containers that were transported from Earth. Since bringing water from Earth is expensive, scientists have developed technology to collect humidity from the air. In the future, every drop of water, from waste water to water used for hygiene, may be recycled and purified on the ISS. On Earth, when we **recycle,** we reuse something instead of discarding it. On the ISS, it is very important to find ways to recycle all materials and to reduce waste as much as possible.

Designing materials so they can be reused is important. Most garbage is packed up and returned to Earth, but sometimes it is deposited into space, where it burns up. Staying clean on the space station is a must. Micro-organisms (bacteria) grow easily in a closed system. Astronauts do not get very dirty in space. To stay clean, they use a moist cloth to wipe themselves clean.

What about personal wastes? To use a toilet on the ISS, astronauts first strap themselves in so they will not float away (**Figure 8**). They then sit on a rubber ring to create a seal around the toilet as their solid waste is vacuumed into a waste receptacle. There is a hose to collect urine. All liquids, including urine, are processed to remove pure water, which can be reused.

Figure 8
The toilet on the ISS is quite a bit different from the toilets on Earth.

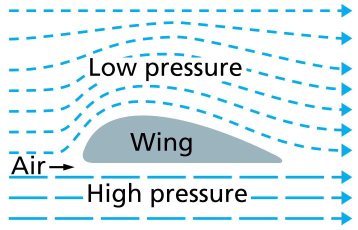
CHECK YOUR UNDERSTANDING

1. How are astronauts able to breathe on the ISS?
2. What are some functions of a space suit?
3. Water is a valuable resource on Earth and on the ISS. Compare how you use water to how an astronaut uses water.
4. Why is it important for astronauts to exercise in space?
5. Compare the needs of an astronaut on a space flight for a few days with the needs of an astronaut living in space for a few months.

11 Chapter Review

Technology allows us to explore the extreme environment of space.

Key Idea: **Flight technology allows us to explore the skies.**



Curved wings give an airplane lift so it can fly.

Vocabulary

lift p. 204

Key Idea: **Rocket technology allows us to travel through Earth's atmosphere and into space.**

The space shuttle

Vocabulary

thrust p. 210

Key Idea: **Canadian scientists make important contributions to space exploration.**

The Canadarm and RADARSAT are Canadian contributions to space exploration.

Vocabulary

Canadarm p. 212

Key Idea: **Living and working in space requires protection from extreme temperatures, a lack of air pressure, and low gravity.**

The International Space Station is a laboratory in space.

Vocabulary

life-support systems p. 220

recycle p. 224

Review Key Ideas and Vocabulary

When answering the questions, remember to use the chapter vocabulary.

1. How did an understanding of lift help people develop the technology of flight?
2. Give an example of a flying machine, such as a helicopter, that humans have invented. What things or creatures from nature may have inspired the design?
3. How does thrust cause a rocket to launch into space?
4. What are the three main obstacles to human survival in space? For each obstacle, discuss a technology that has made it possible for humans to survive in space.
5. Describe two important Canadian contributions to space exploration.

Use What You've Learned

6. What happens if one member of a scientific team does not complete his or her job properly? For example, in Investigation 11.4, there were three members on each team. Write a paragraph about the importance of completing a job properly. Infer how your experiences in this investigation could relate to space exploration.
7. Research the countries that are involved in the International Space Station.

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8. Research Canada's contributions to the ISS.

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9. Research a Canadian astronaut. When did this astronaut go into space? What did he or she do on the mission?

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10. On October 5, 2004, *SpaceShipOne* became the first privately built manned rocket ship to fly into space (**Figure 1**). In the future, people may be able to fly into space on board rocket ships like *SpaceShipOne*. What do you think about the possibility of riding in a rocket ship? What could this mean for the future of space exploration?

Figure 1
SpaceShipOne and its launch ship

Think Critically

11. What lessons about recycling on Earth can be implemented to reduce waste in space?
12. What do you think would be the most difficult part of living in space? Why?

Reflect on Your Learning

13. Which activity best helped you understand the concepts presented in this chapter? How do you learn best?
14. In this chapter, you have learned about the exploration of space, the most extreme environment. What aspect of space exploration interested you the most? What questions do you have about future space explorations?