12.3 Exploring Space: Past, Present, and Future

Telescopes allow humans to extend their ability to observe space. Different telescopes study different parts of the electromagnetic spectrum, including optical, radio, infrared, and X-ray waves. Satellites and probes visit regions in space too difficult for humans to explore. New technology is quickly making ideas such as colonization and terraforming possible.

Words to Know

ethics
geosynchronous orbit
optical telescope
probe
radio telescope
rover
satellite
terraforming

Our success in learning about the sky and beyond has long depended on the tools available to extend our vision. Observation improved greatly after the invention of the first optical telescope in the 17th century. Suddenly, people were able to see details they could never have imagined were there before. This was how they came to realize that the Moon has craters, stars exist in the millions rather than thousands, and Earth is not the centre of the universe (Figure 12.19).

Constant improvement of a range of tools and technologies has helped astronomers continue to make new discoveries, both from Earth and by going into space.

Physically exploring outside Earth's atmosphere is more than just an activity to answer scientific curiosity. Humans are now pushing the limits of technology to travel into space for fun and profit. Since the first astronaut was sent into space in 1961, more than 400 people have successfully journeyed there and back again. In the next 50 years, even average citizens may be regularly paying for the opportunity to take the trip of a lifetime.

Figure 12.19 The mysteries of the universe have long captured the curiosity and imagination of humans.

Earth-based Observation Technology

The first telescope was invented by the Dutch eyeglass maker Hans Lippershey in 1608. Since then, many changes to its design have improved its light-collecting capabilities. There are two types of **optical telescopes**: refracting and reflecting.

Optical telescopes

Refracting optical telescopes use lenses to gather and focus light to provide a magnified view. Reflecting telescopes use a series of mirrors to collect light and project the image to an eyepiece lens for the viewer. The largest reflecting telescopes in the world today are the twin Keck telescopes built at an altitude of 4200 m on Mauna Kea in Hawaii. The main mirror of each Keck telescope is 10 m in diameter. Each is composed of 36 individual hexagonal segments. Even bigger than the two Keck telescopes will be the Thirty Metre Telescope, with a 30 m diameter mirror. It is now under construction by an international group that includes Canada and is to be completed in 2015. The Thirty Metre Telescope is expected to be able to see objects more than 150 times fainter than can be seen by the Hubble Space Telescope.

Did You Know?

Building large telescopes can be difficult and expensive. Another strategy is to use two or more smaller telescopes to create the power of a single large one. Combining a series of telescopes to imitate the sensitivity of a single, larger telescope is called interferometry.

12-3A Build Your Own Telescope

Find Out ACTIVITY

In a refracting telescope, an objective lens gathers light from a distant object and focusses the image in the telescope. The light of the image is then magnified by an eyepiece lens, which is where you see the image with your eye. In this activity, you will build your own refracting telescope.

Safety

- Handle scissors carefully.
- Glass lenses are breakable. Handle them carefully.

Materials

- ruler
- pencil
- one toilet paper tube (~4 cm in diameter)
- one paper towel tube (~4.3 cm in diameter)
- scissors
- two convex lenses, approximately 4.5 cm in diameter
- clear adhesive tape
- metre stick
- page of small-print text (such as the page of a newspaper or magazine)

What to Do

1. Use the ruler and pencil to mark a line about 2.5 cm from one end of the toilet paper tube. Do the same on the paper towel tube.
2. With the scissors, carefully cut an opening in each tube along the line you drew, but only halfway around.
3. Insert one of the lenses into the opening you made in the toilet paper tube. Use the tape to secure the lens to the outside of the tube. Repeat this step for the paper towel tube.
4. Slide the empty end of the toilet paper tube (the end without the lens) into the empty end of the paper towel tube.
5. Have a partner hold the page of text about 1 m away from you. Look through your telescope at the page. To focus the image, slide the inner tube back and forth inside the outer tube.
6. Test your telescope by having your partner hold the page at different distances from you.
7. Repeat step 6 until you cannot see a clear image. Measure this distance using the metre stick and record the number.

What Did You Find Out?

1. What did you notice about the image you observed when you were 1 m from the page?
2. Explain what you had to do to the telescope to make the image clearer when you were:
   (a) closer to the page
   (b) farther from the page
3. What was the maximum distance at which you could still see a clear, magnified image?
4. Suggest a change to the design of the telescope that would allow you to see a clear image of the page from farther away.

internet connect

Many secrets of the universe are revealed when we use instruments that search for energy from all parts of the electromagnetic spectrum, not just the narrow part of visible light. Research how different types of telescopes obtain "non-visible" information about celestial objects. Start at **www.bcscience9.ca**.

Non-optical telescopes

The first telescopes collected only light for observing the universe. Eventually, however, astronomers realized that they could use other wavelengths on the electromagnetic spectrum for their telescopes. Many objects in space produce energy that is not visible to the human eye, including X rays, gamma rays, and radio waves. Non-optical telescopes were developed to view these wavelengths. However, Earth's atmosphere blocks some of this incoming electromagnetic radiation, so telescopes operating at these wavelengths must be sent into space. An example of an X-ray telescope is the Chandra X-Ray Observatory.

To collect wavelengths that are longer than those of light and infrared radiation, **radio telescopes** are used. Radio telescopes are large receivers, similar to satellite dishes you can often see attached to people's homes. Radio signals coming from a distant object are collected and focussed on a receiver. The electric signals are then converted into data and interpreted. Radio telescopes reveal characteristics of celestial objects that could not be studied using optical telescopes.

A photograph of the world's largest radio receiver, located at Arecibo, Puerto Rico, appears in the "www science" feature in section 10.2. Data collected from a radio telescope receiver is shown in Figure 12.20.

Figure 12.20. A radio telescope image showing two galaxies that astronomers believe collided about 50 million years ago.

As with optical telescopes, radio telescopes can be joined electronically to produce the results of one very large telescope. The Very Large Array radio astronomy observatory, located in New Mexico, is made up of 27 antennas that are each 25 m across (Figure 12.21). The result simulates one giant radio telescope that would be 36 km wide.

Figure 12.21 The Very Large Array facility is used by astronomers from all over the world to study galaxies, black holes, planetary nebulae, and other areas of astronomy.

Reading Check

1. How has the invention of the telescope helped the science of astronomy?
2. Name the two types of optical telescopes.
3. What is the advantage of using several small telescopes combined rather than one large telescope?
4. What is the main difference between reflecting and refracting telescopes?
5. Why were non-optical telescopes developed?

Space-based Observation Technology

Earth-based telescopes, as sophisticated as they are, are affected by a number of conditions that can make observing difficult or impossible. These conditions include cloudy weather, air and light pollution, and distortion caused by heat and atmosphere. Furthermore, telescopes are limited in their ability to analyze the data from the objects they are studying.

For all these reasons, scientists have spent the last 50 years developing ways of getting telescopes and other data-collecting instruments off Earth's surface and into orbit. As well, truly remarkable efforts have permitted humans to walk on the Moon, live in space, and consider visiting other planets. Experience has taught us that this approach is very expensive, time-consuming, and dangerous for humans. Fortunately, other options for space exploration have been developed to overcome some of these challenges. The most successful of these advanced technologies are satellites, probes, and robotic rovers.

Satellites

Artificial **satellites** are electronic devices put in orbit around Earth to relay information. "Satellite" means any body that orbits around another body in space. Our Moon orbiting Earth, for example, is Earth's natural satellite. It is usual when talking about space technology to refer to artificial satellites simply as satellites.

Satellites are a very important part of your everyday life. When you decide what clothes to wear based on a weather report, or when you watch television, phone a friend, or check out a website, satellites are likely playing some role (Figure 12.22). Satellites used for communications tend to be stationary above a fixed point on Earth. This is called a **geosynchronous orbit**. These satellites orbit Earth at the same rate that Earth is rotating. As a result, the satellite appears to be staying in one position. Television satellites do this so that ground-based satellite dishes can be aimed at the transmitting satellite.

Figure 12.22 Canada has been in the field of space communications for nearly 50 years. Whether you are aware of it or not, you benefit every day from such technology.

Satellites are also used for many other purposes besides providing communications services. Through remote sensing, for example, satellites are used to monitor forest fires, track migrating salmon, calculate the depth of oceans, and measure ground movement in an effort to predict earthquakes and volcanic eruptions. Remote sensing is a technique of collecting information about Earth from satellites, aerial photographs, or other means by "sensing" the planet from high above it.

One of the Canadian Space Agency's first remote sensing satellites was *RADARSAT 1*. *RADARSAT 1* has been used for mining exploration, urban planning, and even hurricane tracking. *RADARSAT 2*, shown in Figure 12.23, is the newer version.

Figure 12.23 *RADARSAT 2* orbits at an altitude of 798 km and has many uses, such as geological mapping, forest mapping, iceberg detection, and marine surveillance.

Probes

A space vehicle sent to other celestial bodies is called a **probe**. Probes are designed to travel millions of kilometres, carrying scientific instruments to analyze distant objects in space. They may fly past, orbit, or land on a planet, moon, comet, or asteroid and send back information about its atmosphere and surface features. Every planet in our solar system has been visited by a probe. The *New Horizons* probe, launched in 2006, is destined for Pluto. It expected to reach that dwarf planet in 2015.

Space probes do not need a crew, which eliminates the risk to human life. They also do not need to return to Earth. From the late 1960s to early 1980s, for example, the Soviet Union landed several *Venera* probes on Venus. The planet's sulphuric acid clouds, 467°C temperature, and extreme surface pressure meant that most of the probes lasted less than half an hour before communication was lost. Despite that, the data and images the probes were able to transmit have been invaluable.

Two of the most successful American space probes have been *Voyager 1* and *Voyager 2*. Launched in the late 1970s, the two interplanetary explorers were the first to fly past the gas giants and the moons of the outer solar system (Figure 12.24). Today the probes continue to send back data from the farthest reaches of our solar system.

Explore More

Archaeologists, people who study ancient life, sometimes use satellites to detect evidence of past civilizations deep beneath surface layers of water, soil, and even jungle. Follow the links at **www.bcscience9.ca** to learn more about this unusual archaeological tool.

Figure 12.24 Jupiter and one of its moons as viewed by *Voyager 2*

Rovers

Sending human explorers on long space journeys to distant, dangerous planets is not a practical idea. One reason is the risk to human life. Another reason is the enormous cost. Robot space explorers offer a better option. These robotic devices, or **rovers** as they are commonly known, can be programmed to carry out tests that humans would otherwise make. Rovers are small, sophisticated, movable probes designed to land on a planet, explore and test the surface, and send the information back to Earth. Because of the length of time it can take for radio signals to travel between Earth and a remote location, rovers must be programmed to solve many problems on their own, without help from scientists at mission control.

Robotic space rovers work all day long, pausing only at night to conserve their battery strength. They operate in hostile environments that can range from the freezing surface of Mars to the furnace-like surface of Venus. The work they do includes conducting experiments in geology, meteorology, and biology.

The latest rovers to explore another planet are twins called *Spirit* and *Opportunity*. Sent to Mars, these "robotic geologists" have been testing rock samples and looking for evidence of water since January 2004 (Figure 12.25). They continue to send data, long past their original three-month mission.

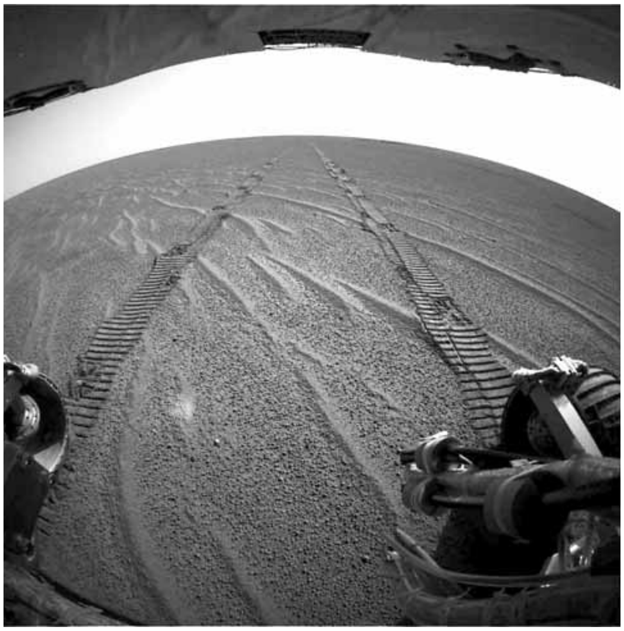


Figure 12.25 *Spirit* and *Opportunity*, shown here, have travelled several kilometres from their landing sites on opposite sides of Mars.

Reading Check

1. Define the term "satellite."
2. Besides communication, list three ways satellites help scientists.
3. How are interplanetary probes different from satellites?
4. What do interplanetary rovers do that probes do not do?
5. Give two reasons why a probe would be sent to another planet before a human would.

12-3B Roving Mars

Think About It

NASA has documented the journey of its twin surface rovers, *Spirit* and *Opportunity*, on Mars. In this activity, you will watch the rovers at work and write about Mars exploration.

What to Do

1. Research information about the conditions on Mars. Start your search at **www.bcscience9.ca.** Watch film footage of the rovers *Spirit* and *Opportunity* as they explore the surface of Mars.
2. Write a short story describing what you would see and feel on a typical day if you were a space scientist sent out instead of the rovers to explore Mars.

Technology of Space Travel

Breaking the hold of Earth's gravitational pull was the first challenge for scientists wishing to send telescopes, other instruments, or humans out into space. This is done with rockets. Rocket technology has advanced dramatically since its humble beginnings in China in the first century C.E. The establishment of a space-based research facility on the International Space Station has taken space exploration to the next level.

Rockets

A rocket is a system used for transporting materials and astronauts into space. Much of the body of a rocket is filled with explosive fuels that combine to create thrust (Figure 12.26).

Thrust is the force that pushes against the rocket, causing it to move. A similar reaction occurs when you blow up a balloon and release it. The air escapes from the neck of the balloon and produces thrust, which forces the balloon to fly away. As fuel is used up, parts of the propulsion system are released from the rocket to make the body lighter.

Suggested Activity

Conduct an Investigation 12-3C on page 446

Did You Know?

On its 3.8 billion km journey to Jupiter, the *Galileo* spacecraft had to adjust its direction from time to time with small bursts from its rockets. Doing this used only about 254 L of fuel for the whole trip, a fuel use of 15.6 million km/L.

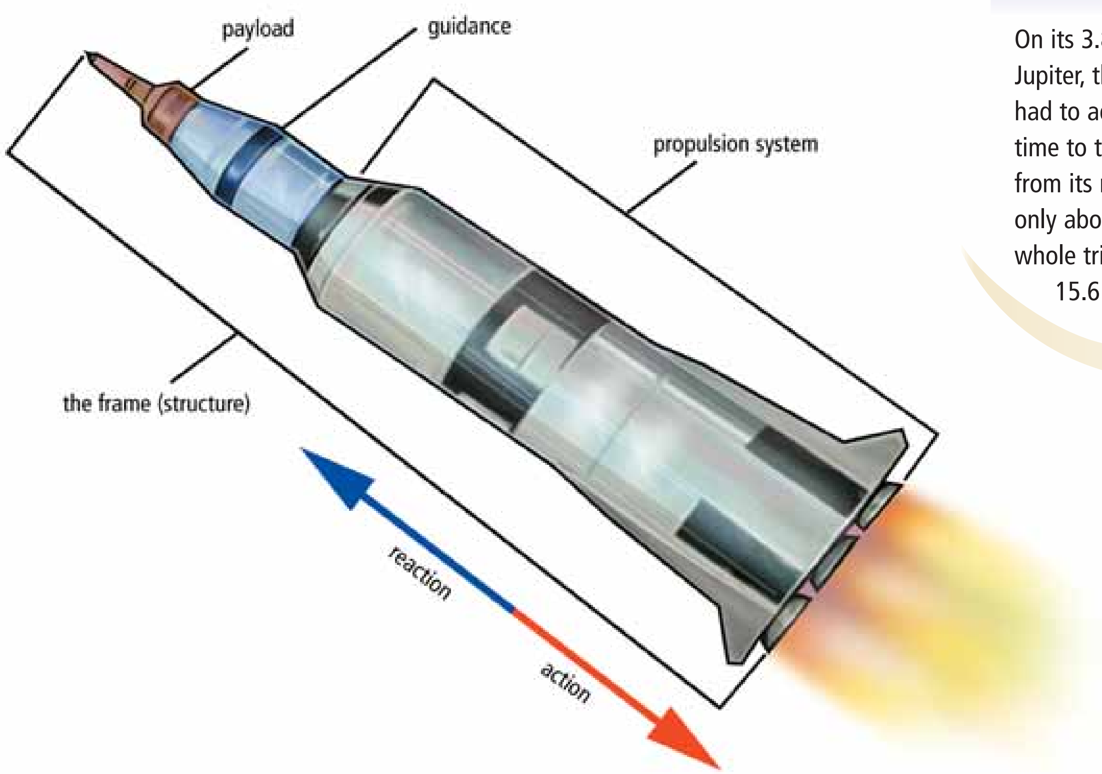


Figure 12.26 All rockets have four main systems: structural (the frame), payload, guidance, and propulsion. The payload is the cargo that the rocket carries. It could be astronauts, satellites, or other objects. The propulsion system produces thrust, the force needed to launch the rocket.

Figure 12.27 A space shuttle, such as *Discovery* shown here, reaches its orbital speed of 27 200 km/h in just under 8 min.

Space shuttle program

Besides a rocket's payload, not much of the structure is saved or used again. Most of the material falls back to Earth, burning up during re-entry into the atmosphere or crashing into the ocean. For this reason, space shuttles were designed to be reusable spacecraft. Each shuttle is rocketed into space, completes its mission, and returns to Earth, gliding in on a runway like a regular airplane (Figure 12.27). The only discarded materials are the external fuel tanks.

In addition to launching and retrieving satellites, the shuttle is used as a means of delivering astronauts, supplies, and equipment to the International Space Station.

International Space Station

Since construction began in 1993, the International Space Station has been built piece by piece from components delivered by the space shuttle and from conventional rockets from Russia. Sixteen countries, including Canada, are involved in this space-based laboratory, which orbits about 350 km above Earth. Travelling at more than 27 000 km/h, the space station circles Earth in about 90 min. The onboard crew members conduct numerous experiments in the microgravity environment (Figure 12.28). Microgravity is the condition of weightlessness experienced by all objects, including spacecraft and humans, in space. It is very weak gravity, less than one-millionth the effect on Earth. Scientists at the Canadian Space Agency are known around the world for their work in microgravity research. The lifetime of the International Space Station is expected to be about 30 years.

Figure 12.28 Crew in the International Space Station carry out a wide range of experiments, such as testing new materials and studying the long-term effects of space travel on humans.

Space Travel

The first stages of space travel involved launching uncrewed probes. Animals were then sent up to test the living conditions required for space travel. The next phase involved sending up humans. From there, the Moon became the focus of attention (Figure 12.29). In 1969, the U.S. landed the first person on the Moon, Neil Armstrong.

As countries realized how expensive space exploration was, they started working together. The International Space Station is an excellent example of a truly international mission. Numerous partnerships between private business and governments are now also working on space projects.

Figure 12.29 The first landing of a human on the Moon, 1969

Canadian contributions to space exploration

One of the largest successes in NASA's space program has been the Canadian-designed and -built robotic arms. The first "Canadarm" was used to retrieve and launch many satellites and to provide a stable platform for astronauts going about their tasks in space.

Canadarm 2, a mobile remote manipulator system designed for the International Space Station, does everything that Canadarm 1 did, but it is larger and able to move by itself (Figure 12.30). Moving like a caterpillar, the system can travel to nearly every part of the space station's exterior. The newest development is the robotic manipulator officially named Dextre (for "dexterous"), a two-armed robot that attaches to the end of Canadarm 2. It can perform tasks that previously required astronauts to work outside the safety of the space station.

Explore More

Find out more about Dextre, the Canadian Space Agency's "Special Purpose Dexterous Manipulator." Start by going to **www.bcscience9.ca**.

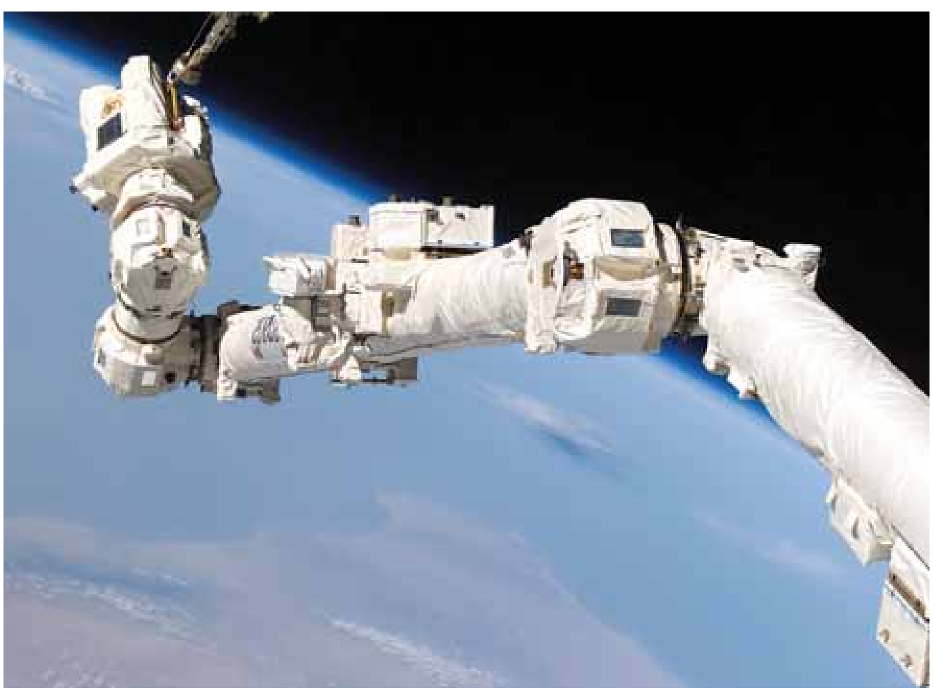


Figure 12.30 Canadarm 2 is used to move large payloads, dock the shuttle, and assist astronauts with repair and assembly duties.

Figure 12.31 Many things you use every day were originally invented by scientists and engineers for use in space.

Rewards of Space Travel

Spinoff technology

A great deal of technology that was originally invented and designed for use in space has found new purpose on Earth. These **spinoff technologies** include hundreds of items we use in our day-to-day lives. The list is long, but some examples are freeze-dried foods, high-tech running shoes, bicycle helmets, cold weather clothing, light sportswear, sunglasses, insulin pumps, eye examination systems, locator beacons, and self-repairing computers (Figure 12.31).

Space tourism

The lure of space travel is not reserved just for highly trained astronauts. Progress in space travel technology has meant improvements in safety and significantly lowered costs. As a result, some companies are now coming up with clever ways to attract adventurous travellers into space such as charging people to stay at the International Space Station and selling tickets for a short flight into space.

Another idea related to space tourism is **terraforming**. Terraforming is the idea that an extraterrestrial environment, such as Mars, could be transformed into an Earth-like biosphere that humans could inhabit (Figure 12.32). An effort like this would, of course, be extremely costly—if it were even possible. Most scientists argue that because Mars was not large enough to hold its original atmosphere, it would not be able to maintain a newly created atmosphere.

Figure 12.32 The process of terraforming Mars would require creating large natural systems such as a water cycle and plant life to generate and maintain an atmosphere like Earth's. This image shows an artist's idea of a terraformed Mars.

Risks of Space Travel

Equipment failure

The most obvious hazard of space flight is the ever-present risk of equipment failure. This can be caused by a malfunction during takeoff, collision with space debris, or failure of a heat shield to protect the spacecraft during re-entry. The fuel tank of a space shuttle holds more than 750 000 kg of highly explosive fuel, which is why takeoffs occur only after every safety precaution has been taken. The death of the crews aboard the space shuttles *Challenger* and *Columbia* are sombre reminders of the risks in travelling into space and back.

Word Connect

"Terraforming" is a modern word that combines two concepts. The first part comes from the Latin *terra*, which means Earth. "Forming" is added to indicate change.

Hazards from orbiting space debris

Despite the care and attention of space scientists, materials still manage to fall off shuttles, break off rockets, or rupture from satellites. NASA estimates that there are more than a million pieces of debris orbiting Earth at any one time. These can range in size from flakes of paint and small bolts to old satellites. This "space junk," regardless of size, can damage anything it hits (Figure 12.33). In space, an apple-sized metal ball would crash with the explosive force of two dozen sticks of dynamite.

Because any collision could be costly and even fatal for astronauts, the position and path of travel of the larger debris is closely monitored by Earth-based radar. Steps are taken to avoid the objects for takeoffs and landings of spacecraft. Windshields on the shuttles have been replaced numerous times because of the damage caused by the impact of space debris.

Figure 12.33 NASA estimates that at least two collisions a day occur between operational satellites and space junk in Earth orbit. This artwork shows a satellite solar panel being snapped after colliding with a sliver of metal.

Hazards from falling space debris

Floating debris in orbit around Earth is constantly affected by Earth's gravitational pull. Occasionally, this will cause debris to re-enter the atmosphere. Most of the materials falling back to Earth burn up on re-entry through the atmosphere, although large materials occasionally do crash to Earth's surface. In 1978, a Soviet satellite hit the ground in the Great Slave Lake area of northern Canada. Fortunately, because it is sparsely populated, there were no injuries. In 2003, the space shuttle *Columbia* burst into flames during re-entry into Earth's atmosphere, claiming the lives of all the astronauts on board. Nobody on the ground was hurt, despite debris from the shuttle hitting the ground over three American states.

Did You Know?

In 1979, the first American space station, Skylab, broke into thousands of chunks during re-entry through Earth's atmosphere. These crashed into the Indian Ocean, and some pieces landed in Australia. The Australian government fined the U.S. $400 for littering.

Unethical use of space resources

The term **ethics** refers to the set of moral principles and values that guides a person's actions and helps him or her decide what is right and what is wrong. When discussing space exploration and the use of space resources, it is important to consider the ethical issues related to space travel. Closely tied to ethical issues are environmental and political issues. As with any resource, economic matters should be balanced with consideration for the environment and for people. Humans must consider the potential damage their actions might cause to humans' and Earth's well-being. The list below outlines some of the questions that humans will have to answer if we are to prevent the unethical use of space and its resources in future.

Questions That Must Be Asked About Space Travel

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 invade other unique environments around the solar system? • Do we have the right to take materials from other bodies in the solar system? • Are there other problems on Earth that could be solved with the money now used for space programs?
Environmental	• What will be the effects of space travel on Earth's natural systems? • What effect does resource removal have on asteroids, moons, and planets? • Who is responsible for policing environmental impacts? • Who must be responsible for cleaning up any damage or debris from space development?
Political	• Who has ownership of space resources? • Should countries share technology and resources? • Who should decide how space resources will be used?

Because of the rate at which space exploration is proceeding, the issues facing Earth as a community need to be addressed. One of the biggest questions to be dealt with is: Should we be thinking about travelling to space before we deal with problems on our home planet? These concerns are not for some future generation but are ones that you will likely confront in the next several years.

Reading Check

1. What is Canadarm 2 and what can it do?
2. Name five spinoffs of space exploration technology that we use on Earth.
3. What is space junk?
4. Why is debris floating in Earth's orbit a concern for astronauts?
5. How do ethics apply to space exploration?

New Ideas for Interplanetary Travel

Because distances in our solar system are so great, the fuel that would be required to regularly transport equipment and humans from Earth to other planets would be enormous. To get astronauts safely to Mars and back, for example, fuel would take up about 95 percent of the payload space. Even deep space probes require a lot of fuel. Space scientists have been working on a number of ideas to keep down both costs and fuel requirements for space exploration. Two ideas at very early stages of development are described below.

Space sled

Space sleds combine the principle of magnetic repulsion with the slingshot idea. NASA has designed a system that uses magnets to propel a spacecraft along a rail and up a ramp at 600 km/h (Figure 12.34). The idea is that rockets would then help the spacecraft get out of the atmosphere.

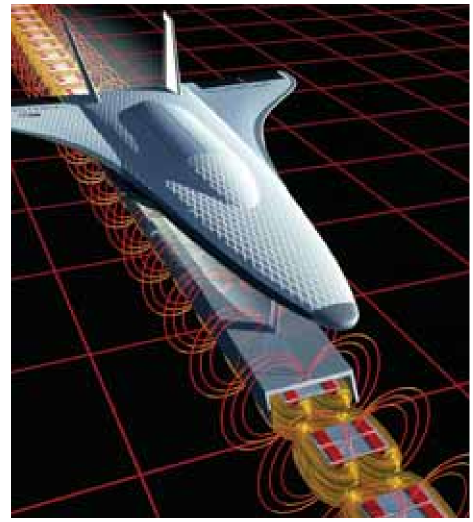


Figure 12.34 It is estimated that the cost to launch a space sled could be as little as $100.

Space elevator

Researchers are investigating the possibility of using a space elevator to transport people and supplies into Earth's orbit (Figure 12.35). The technique would rely on a long cable attaching a base on Earth with a platform, like a space station, in Earth's orbit. An elevator connected to the cable would be propelled by a laser beam from Earth's surface. The cable would be made of carbon nanotubes, which would give the cable many times the strength of steel, and would be about 36 000 km long. What makes the project appealing is the cost of getting materials into space. Currently, it costs $22 000/kg to transport materials. Using the space elevator, a person (with one suitcase) would be able to take the 5 h ride for about $200.

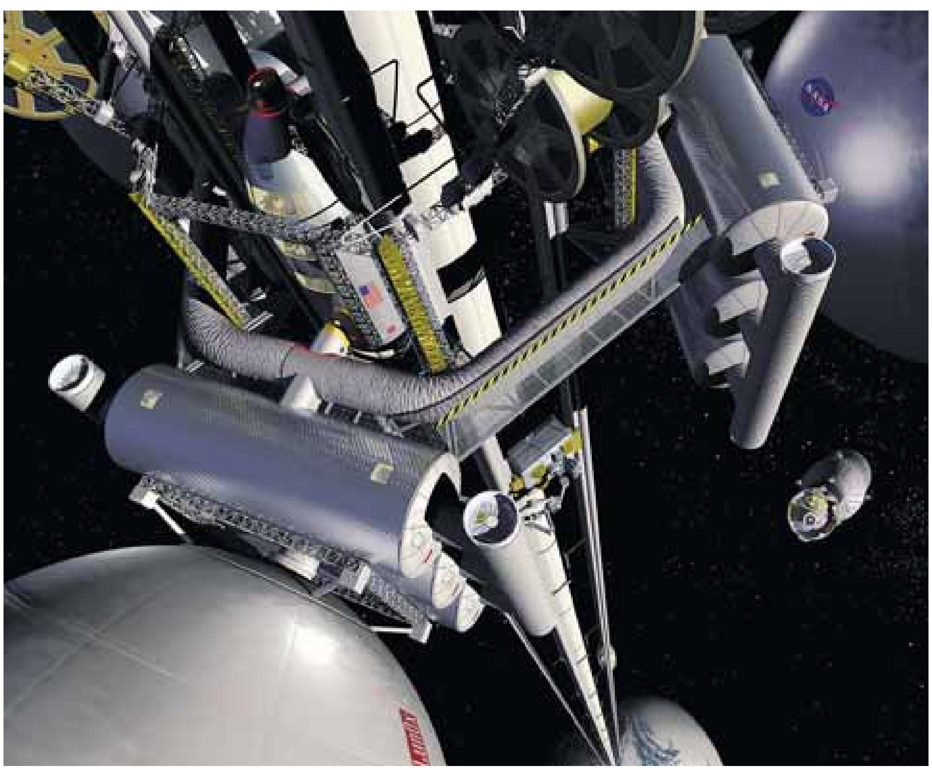


Figure 12.35 An artist's idea of what a space elevator might look like

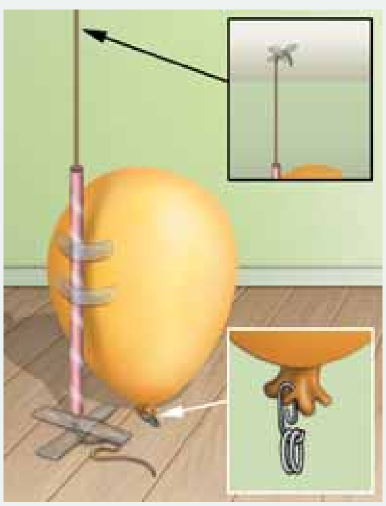
12-3C Calculating the Thrust of a Balloon Rocket

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck
- Observing
- Measuring
- Calculating
- Modelling

Materials
- 4 m of string
- plastic drinking straw
- clear adhesive tape
- balloon
- twist-tie
- 10 small washers of the same size
- scale (or triple-beam balance)
- paper clip



Hint: You will need to convert the mass of the washers into kilograms to complete the calculation.

In this activity, you will simulate the forces needed to generate thrust in a rocket engine, and you will determine the maximum thrust of a balloon rocket engine.

Question
What is the maximum load of a balloon rocket?

Procedure
1. Connect one end of the string to the ceiling. Insert the other end of the string through the straw, pull the string tight, and tape the end to the floor.
2. Copy the following table into your notebook.

Trial Number	Number of Washers	Mass of Washers	Description of Motion
1	0		
2	1		
3	2		
4	3		

3. Inflate the balloon, twist the neck, and tie it closed with the twist-tie. Use the tape to attach the side of the balloon to the straw. The clamped end of the balloon should be facing the floor.
4. Release the twist-tie and observe the motion of the balloon. Record your observations in the table.
5. Measure the mass of a washer using the scale. Record the mass in the table.
6. Inflate the balloon again to the same size it was for step 3. Tie it closed as before. Using the paper clip to make a hook, attach it to the bottom of the balloon and hang a washer from the hook. Release the balloon, and record your observations.
7. Repeat step 6 several times, adding one washer each time, until your balloon rocket can no longer take off. At that point, the weight of the rocket equals the thrust.

Analyze
1. In step 4, you released the twist-tie on the balloon attached to the string.
   (a) In what direction did the air in the balloon move?
   (b) In what direction did the balloon rocket move?
2. Why does the air in the balloon move the way it does?
3. What happened to the speed of the rocket as the load (mass) was increased?
4. Besides load, what other factors might affect the balloon rocket's motion?

Conclude and Apply
1. Explain how the balloon rocket's motion is similar to the motion of a real rocket.
2. Use the data you collected to determine the thrust of your balloon rocket.

   $F = m \times g$ where g = the acceleration lost because of gravity = 10 N/kg

   m = the mass of the washers

12-3D The Great Space Debate

Conduct an INVESTIGATION

Decision-Making Focus

SkillCheck

- Communicating
- Evaluating information
- Working co-operatively
- Identifying ethical issues

The Issue

Should large amounts of money be spent on space exploration rather than being used for projects on Earth?

Background Information

As technology opens up the "space age," new issues arise about the nature of space exploration. What was once the scientific pursuit of knowledge is quickly becoming a race to see who can make the most money from space. There is no doubt that space can provide limitless opportunity. However, as we have seen on Earth, exploitation of resources usually comes at some environmental cost. Humans need to assess the risks and rewards of space travel before making decisions that cannot be reversed. For some people thinking about the matter, the question "Can we go?" should be replaced with "Should we go at all?" This chapter focusses on the risks and rewards of space travel.

Identify and Analyze Alternatives

In this unit, you have been learning how humans use technology to observe, study, and explore space. The benefits and spinoffs of space exploration include great advances in health, communications, and Earth observation. However, as you have also learned, space exploration requires great amounts of resources and money. The drive to improve our understanding of the universe must be balanced with concern for the space environment, financial costs, and even the potential for battles over military control of space. Each year, it seems that "outer space" is becoming increasingly more accessible to humans. Hotels in orbit, vacations on the Moon, and even interplanetary travel are ideas that used to be considered science fiction.

The question constantly faced by the space industry is whether humans should be spending so much money on space exploration or instead putting these resources into solving Earth-bound issues and problems. Your goal in this activity is to choose a position, either for or against investing large sums of money in space exploration, and to support it with evidence. Conduct your research using the following resources.

1. Begin your research at **www.bcscience9.ca** to determine both the costs and benefits of space exploration.
2. Search print materials such as journals, magazines, and newspapers for articles relating to the positive and negative effects of space exploration.
3. Choose a viewpoint based on your research. Summarize your information in a short report.
4. Share your opinion with your classmates in the form of a presentation or a debate. It is important for you to be able to defend your point of view with appropriate data.

Science Skills

Go to Science Skill 4 for information about developing societal decision-making skills.

Evaluate

Present your opinion and findings to your classmates as a presentation or a debate.

Visualizing Rocket Motion

NATIONAL GEOGRAPHIC

On the afternoon of July 16, 1969, Apollo 11 lifted off from Cape Kennedy, Florida, bound for the Moon. Eight days later, the spacecraft returned to Earth, splashing down safely in the Pacific Ocean. The motion of the spacecraft to the Moon and back is governed by Newton's laws of motion.

◀ *Apollo 11* roars toward the Moon. At launch, a rocket's engines must produce enough force and acceleration to overcome the pull of Earth's gravity. A rocket's liftoff is an illustration of Newton's third law: For every action there is an equal and opposite reaction.

▲ As *Apollo* rises, it burns fuel and ejects its rocket booster engines. This decreases its mass, and helps *Apollo* move faster. This is Newton's second law in action: As mass decreases, acceleration can increase.

▶ The lunar module uses other engines to slow down and ease into a soft touch-down on the Moon. A day later, the same engines lift the lunar module again into outer space.

▲ After the lunar module returns to *Apollo*, the rocket fires its engines to set it into motion toward Earth. The rocket then shuts off its engines, moving according to Newton's first law. As it nears Earth, the rocket accelerates at an increasing rate because of Earth's gravity.

Check Your Understanding

Checking Concepts

1. State the difference between:
(a) optical and non-optical telescopes
(b) satellites and probes

2. What is the main purpose of a rocket?

3. Why is the International Space Station called "international"?

4. Name two items you use in your daily life that were originally designed for use in space.

5. Explain why it is unlikely that terraforming of Mars will occur in your lifetime.

6. Most of the debris floating around Earth is smaller than a softball. Why should objects that small concern astronauts aboard the International Space Station?

Understanding Key Ideas

7. Describe a disadvantage of using a telescope positioned in space.

8. Match the systems of a rocket in column A with their description in column B.

A Systems of Rocket		B Description
(i) structure	___	(a) provides fuel to power the rocket
(ii) payload	___	(b) controls the direction of the rocket
(iii) guidance	___	(c) frame for holding all the rocket systems
(iv) propulsion	___	(d) the material, including astronauts, carried by a rocket

9. What advantage is there to doing laboratory experiments on the International Space Station rather than doing the same experiments on Earth?

10. Why did the Mars robotic explorers *Spirit* and *Opportunity* have to be programmed to solve problems on their own rather than be totally controlled by scientists on Earth?

11. (a) On its journey from Earth to Saturn, the *Cassini* spacecraft was considered to be a probe. Now that it has reached Saturn, it is considered to be a satellite of Saturn. Explain the name change.
(b) *Cassini* dropped the *Huygens* spacecraft onto the surface of Titan, Saturn's largest moon. Why is *Huygens* called a probe rather than a satellite or a rover?

12. Imagine you are an astronaut about to travel to a base on the Moon. What are three hazards that could affect your flight?

13. Why should ethics be discussed before space resources are claimed and space exploration takes place?

14. Thirty-five different nations have sent their citizens into space. In your opinion, how should we determine who owns space?

Pause and Reflect

In this section, you have learned about the various opportunities awaiting adventurous space explorers. You have also learned that such adventure does not come without a degree of risk. If you were given a chance to be one of the first astronauts to journey to Mars, would you go or not? Write a short paragraph that explains what your decision would be and why you came to that conclusion.

Prepare Your Own Summary

Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 5 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Interactions Between the Sun and Earth
2. The Moon and Earth
3. Aboriginal Perspectives on the Solar System
4. Technologies for Observing Space
5. Human Space Travel and Exploration

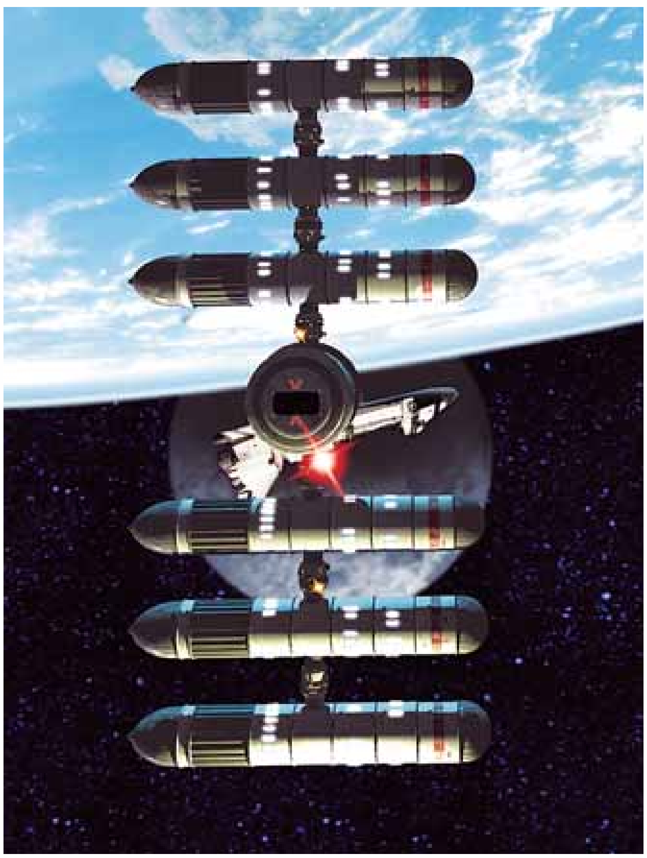
Checking Concepts

1. Why was recording the movement of stars in the night sky important to ancient people?
2. Why did early astronomers name the dark areas of the Moon mare after the Latin word for seas?
3. Why does the Moon have phases?
4. Explain why people in the northern hemisphere experience seasons.
5. (a) What is a solstice?
   (b) Why was it important for ancient peoples to know when the summer and winter solstices occurred?
6. Why is the entire Earth not dark during a total solar eclipse?
7. What causes "shooting stars," the streaks of light that cross the night sky?
8. How have Aboriginal hunters and mariners traditionally used the positions of stars to help them?
9. What advantages do orbiting telescopes, such as the Hubble Space Telescope, have over telescopes located on Earth?
10. What are the advantages of using a number of small telescopes together rather than one single, large telescope?
11. Explain why it is less expensive to send robotic explorers to another planet than it is to send human astronauts.
12. (a) What is the name of the force that causes a rocket to move?
    (b) How is this force applied to a rocket?
13. (a) What is a space "spinoff"?
    (b) Name two space spinoffs you use in your daily life.

Understanding Key Ideas

14. Compare and contrast the geocentric model with the heliocentric model of the solar system.
15. Scientists believe the Moon formed as a result of a Mars-sized object colliding with a young Earth. What do you think might have occurred if the object had been larger than Earth?
16. Because the Moon rotates at about the same rate as it revolves, Earth always sees the same side of the Moon. Would a person living in a lunar colony experience day and night? Explain.
17. Explain why landing a spacecraft on the surface of a Jovian planet would be very difficult.
18. Describe an advantage of conducting experiments on the International Space Station.
19. Explain why scientists are considering using a space sled or a space elevator to transport humans and materials into space.
20. Imagine that a country on Earth decided to claim as its own territory one of the moons of Jupiter. Describe the ethical issues associated with such an action.
21. Describe some problems that could occur if the only requirement for a person who wished to go into space were having enough money for the ticket.
22. What might be some hazards associated with having a hotel on the surface of the Moon?

23. Guests in an orbiting space hotel, such as the one shown in the drawing below, would experience microgravity, the sensation of weightlessness. Describe how weightlessness might affect the following activities associated with hotels on Earth.
(a) eating at a restaurant
(b) sleeping in your room
(c) moving from your room to the lobby area
(d) taking a shower
(e) playing an indoor game of tennis or basketball



Pause and Reflect

You have learned how technology is at a point where space travel is accessible to more people than just astronauts. Companies are preparing to make a business out of different aspects of space travel by offering, for example, rides in spacecraft, visits to orbiting hotels, and a chance to live in colonies on the Moon. Imagine you are in charge of the United Nations task force for space exploration. In a paragraph or two, write a space treaty that discusses the rules of conduct for any nation or company that wishes to explore space.

10 Scientific evidence suggests the universe formed about 13.7 billion years ago.

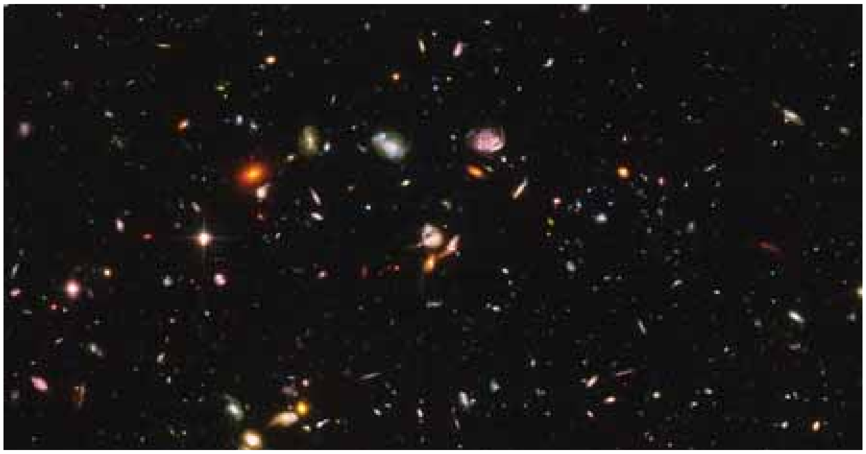
- The universe is believed to have formed about 13.7 billion years ago in a moment of sudden, rapid expansion. This is the Big Bang theory of the universe's formation. (10.1)
- Much evidence collected today by astronomers supports the Big Bang theory. (10.1)
- A shift in the spectra of galaxies shows that all galaxies are moving away from each other. (10.1)
- Galaxies have many different shapes and characteristics. (10.2)
- Within galaxies, stars often form in distinct patterns called star clusters. (10.2)

11 The components of the universe are separated by unimaginably vast distances.

- Stars go through different stages in their life cycles. (11.1)
- A shift toward the red part of the spectrum indicates a star is moving away from Earth. (11.1)
- The Sun is the centre of our solar system, and eight planets revolve around it. (11.2)
- Earth spins, or rotates, on its axis as it revolves around the Sun. (11.2)
- Distances between stars and galaxies are measured in light-years. (11.3)
- Triangulation and parallax are techniques used to calculate distances to stars. (11.3)

12 Human understanding of Earth and the universe continues to increase through observation and exploration.

- Models of the solar system have improved as better technology has been developed. (12.1)
- The appearance of the Moon changes as it revolves around Earth. (12.1)
- Seasons are created by Earth's tilt and revolution. (12.1)
- Aboriginal peoples of British Columbia have long observed the nature of celestial bodies and used this knowledge to guide many activities in their daily lives. (12.2)
- Technology extends humankind's ability to explore space. (12.3)



Key Terms

- Big Bang theory
- galaxy
- nebulae
- spectroscope
- star clusters

Key Terms

- asteroid
- comet
- moons
- planet
- revolution
- rotation
- Sun

Key Terms

- axis tilt
- constellations
- Copernicus
- Kepler
- probe
- Ptolemy
- satellite
- solar and lunar eclipses
- optical and radio telescopes
- terraforming

Designing a Mining Town for the Moon

In this unit, you have learned much about the nature of space, developments in space exploration, and ideas about space travel. Many scientists believe that our nearest celestial neighbour, the Moon, offers large quantities of valuable resources such as iron and numerous other minerals.

Imagine that you are part of a design team that has been asked by a private company to assist it in designing and building a scale model of a modern mining town for colonists on the Moon.

Problem

What needs in a Moon-based colony must be met to ensure humans can safely live there and successfully mine minerals to send back to Earth?

Criteria

Your lunar base model must have a number of sections that are all connected together. The size, shape, and number of sections should be decided by your group, but your design and model must show that you have considered the following:

- living quarters
- transportation at the base
- recreation
- excavation strategies and technology for the minerals to be mined
- the physical and mental health of the colonists

Procedure

Part 1 The Design

1. With your group, brainstorm ideas about all the things you think people in a lunar mining base would need to live and work for several months at a time.
2. Think about the challenges for humans living on the Moon and decide how the various sections of your base will address those challenges. Ask your teacher for guidance if you require it, or go to **www.bcscience9.ca** for suggestions.
3. Draw a sketch of your model plans, using a suitable scale for your model. For example, a shoe box may be the right scale to represent the living quarters.
4. Make a list of the materials you could use to build the model of the base. Choose easy-to-find materials to represent the objects you want to add to each section or consider making the model and objects from cardboard or paper. Before you begin collecting materials, ask your teacher to review your list.

Part 2 Building Your Model

5. Using your sketch as a guide, gather your construction materials and build the scale model.
6. Once you have completed your model, review the criteria listed at the beginning of this project. Your model should be able to accommodate the moon colonists and should also be able to function as a mining operation.

Report Out

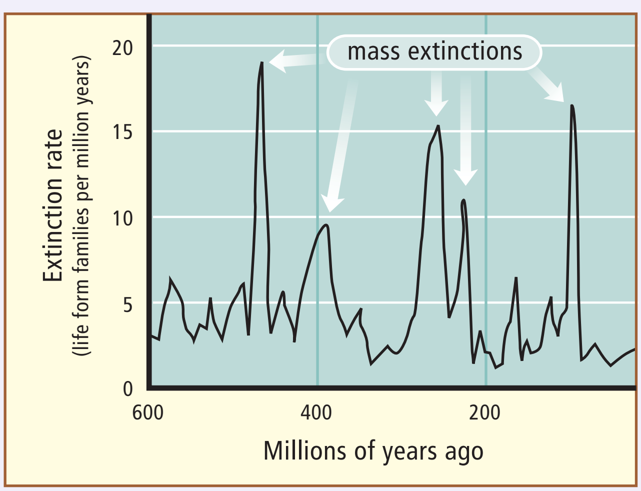
1. After you have completed your drawings and scale model, your teacher will provide you with instructions for presenting your project to the class. In your presentation, you will need to describe how you addressed all the items listed above under "Criteria." Compare your group's design with that of other groups. What was similar, and what were the differences?

"It's a Bird, It's a Plane, It's an Asteroid!"

"Near Earth Objects" are what astronomers call asteroids, comets and similar-size bodies whose orbits have brought them closer to Earth as a result of the planet's gravitational pull. A subset of Near Earth Objects is a group of asteroids known as Potentially Hazardous Asteroids. These asteroids are larger than 2 km wide and have the potential to strike Earth with a force that would generate as much energy as millions of megatonnes of explosives.

Background

Collisions between Earth and another large object from space are estimated to occur about once every 100 million years. That means the risk of Earth being struck is extremely low. When a collision does occur, however, the consequences are catastrophic. Past impacts are believed to have set off earthquakes around the world and to have ejected so much dust and debris into the atmosphere that sunlight was blocked and global climate patterns changed for years. Some scientists believe that an asteroid impact 65 million years ago led to the extinction of the dinosaurs.



This graph shows five mass extinctions that have occurred in the past 600 million years. Scientists believe that asteroid impacts contributed to at least two of these mass extinctions.

What would happen if astronomers discovered a large asteroid headed for Earth? In a best-case scenario, the warning would come years before the collision. That still leaves the enormous problem of how to divert the asteroid from its collision course. Many scientists, engineers, and technologists have been thinking of a solution to the challenge for years. Ideas include using miniature robots or nuclear explosions to break up the asteroid before it reaches Earth or attaching rockets to the incoming asteroid to push or pull it off course.

A small asteroid could cause much localized damage on Earth. A Potentially Hazardous Asteroid could cause damage on a global level. Fortunately, Earth-asteroid collisions are extremely rare.

Find Out More

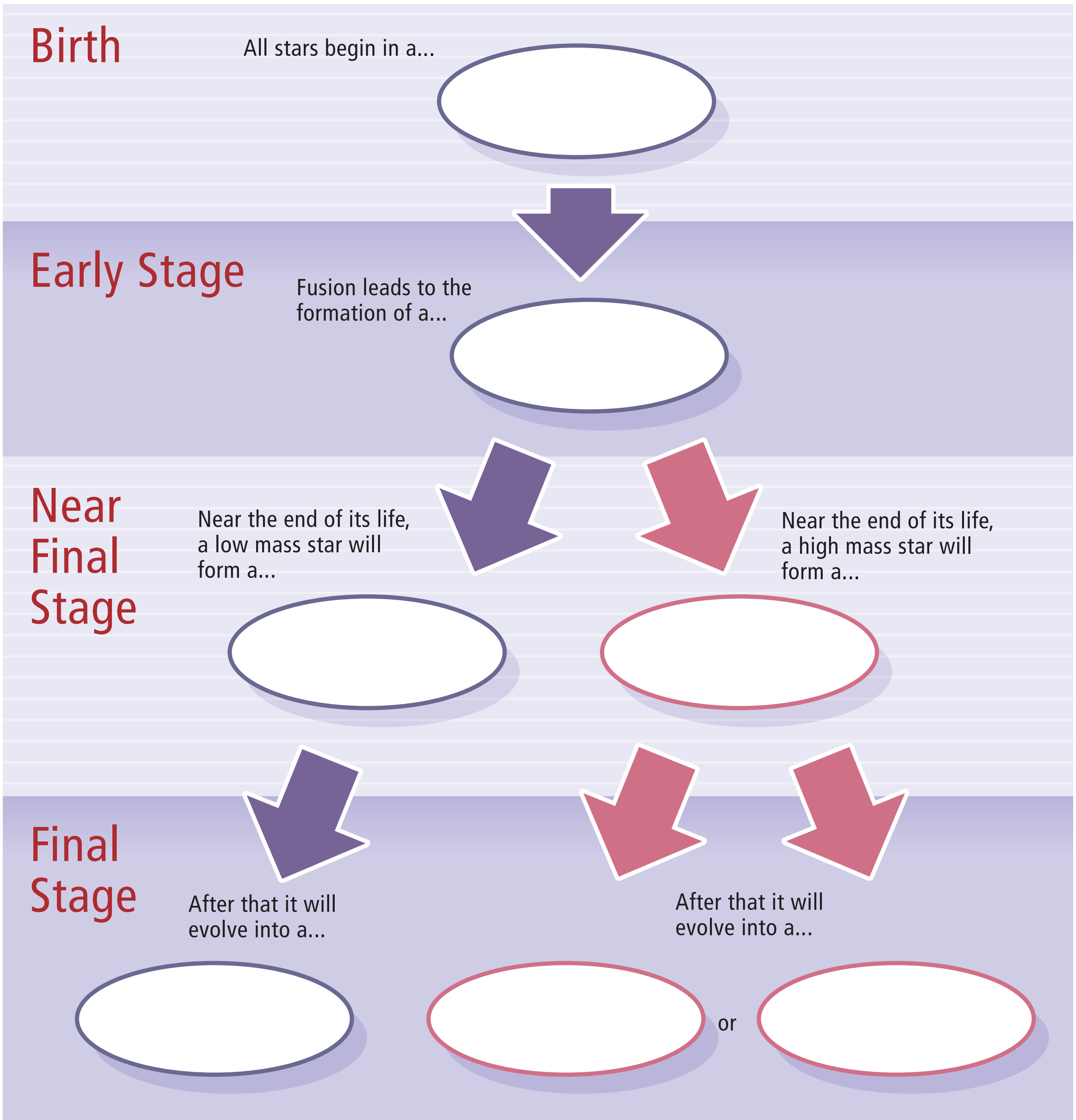
Research a range of techniques scientists have proposed for protecting Earth from Near Earth Objects, particularly asteroids. Use the Internet (start at **www.bcscience9.ca**), magazines, journals, and newspapers. You may also wish to contact a university astronomy department or the nearest chapter of the Royal Astronomical Society of Canada for relevant information.

Report Out

1. Choose one of the techniques you researched and prepare a report, poster, or model to present your findings.
2. Whichever form of presentation you use, be sure to answer each of the following questions.
   (a) Does the technology exist, or is it still being researched?
   (b) How much warning of an incoming asteroid would be required before the technique could be put into action?

Visualizing the Key Ideas

1. Copy the concept map below into your notebook, and complete it by filling in the correct vocabulary words that describe the life cycle of stars.



Using Key Terms

2. In your notebook, state whether each of the following statements is true or false. If false, rewrite the statement to make it true.
   (a) The Big Bang theory suggests the moment at which Earth formed.
   (b) A star's core is like a nuclear furnace.
   (c) A group of millions or billions of planets is called a galaxy.
   (d) Most stars form in a swirling cloud of gas and dust called a star cluster.
   (e) Black holes have such intense gravitational force that not even light can escape from them.
   (f) A collection of planets that forms a pattern in the sky is called a constellation.
   (g) The Hertzsprung-Russell diagram is used to compare the temperature of stars with their distance from Earth.
   (h) The Doppler effect indicates the direction a star is moving relative to Earth.
   (i) Revolution describes a planet spinning on its axis.
   (j) There are eight planets in our solar system.
   (k) Distances between planets are measured in light-years.
   (l) An eclipse occurs when the Moon passes between the Sun and Earth.
   (m) Aboriginal knowledge of the solar system and the universe is communicated from generation to generation by oral (spoken) traditions.
   (n) Rovers are sent to orbit distant planets.

Checking Concepts

10

3. (a) What is the name of the most widely accepted theory of how the universe formed?
   (b) How long ago do astronomers believe the universe formed?
4. American astronomer Edwin Hubble noticed that the light from distant galaxies was shifted toward the red part of the spectrum. What explanation did he give for this?
5. What type of galaxy is shown below?

6. (a) How are galaxies and globular clusters similar?
   (b) How are they different?

11

7. What nuclear process creates energy in stars?
8. Which type of star, in terms of mass, becomes a red giant in its life cycle?
9. What is the name of the part of the Sun that we see as its yellow surface?
10. Why do sunspots appear darker than the areas surrounding them?
11. Early astronomers suggested that planets orbited the Sun in circular paths. What is the true shape of the planets' orbits?
12. List four ways in which Mercury and Jupiter differ.
13. Why do scientists not use astronomical units to measure the distance to stars?

12

14. Ancient people built large structures such as Stonehenge and Chichén Itzá as sites to hold traditional ceremonies. What other purpose were these structures used for?
15. (a) What is the geocentric model of the solar system?
    (b) Why do we now know that the geocentric model of the solar system is incorrect?

16. How is the Moon believed to have formed?
17. Why does the Moon have phases?
18. What is the difference between a solar eclipse and a lunar eclipse?
19. What is the length of a lunar month?
20. List two rewards and two risks of space travel.
21. Explain what terraforming means.

Understanding Key Ideas

22. (a) Which of the following events occurred first?
    (b) Which occurred most recently?
    Formation of galaxies
    Formation of solar system
    Formation of the universe
23. Astronomers believe that the universe is expanding. What does this statement mean?
24. Earth-based telescopes and satellites in space observe solar storms very carefully. How can storms on the Sun affect people on Earth?
25. What would an astronomer conclude if he or she observed the spectral lines of a star shifted to the red end of its spectrum?
26. Imagine that a new planet has been discovered between Mercury and Venus. Describe the characteristics you would expect this planet to have.
27. Name two characteristics that an astronomer can tell from a star's spectrum.
28. Why does it make more sense to try to land a rover on a moon of an outer planet rather than on the planet itself?
29. Explain why constellations appear to move through the night sky.
30. How did British Columbia's Aboriginal peoples use their knowledge of the position and movement of the Sun and planets?
31. Draw a sketch to show the difference between rotation and revolution.
32. Explain why oceans experience high and low tides.
33. Why did Aboriginal people need to understand how the Moon affects Earth?
34. (a) Explain the difference between an optical telescope and a non-optical telescope.
    (b) List two advantages of using a radio telescope rather than an optical telescope.
35. (a) How are probes, satellites, and rovers similar?
    (b) How are they different?

Thinking Critically

36. An astronomer is using parallax to calculate the distances between Earth and two stars. She uses the same reference star for both observations and notices that star A shifts far more than star B.
    (a) What could the astronomer conclude about how the distance to one star compares with the distance to the other one?
    (b) Explain how she is able to make this conclusion.
37. Like planets, some comets orbit the Sun in regular periods of time. Why do astronomers not consider these comets to be planets?
38. Part of Earth is closer to the Sun in January than in July.
    (a) Explain why the northern hemisphere experiences summer in July.
    (b) How might seasons on Earth be affected if Earth were twice as far from the Sun as it is now?
    (c) Explain why the order of seasons would not change if the situation in (b) were true.
39. Imagine that a group of people wanted to colonize a moon of Jupiter. Describe three problems they would have to overcome to be successful.

Developing Skills

40. The figure below shows a solar system many light-years from ours. Astronomers have classified the five planets as shown and determined their distances from the star they orbit. Astronomers believe there is a sixth planet in the solar system located somewhere in the region marked X.

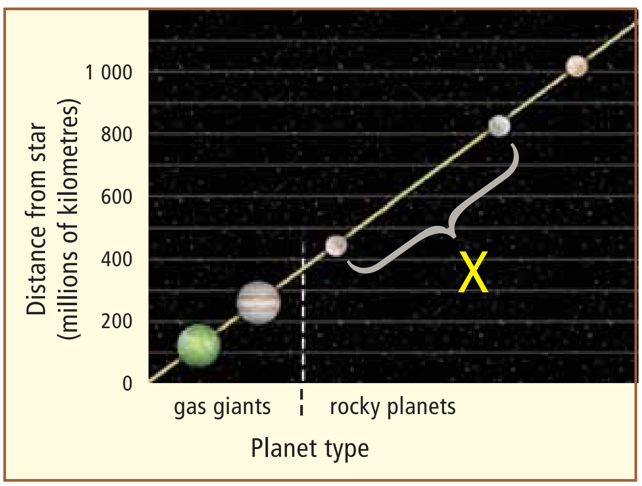
(a) What type of planet would you expect to find in this region?

(b) Explain your answer to (a).

(c) At what distance would you expect the new planet to be found?

(d) Why did you choose this distance?

(e) How is this solar system arrangement different from ours?



41. On Earth, if you drop something it falls to the ground. The rate at which it falls is called the acceleration due to gravity. If you were to drop something while standing on another object in space, the rate of acceleration due to gravity would be different. The table in the next column shows what the mass of a 70 kg person would be if he or she stood on a variety of different objects in space. You can calculate how gravity on Earth compares with gravity on the different objects. The example of Jupiter is provided for you.

Example: How much greater is the gravity on Jupiter than on Earth?

Assume that Earth's gravity = 1

$$\frac{\text{mass of person on object}}{\text{mass of person on Earth}} = \text{gravity on object compared with gravity on Earth}$$

$$\frac{837\ \text{kg}}{70\ \text{kg}} = 2.5$$

(a) Copy the table below into your notebook and calculate the gravity relative to Earth for the asteroid, Moon, Sun, and a neutron star.

Object	Mass on Object (kg)	Gravity Relative to Earth
Earth	70.00	1.0
Jupiter	837.00	2.5
asteroid	0.05	
Moon	12.00	
Sun	1 913.00	
neutron star	19 000 000.00	

(b) Explain what factors determine whether the gravity of an object in space will be more or less than the gravity on Earth.

Pause and Reflect

In this unit, you have learned about the commercialization of space travel. To date, there have only been a few space tourists willing to pay tens of millions of dollars each for a travel opportunity that is usually only for astronauts. Should space travel be available to only astronauts and the rich, or should it be accessible to the general public?