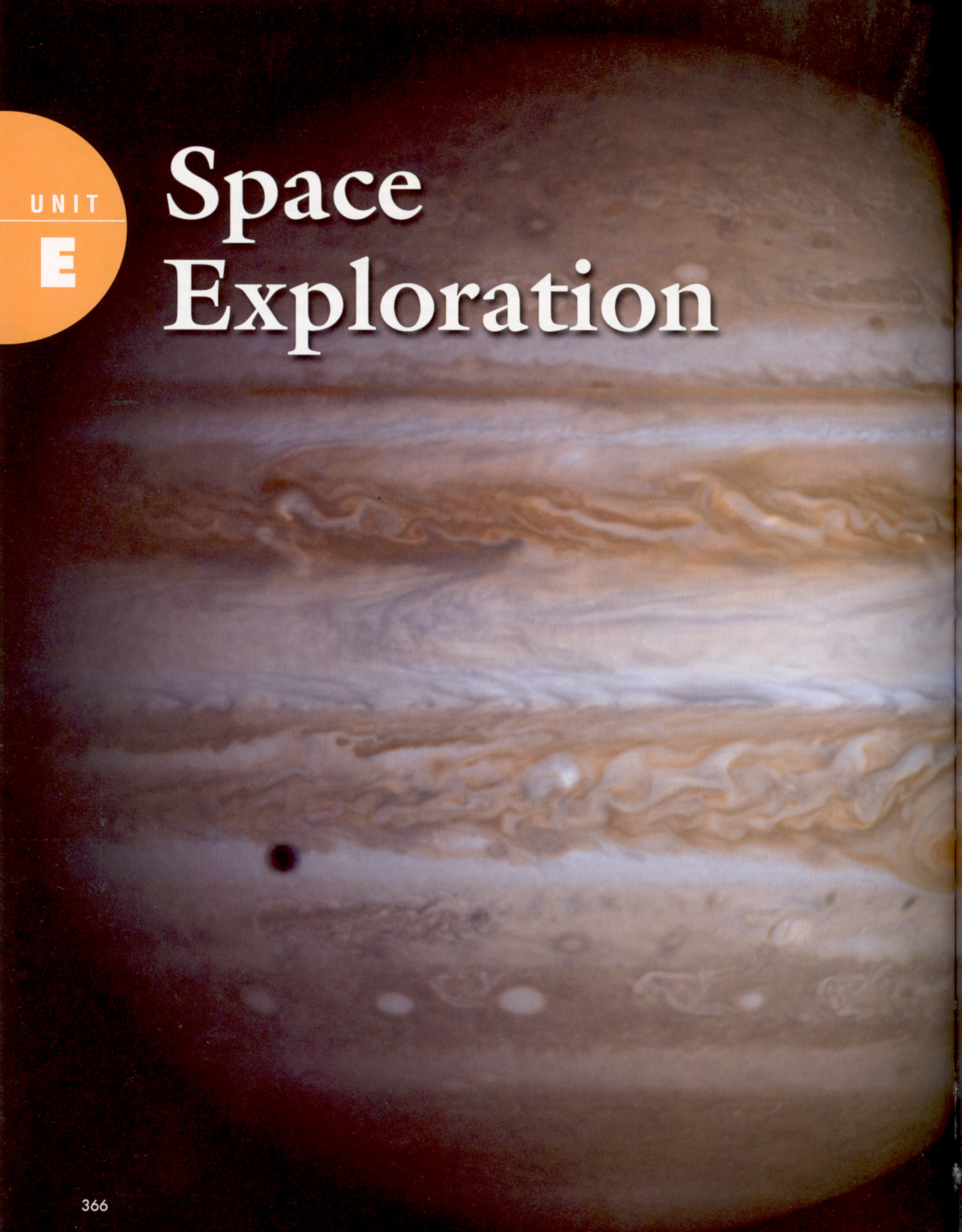
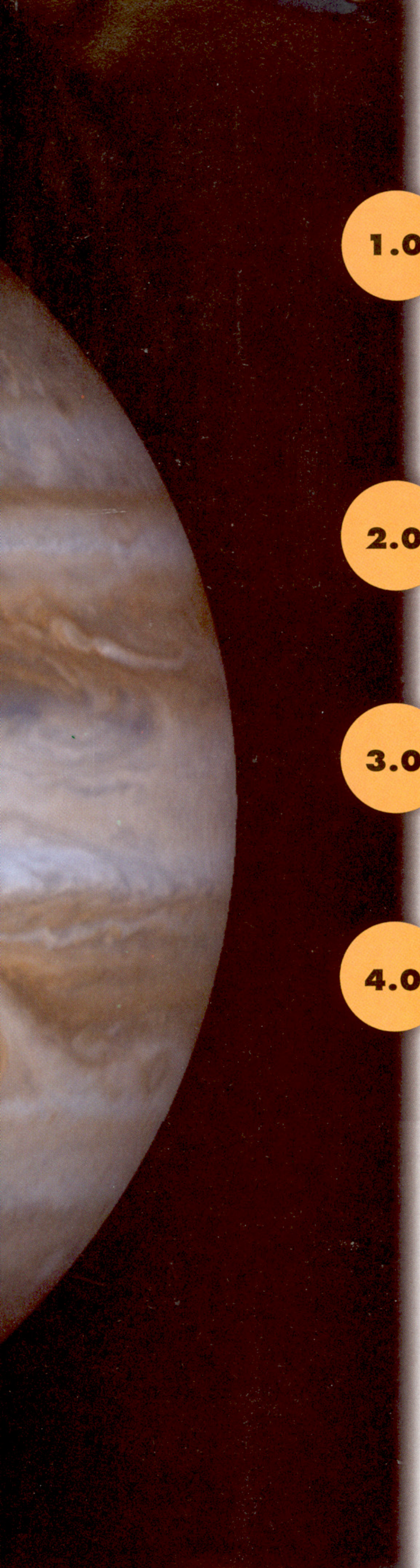
UNIT
E

Space Exploration





In this unit, you will cover the following sections:

1.0

Human understanding of both Earth and space has changed over time.

- **1.1** Early Views About the Cosmos
- **1.2** Discovery Through Technology
- **1.3** The Distribution of Matter in Space
- **1.4** Our Solar Neighbourhood
- **1.5** Describing the Position of Objects in Space

2.0

Technological developments are making space exploration possible and offer benefits on Earth.

- **2.1** Getting There: Technologies for Space Transport
- **2.2** Surviving There: Technologies for Living in Space
- **2.3** Using Space Technology to Meet Human Needs on Earth

3.0

Optical telescopes, radio telescopes, and other technologies advance our understanding of space.

- **3.1** Using Technology to See the Visible
- **3.2** Using Technology to See Beyond the Visible
- **3.3** Using Technology to Interpret Space

4.0

Society and the environment are affected by space exploration and the development of space technologies.

- **4.1** The Risks and Dangers of Space Exploration
- **4.2** Canadian Contributions to Space Exploration and *Observation*
- **4.3** Issues Related to Space Exploration

2.0 Technological developments are making space exploration possible and offer benefits on Earth.

Key Concepts

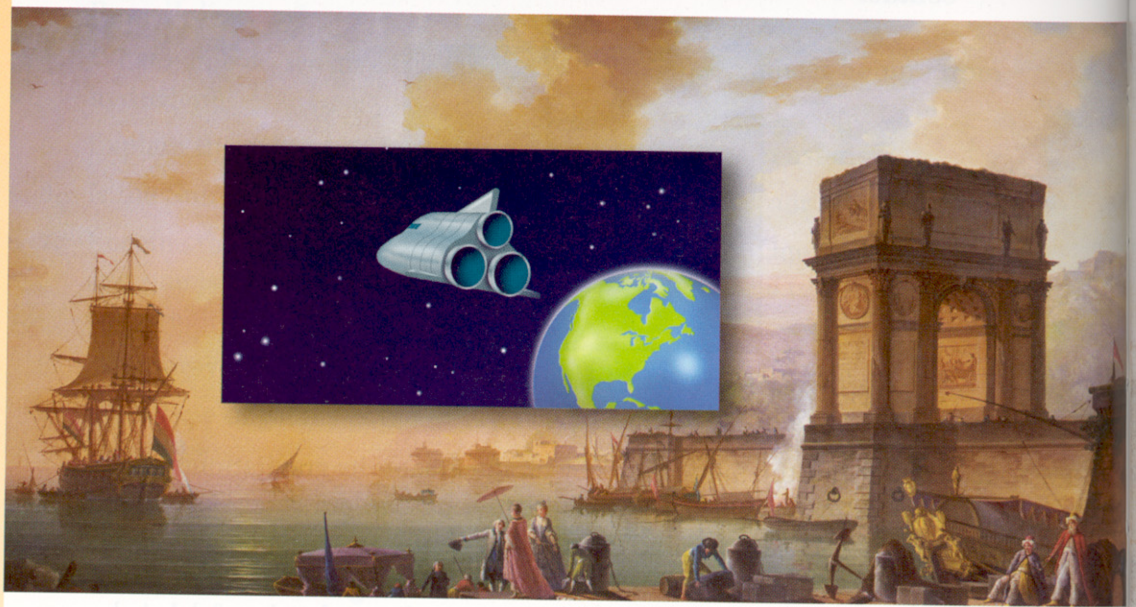
In this section you will learn about the following key concepts:

- technologies for space exploration
- life support technologies
- communication technologies

Learning Outcomes

When you have completed this section, you will be able to:

- analyze space environments, and identify challenges that must be met in developing life-supporting systems
- describe technologies for life-support systems, and interpret the scientific principles on which they are based
- describe technologies for space transport, and interpret the scientific principles involved
- identify materials and processes developed to meet needs in space, and identify related applications
- describe the development of artificial satellites, and explain the major purposes for which they are used



"From space, if you look back just a few degrees away from Earth, you see the black void of the universe—the cold vacuum of space. But when you look back at the Earth, bathed in sunlight, you see where we all live. We are all voyagers in space together."

—Roberta Bondar, Canadian astronaut, quoted in the Canadian Space Agency's "Canada in Space: Destination Earth" (1993)

The lure of leaving Earth to explore other planets and beyond is the same lure that has always drawn humans to explore what lies over the horizon. The urge to venture into uncharted seas, distant countries, and extreme environments, such as the Arctic and Antarctica, is no different than the urge to venture into space.

From the earliest unmanned rockets to the re-useable space shuttles of today, the biggest challenges of exploring space have been finding ways: 1) to go fast enough to achieve orbit around Earth or break free of Earth's gravity and travel to other planets; 2) to keep equipment operating in the extreme environment of space; and 3) to transport people out and back safely. In searching for solutions to these problems, scientists have used technology and technologists have used science.

In this section, you will learn about technologies developed to send objects into space and to make life support and transport in space possible. You will also learn about the spin-offs from such innovations that are being used here on Earth.

For Web links relating to 2.0, visit **www.pearsoned.ca/scienceinaction**

2.1 Getting There: Technologies for Space Transport

Humans have come a long way since their early experiments with rocketry to propel objects high into the sky. Today, hundreds of satellites circle Earth. They transmit non-stop information for use in communications, navigation, research, and weather forecasting. Robotic space probes have investigated all the planets of our solar system except Pluto. As well, manned spacecraft—notably the Russian *Mir* space station, the American space shuttle, and the International space station—have conducted studies while in Earth's orbit.

Getting an object into "space" (outside Earth's atmosphere) first required figuring out what speed an object needed to overcome the force of gravity pulling the object back toward Earth. That speed, it was found, had to be at least 28 000 km/h.

infoBIT

The First Rocketeer
A legend from 16th century China suggests that the first rocket-assisted flight was attempted by Wan-Hu, a Chinese official. Forty-seven rockets were attached to a chair that was connected to two kites. After all the rockets were ignited, there was a massive explosion. No traces of Wan-Hu, the chair, or the kites were ever found.

QUICKLAB

The Power of Steam

Note: This may be done as a teacher demonstration.

Caution!
Be careful around the heating tray to avoid getting a burn.

Purpose

To observe the power of steam propulsion

Procedure

1. Set up the apparatus as shown in Figure 2.1.
2. Fill the beaker until it is about half full of water.
3. Turn on the heating tray to boil the water.
4. When the water starts boiling, record your observations.
5. After you have completed the activity, turn off the power to the heating tray. DO NOT touch the apparatus until it has had sufficient time to cool down.

Questions

6. What made the pinwheel turn?
7. Why was the funnel put over the beaker upside down?
8. Would the pinwheel have turned if no funnel were used? Explain your answer.
9. How could you improve this set-up to make the pinwheel spin faster?

Materials & Equipment

- plastic pinwheel
- test-tube clamp
- thermometer clamp
- plastic funnel to fit beaker
- one 250-mL beaker
- water
- heating tray
- pencil and notepaper

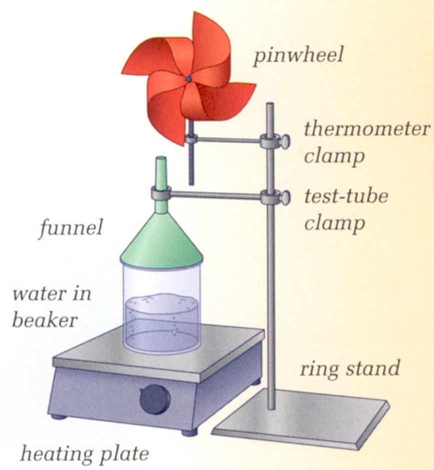


Figure 2.1 Step 1

QUICKLAB

Stabilizing Rocket Flight

Have you ever wondered why rockets have fins?

Purpose

To test the effects of fins in stabilizing a rocket for flight

Procedure

1. Cut a strip about 13 cm long and 3 cm wide from the paper. Roll the strip snugly around the pencil and tape it closed to create a long tube (your "rocket"). Twist the end of the paper around the pencil point to make the nose cone.
2. Slip the pencil out the other end of the tube. Gently blow into the open end of the tube and feel for leaks along its length. If air is escaping, seal the leaks with more tape.
3. Test Flight 1: Insert one end of the straw into your rocket. With the other end of the straw in your mouth, tilt your head back slightly and blow a quick puff of air into the rocket. Observe how the rocket flies.
4. Retrieve the rocket. From the left-over paper, cut out two sets of fins. Tape these to the tube as shown below. (Hint: Adding tabs to the fins makes them easier to tape to the tube.)
5. Test Flight 2: Again, launch your rocket with the straw and observe the rocket's flight.

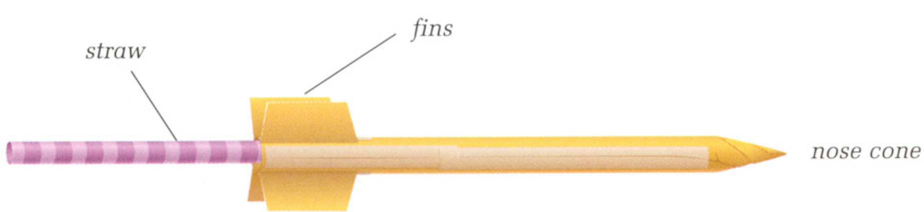


Figure 2.6 Model rocket

Questions

6 How does the rocket's performance in the first test compare to that in the second test? Write a brief conclusion about how fins affect a rocket in flight.

7 Do you think that fins would have much effect on a rocket's performance outside Earth's atmosphere?

Materials & Equipment

- a sheet of paper
- scissors
- a pencil (at least 14 cm long)
- tape
- a drinking straw (a little narrower than the pencil)

Caution!
Point your rocket in a safe direction only, away from other people.

CHECK AND REFLECT

Key Concept Review

1. Briefly describe how working on the International Space Station might affect a person psychologically.
2. How does living in a microgravity environment for a long period of time affect the human body?
3. Why must a space suit be flexible?
4. How many people are there in a typical crew on the International Space Station?

Connect Your Understanding

5. Name four necessities of an astronaut, in order to work outside a spacecraft.
6. Explain why a regular ballpoint pen will not work in space.
7. What problems do astronauts encounter when trying to eat and swallow their food?

Extend Your Understanding

8. The following table shows the problems that the human body encounters when it is in space for a long time. Copy the table into your notebook and write a recommended solution to each problem. This may require some out of class research.

Problems of Living in Space	Recommendations
1. Loss of body mass	
2. Decrease in the production of red blood cells	
3. Loss of bone mass and density	
4. Loss of calcium, electrolytes, and plasma with excretion of body fluids	
5. Loneliness, isolation, depression	

9. Imagine you were going to spend 3 months in the International Space Station. Make a list of all the items you would like to bring for recreation during that period. Remember the storage and mass limitations.
10. Adjust your list in question 9 so that the total mass of the items equals 1 kg (your allowed limit). Explain which item is the most important item to you and why.

Satellites as Personal Tracking Devices

Imagine always knowing your position on the planet, accurate to within a few metres. The Global Positioning System (GPS) lets you do just that. This technology was designed to give people, wherever they are, their location on the ground at any time. Twenty-four GPS satellites are in orbit around Earth, which means that at least three are above any given location in the world at any given moment. Radio signals from the satellites are picked up by a hand-held receiver (which is about the size of a small hand-held video game). The signals are translated by a computer in the receiver, which then shows on a digital display the operator's position in relation to the satellites.

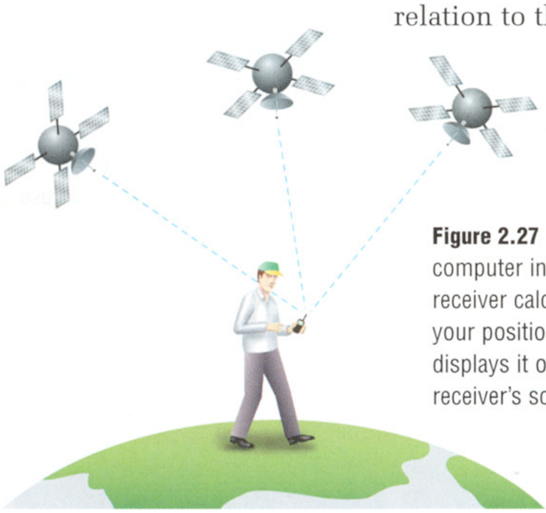


Figure 2.27 The computer in a GPS receiver calculates your position and displays it on the receiver's screen.

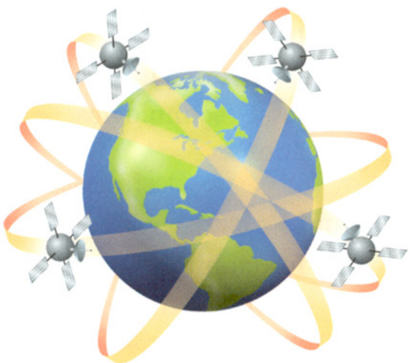


Figure 2.28 With 24 satellites in orbit, there are at least three above the horizon, relative to a person's location on Earth, at any one time.

SKILL PRACTICE

On Location with GPS

This activity illustrates in a two-dimensional way how the Global Positioning System uses satellite signals to determine the position of someone holding a GPS receiver. You will need a pencil and a geometry compass.

1 Your teacher will give you an enlarged copy of the map shown here . Imagine that you are standing in a location somewhere on this map when you turn on your GPS receiver.

2 Satellite 1 transmits a radio signal to the receiver in your hand and the GPS device calculates that you are 1000 km from the satellite. Using the compass, measure 1000 km on the scale provided.

3 Next, place the compass point on the position labelled Satellite 1 and draw a circle that has a radius equal to the distance from the satellite.

4 Repeat steps 2 and 3 for Satellites 2 and 3, using the information in the table.

5 The spot where all three circles meet on the map indicates your position on the ground.

6 Suggest how satellites know where their position is in relation to Earth.

Satellite	Distance to GPS Receiver
1	1000 km
2	300 km
3	940 km

ACTIVITY E-6

Inquiry

HOW FAR IS IT?

The Question

How accurately can the length of a playing field be measured using triangulation?

The Prediction

You will be calculating percent error for this activity. Predict the degree of accuracy that you expect. Example: *Our calculations will be off by 10%.*

Materials & Equipment

- measuring tape (at least 50 m long)
- two metre-sticks
- protractor
- paper
- pencil
- ruler

Procedure

1. Copy the table below into your notebook.

Baseline length (m)	Angle from position (A) (°)	Angle from position (B) (°)	Calculated length of field (m)	Actual length of field (m)	Percent error (%)
10					
20					
50					

2. Go outside to a large flat area, ideally a soccer or football field.
3. Working in a small group, use the measuring tape to measure off a baseline of 10 m along the goal line of the field.
4. Stand a metre-stick in the ground at each end of the baseline to serve as guideposts (A) and (B).
5. Standing at one end of the baseline (A), looking directly at the right goal post at the far end of the field. Determine the straight line betweem A and the right goal post. Measure the angle between this line and the baseline. In your data table, record the angle you found. Repeat this step from the other end of the baseline (B) and again record the angle.
6. Repeat steps 3 to 5, using a baseline of 20 m and then one of 50 m.

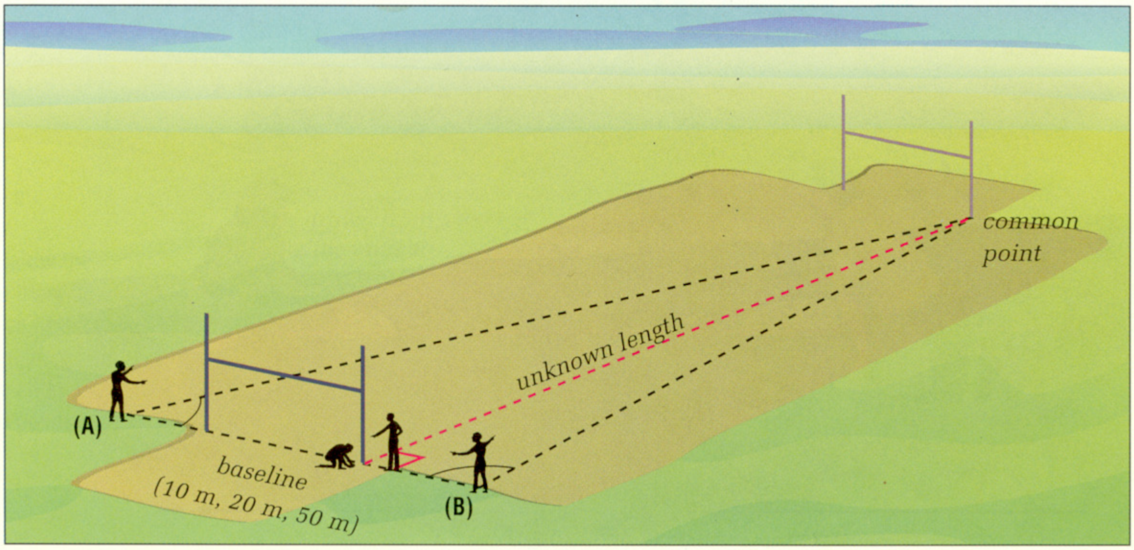


Figure 3.21 Step 5

Analyzing and Interpreting

7 For each baseline length, make a scale drawing of a triangle, using the two angles you measured each time. Use a scale of 1 cm = 5 m.

8 On each of your scale drawings, measure the length of the field and record your results in the table. Do you get the same length for all three baselines? Explain your answer.

9 Find the actual length of the field (either measure it directly, or ask the athletic director of your school). Add this information to your table.

10 Calculate the accuracy of your results for each baseline length. Use the percent error equation below. Record these figures in the table.

$$\text{percent error} = \frac{(\text{actual value} - \text{measured value})}{\text{actual value}} \times 100$$

11 Determine the average of your three lengths and calculate the percent error.

Forming Conclusions

12 How accurate was your calculated average length of the playing field?

13 Which baseline resulted in the most accurate field length? Explain why that was.

14 How close were you to your predicted error?

Applying and Connecting

For a technique like this to work, precise measurements must be made. With reference to your percent error, describe what you think may be sources of error in this activity. What are the limitations of using triangulation on the ground? How do these limitations compare with those that apply when one is using triangulation to find distances to stars?

Unit Summary: Space Exploration

Key Concepts / Section Summaries

1.0

Key Concepts

- technologies for space exploration and observation
- reference frames for describing the position and motion of bodies in space
- distribution of matter through space
- composition and characteristics of bodies in space

1.0 Human understanding of both Earth and space has changed over time.

- Ancient cultures explained their observations of bodies in space with myths and legends.
- Technology used to study space has evolved throughout history. With each technological advance came better explanations for what was observed.
- The planet Earth orbits a star that is one of billions of stars in a spiral galaxy called the Milky Way.
- Years of accurate data collection and advances in telescope technology have improved our scientific understanding of the solar system.
- A star's position when viewed from a particular point, can be determined given the compass direction (azimuth) and the altitude.

2.0

Key Concepts

- technologies for space exploration
- life support technologies
- communication technologies

2.0 Technological developments are making space exploration possible and offer benefits on Earth.

- Space transport technology began with simple rockets, and today's spacecraft are still launched using the same principles.
- For humans to live outside of Earth's atmosphere, the basic requirements for life must be met in space. This means that food, shelter, water, and air must be produced artificially.
- Satellites orbiting Earth transmit information to us about weather, agriculture, and natural resources. We can also use space technology to locate our exact position on Earth.
- Many concepts designed for use in space have found applications on Earth. These include materials used for communication, medicine, entertainment, and transportation.

3.0

Key Concepts

- technologies for space exploration and observation
- composition and characteristics of bodies in space
- communication technologies
- triangulation and parallax

3.0 Optical telescopes, radio telescopes, and other technologies advance our understanding of space.

- Reflecting and refracting are two types of optical telescopes. Reflecting telescopes use mirrors to focus light. Refracting telescopes use lenses to focus light.
- Visible light is only one part of the electromagnetic spectrum. This spectrum includes infrared, X-ray, ultraviolet, and gamma radiation. Specific technologies are designed to detect these forms of radiation that come to us from space.
- By observing the shift in the spectrum of a star, we can tell if it is moving toward or away from Earth.
- Triangulation and parallax are two techniques for measuring distances in space.

4.0

Key Concepts

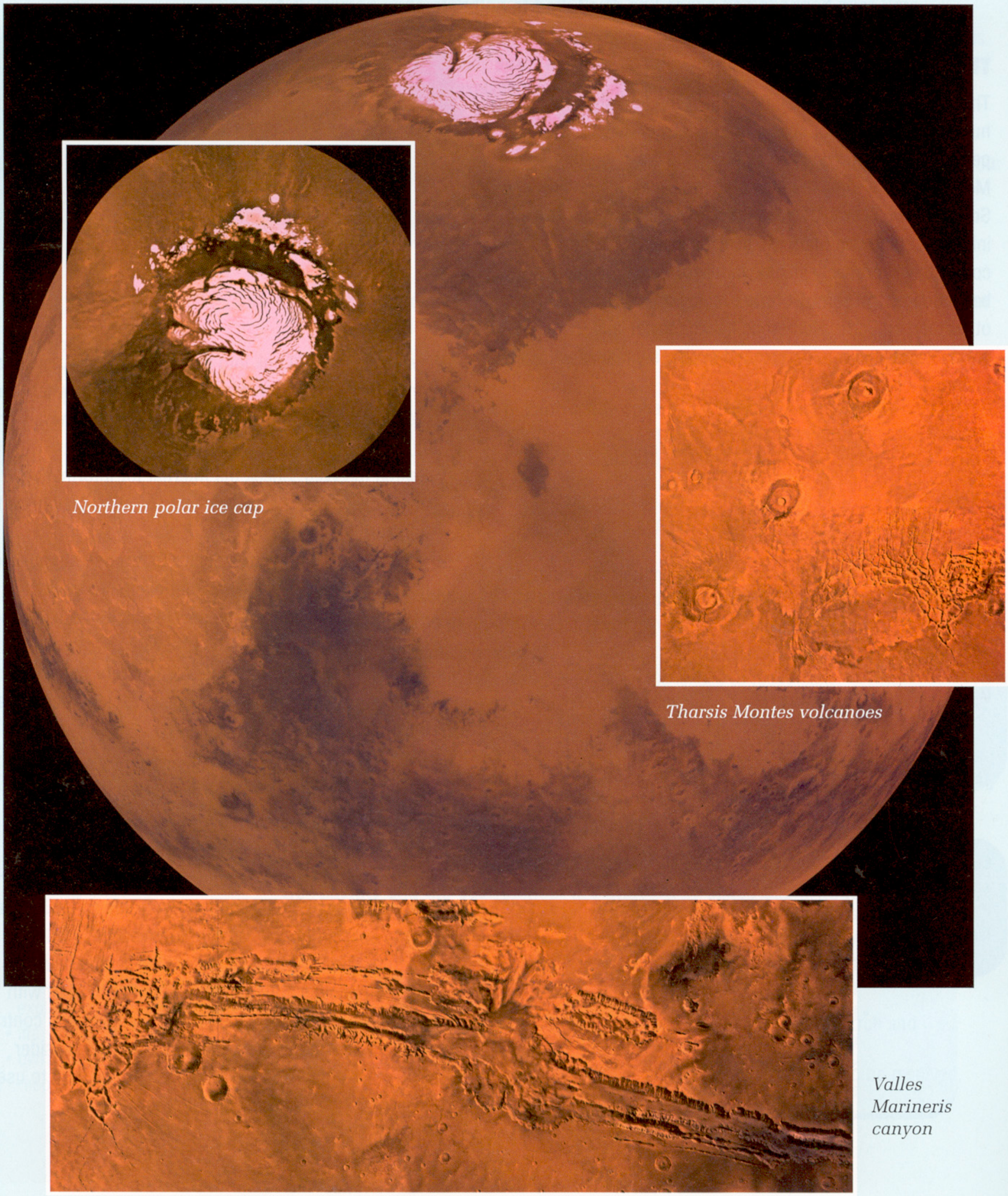
- space exploration risks and dangers
- technologies for space exploration and observation
- life support technologies
- ownership and use of resources in space

4.0 Society and the environment are affected by space exploration and the development of space technologies.

- There are many dangers associated with both manned and unmanned space exploration. Some of those dangers are posed by debris floating in space around Earth and by solar and cosmic radiation.
- Canada has had a long and proud history of participation in space research and exploration.
- Many issues concerning ownership of space and its resources are yet to be resolved. These include political, environmental, and ethical issues.

PROJECT

MISSION TO MARS



Northern polar ice cap

Tharsis Montes volcanoes

Valles Marineris canyon

Getting Started

We have learned much about Mars from telescopes, robotic probes, and satellites, but to really understand the nature of the planet, we will have to see it for ourselves. This project will allow you to apply what you have learned in this unit about space exploration, the requirements of living in space, and the way in which technology and science go hand in hand to advance our knowledge about the universe. You will be designing the first mission to Mars. Where you land is up to you. You can choose between the Valles Marineris canyon, the Tharsis Montes volcanoes, and the northern polar ice cap.

Your Goal

The project has three parts.

- First, design an unmanned probe that will safely touch down and explore the target area on Mars that you have selected.
- Second, design a base camp for a team of eight astronauts (four women and four men) who will be the first humans to colonize Mars. Scale models must be made for both the probe and the base camp.
- Third, decide which feature to study and how.

What You Need to Know

The mission to Mars will last approximately 22 months. That time includes the eight months it will take to travel there, six months to explore the surface, and eight months to return to Earth. In addition to what you learned about the nature of Mars in subsection 1.4, you should keep in mind that dust storms with winds up to 900 km/h can cover most of the planet for weeks. Also, communication signals from Mars can be expected to take about 8 min to reach Earth. Your base camp design must include laboratories, food, water and air supplies, and living space. It must also reflect which feature your mission is going to study and how.

Steps to Success

1 Working with two or three partners, select the area of Mars that will be the focus of your mission. Brainstorm ideas for both the type of landing probe you wish to design and the style of base camp. Using a variety of sources, research the characteristics of the surface feature your mission is going to study. With your partners, identify problems resulting from the conditions on Mars and discuss possible design solutions.

2 Complete two scale drawings, one for the probe, and one showing the layout of the base camp. Include ideas about how the astronauts will travel on the surface of the planet.

3 Construct scale models of your probe and the base camp using materials of your choice.

4 Write descriptions of a) the tasks to be performed during the mission, b) the features of your landing probe, and c) the features of your base camp.

5 Present your work to the class and explain the rationale behind your designs.

How Did It Go?

6 In your notebook, answer each of the following questions in a paragraph.

a) How did your research influence your design for each part of the mission?

b) Did you use current technology, or did you design your own technology to meet the needs of the mission?

c) How effective was the group decision-making process? How were disagreements resolved?

d) After seeing your classmates' presentations, are there any changes you would make to your designs? Explain your answer.

UNIT REVIEW: SPACE EXPLORATION

Unit Vocabulary

1. Make a brief sketch that illustrates each of the following vocabulary words or terms:
   geocentric
   heliocentric
   elliptical
   black hole
   constellation
   galaxy
   solar system
   comets
   meteors
   astronomical unit
   light-year
   Hubble Space Telescope
   spectrum
   space junk

Key Concept Review

1.0

2. What information did constellations provide early sky-watchers?
3. What is the first stage in a star's life called?
4. All stars start from the same "building blocks." What element forms these building blocks?
5. Define a light-year.
6. a) How many stars are estimated to be in the Milky Way galaxy?
   b) How many galaxies are estimated to be in the universe?
7. Explain why you could not locate a star by knowing only its altitude in the sky.

2.0

8. Draw a rocket and label its main parts. What propels a rocket forward?
9. List five basic requirements for humans living in space.
10. Describe some of the effects on the human body that result from living in microgravity .
11. How does the Global Positioning System work? Illustrate your answer.
12. Name four materials or items we use on Earth that were originally designed for use in space.

3.0

13. What part of the electromagnetic spectrum can humans detect?
14. Explain how astronomers use multiple small telescopes to imitate one large telescope.
15. What is the Doppler effect and how is the principle applied in determining star motion?
16. Explain how the process of triangulation can determine distances on the ground.
17. What aspect of Earth makes it difficult to observe the X-rays, gamma rays, and ultraviolet rays that come from space?

4.0

18. Name four risks associated with space exploration.
19. List three different contributions Canada has made to the space industry.
20. Why is space junk an issue in space exploration?

Connect Your Understanding

21. Describe what you consider to be the most important issues facing space exploration.
22. Describe how space exploration, or its spin-off products, have affected you personally.
23. In the late 1970s, when Skylab was due to re-enter Earth's atmosphere, insurance companies were offering policies to insure people who might get hit by pieces of the space station that reached Earth's surface. Explain why it would be highly unlikely for anyone to ever need to use such an insurance policy.
24. If space technology and exploration affect the planet as a whole, how should decisions regarding their use be made?

Extend Your Understanding

25. Explain why looking at stars in the night sky is considered looking into the past.
26. As soon as a comet gets close enough to the Sun to feel the Sun's effects, the gases in the comet begin to bubble (effervesce) and it leaves a trail along the path it has followed. When a comet's tail is visible, it always points away from the Sun. Explain why this occurs.
27. If we knew a galaxy was moving away from Earth, but we see a star in the galaxy with a spectrum shifted towards the blue, what would we conclude?

Practise Your Skills

28. Sketch a diagram that illustrates your understanding of the differences between reflecting, refracting, and radio telescopes.
29. Construct a Venn diagram that compares and contrasts the characteristics of Mars and Earth.
30. Sketch how an ellipse changes in shape when the foci (the two pins that you used in the activity on page 375) are moved farther apart from each other. Relate this to the orbits of planets around the Sun.

Self Assessment

31. Describe three facts that you found most interesting in this unit which you did not know before.
32. What are two questions that you have about technology used for space exploration and travel?
33. Has your opinion about the value of space exploration changed in the course of reading this unit? Explain your answer.
34. Which spin-off of the space industry has had the greatest effect on your life?

Focus On — Science and Technology

In this unit, you have investigated science and technology related to space exploration. Consider the following questions.

35. As improvements are made to technology, our understanding of the universe around us advances. Should decisions that could potentially affect the entire planet be made by only a handful of scientists? Explain your answer.
36. Describe three ways in which the technology from space exploration has potential to benefit all people in the future. What drawbacks to the development of this technology can you think of? Give reasons to support your answer.
37. When making decisions about space exploration and the exploitation of resources in space, what do you feel are essential questions to ask?