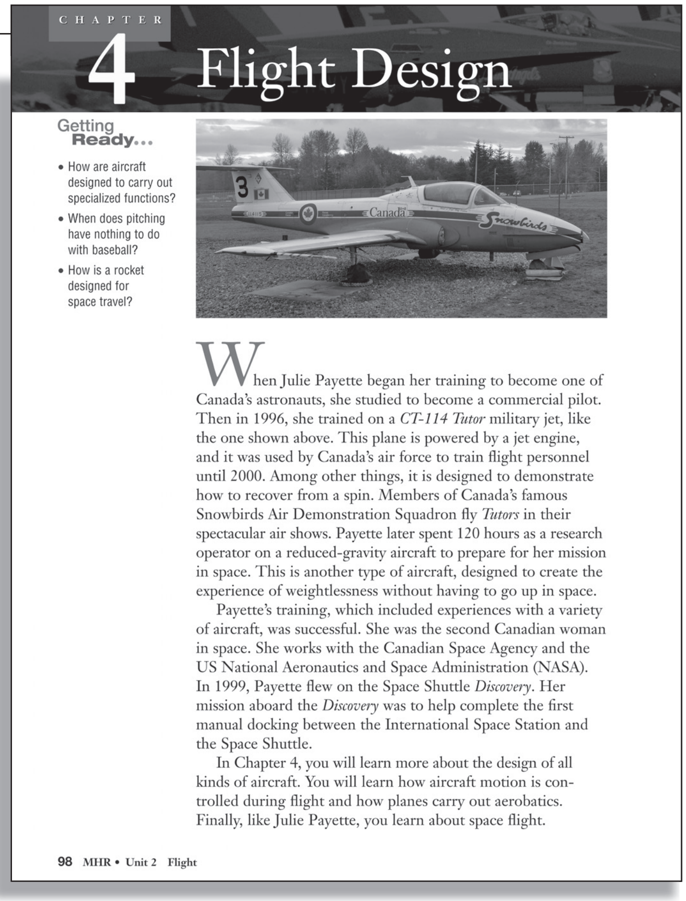
USING THE CHAPTER 4 OPENER

TEACHING STRATEGIES

- **Begin the Lesson**—The Canadian *CT-114 Tutor* is a training plane used by the Canadian Air Force. In 1971, the Snowbirds Demonstration Team was formed. Team members flew the *CT-114 Tutor* until 2001. The Snowbirds perform aerobatics in air shows all over North America. Ask if any students have ever been to an air show or watched a plane doing aerobatics. Have students describe the experience to their classmates. What did they find the most interesting? What was the most surprising?
- Science logbook: Have students continue the flight section in their logbooks by asking and answering questions to determine their current knowledge of flight design and aircraft construction.
  Possible questions include the following:
  – Who designs aircraft?
  – How are aircraft designs related to specific functions?
  – How are aircraft tested?
  – How is the motion of an aircraft controlled during flight?
  – How did aircraft change over time?
  – How are aircraft different from spacecraft?
  Have students share their ideas in small groups. As each new section is explored, have students ask new questions and record their responses in their logbooks.
  – Have students build their own key terms lists by defining the key terms in their own words before beginning each section and updating their definitions after the section is finished. Use BLM 4.1 Key Terms to assess students' definitions of key terms.
- **During Teaching**—Complete the Getting Ready questions as a class. Encourage students to express their opinions and prior knowledge about each point. Review the *What You Will Learn*, *Why It Is Important*, and *Skills You Will Use* sections with students before beginning the chapter. Ask students to provide other reasons why it is important to learn about flight design.
- **After Teaching**—Discuss the role Snowbirds play in Canadian aerobatics. A *CT-114 Tutor* (*Snowbird*) is on display at the Shearwater museum, along with other aircraft.


CHAPTER 4 Flight Design

Getting Ready...

- How are aircraft designed to carry out specialized functions?
- When does pitching have nothing to do with baseball?
- How is a rocket designed for space travel?

When Julie Payette began her training to become one of Canada's astronauts, she studied to become a commercial pilot. Then in 1996, she trained on a *CT-114 Tutor* military jet, like the one shown above. This plane is powered by a jet engine, and it was used by Canada's air force to train flight personnel until 2000. Among other things, it is designed to demonstrate how to recover from a spin. Members of Canada's famous Snowbirds Air Demonstration Squadron fly *Tutors* in their spectacular air shows. Payette later spent 120 hours as a research operator on a reduced-gravity aircraft to prepare for her mission in space. This is another type of aircraft, designed to create the experience of weightlessness without having to go up in space.

Payette's training, which included experiences with a variety of aircraft, was successful. She was the second Canadian woman in space. She works with the Canadian Space Agency and the US National Aeronautics and Space Administration (NASA). In 1999, Payette flew on the Space Shuttle *Discovery*. Her mission aboard the *Discovery* was to help complete the first manual docking between the International Space Station and the Space Shuttle.

In Chapter 4, you will learn more about the design of all kinds of aircraft. You will learn how aircraft motion is controlled during flight and how planes carry out aerobatics. Finally, like Julie Payette, you learn about space flight.

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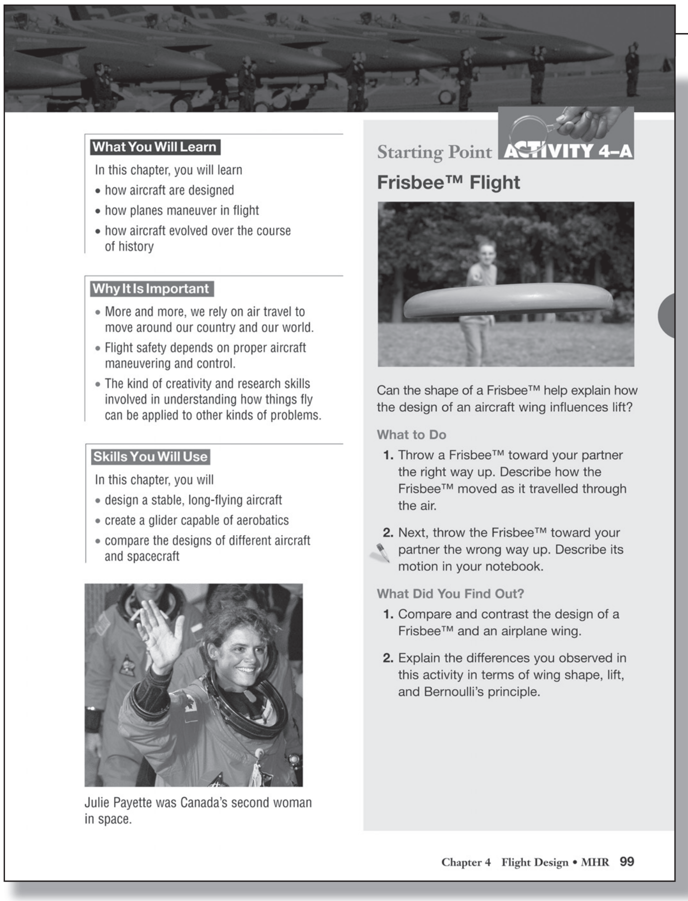
Getting Ready Answers

- **How are aircraft designed to carry out specialized functions?** Aircraft are designed to carry out specialized functions in a variety of ways: stunt planes have special surfaces on them (control surfaces) that help them perform aerobatics; some aircraft have design features that allow them to use alternative fuels, such as solar or pedal power; fighter jets have aerodynamic shapes that allow them to fly faster due to decreased drag; stealth bombers have special shapes and paint coatings that help them avoid radar detection; surveillance aircraft have technology that allows them to be flown by remote control from the ground and stay in the air for long periods of time; helicopters have special "wings" that let them hover in place to perform tasks such as lifting and building.
- **When does pitching have nothing to do with baseball?** Pitching can have nothing to do with baseball if you are referring to pitching of an aircraft, a motion where the nose and tail of the plane alternately rise up and dip down.
- **How is a rocket designed for space travel?** Rockets are designed for space travel in the following ways: they are powered by rocket engines, which can work in both the atmosphere and in the vacuum of space; these rocket engines provide the enormous amount of thrust a rocket needs to break free of gravity; they have features that protect them from the heat generated when they re-enter the atmosphere and from objects that may strike them in space.
- **Further question: How does the angle of a wing affect flight?** The angle of a wing affects flight


What You Will Learn

In this chapter, you will learn
- how aircraft are designed
- how planes maneuver in flight
- how aircraft evolved over the course of history

Why It Is Important
- More and more, we rely on air travel to move around our country and our world.
- Flight safety depends on proper aircraft maneuvering and control.
- The kind of creativity and research skills involved in understanding how things fly can be applied to other kinds of problems.

Skills You Will Use

In this chapter, you will
- design a stable, long-flying aircraft
- create a glider capable of aerobatics
- compare the designs of different aircraft and spacecraft

Julie Payette was Canada's second woman in space.

Starting Point ACTIVITY 4–A

Frisbee™ Flight

Can the shape of a Frisbee™ help explain how the design of an aircraft wing influences lift?

What to Do
1. Throw a Frisbee™ toward your partner the right way up. Describe how the Frisbee™ moved as it travelled through the air.
2. Next, throw the Frisbee™ toward your partner the wrong way up. Describe its motion in your notebook.

What Did You Find Out?
1. Compare and contrast the design of a Frisbee™ and an airplane wing.
2. Explain the differences you observed in this activity in terms of wing shape, lift, and Bernoulli's principle.

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in two ways. First, the angle must be positive (the front of the wing must be tipped slightly upward) for lift to be generated. This deflects air downward and creates lift. Second, if the angle is too steep, drag will result. If there is too much drag, the aircraft will not become or remain airborne.

STARTING POINT ACTIVITY 4-A FRISBEE™ FLIGHT

Purpose
- Students fly a Frisbee™ to determine how wing shape influences lift.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 week before	– Gather together enough Frisbees™ so there is one for every two students.

MATERIALS
Per group: – Frisbee™

Suggested Time
- 10 min

Safety Precautions
- Caution students to only throw the Frisbee™ to their partner, not at other students.

HINTS & HELPS
- Try to find Frisbees™ in a variety of weights and sizes for students to experiment with.

Implementing the Activity
- This activity should be done in partners.
- Review Bernoulli's principle and lift from the previous chapter after students complete the What To Do steps but before they begin the What Did You Find Out? questions.
- Encourage students to write or draw the results in their logbooks.

Activity Wrap-Up
- What Did You Find Out? questions can be completed as part of a wrap-up for this activity.

Assessment Option
- Use Learning Skills Rubric 5 Research Project and/or Learning Skills Rubric 6 Communication for Find Out Activity 4-B Wind Tunnel Presentation

What Did You Find Out? Answers
1. Accept all reasonable answers. The main similarities and differences follow; however, it is unlikely that students will notice all of these differences. Differences: A Frisbee™ is essentially a flying wing. Some airplanes are flying wings as well, but most have two wings. Most airplane wings have special surfaces (control surfaces) to help control the flight of the airplane. A Frisbee™ doesn't have any of these surfaces. Further, airplane wings have a positive wing angle (the front of the wing is tipped up). The wing angle of a Frisbee™ depends on the angle it is thrown at, but most people throw it so it has a minimal angle. Similarities: Like most airplane wings, a Frisbee™ has a curved upper surface and a flat lower surface, which help generate lift. Both are also smooth, rigid structures.
2. Most students will have observed that the Frisbee™ flew well when thrown with the curved side up, but it did not fly well and fell to the ground quickly when it was thrown curved-side down. These results are due to the shape of the Frisbee™ "wing." According to Bernoulli's principle, when air flows faster, its pressure decreases. Air flows faster over the curved surface of the Frisbee™. Thus the air flowing along the flat surface exerts more pressure. If the flat surface is on the bottom, this pressure provides lift and the Frisbee™ flies well. If the flat surface is on the top, this pressure forces the Frisbee™ downward and it does not fly well or at all.

SECTION 4.1 DESIGNING AIRCRAFT

What Students Do in Section 4.1

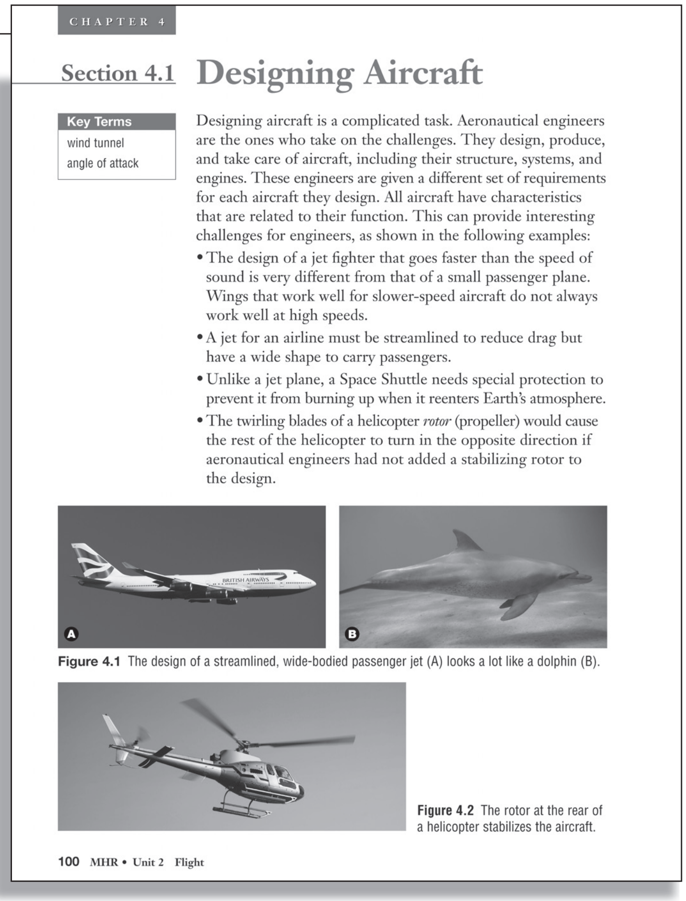
- investigate specialized aircraft design
- research wind tunnels and how they are used in aircraft design
- build a wind tunnel and suspend a wing in different positions within it to determine how wing angle and shape influence lift
- define angle of attack and discover how it influences lift

BACKGROUND INFORMATION

- Aeronautical engineering is one of two branches of aerospace engineering. The other branch is astronautical engineering. While aeronautical engineering deals with aircraft that only fly within Earth's atmosphere, astronautical engineering deals with space flight. Some of the different elements involved in aeronautical engineering are highlighted below.
  - Fluid mechanics: how air flows over parts of the aircraft, such as its wings
  - Propulsion: how aircraft are propelled through the air
  - Aircraft structures: how aircraft are designed to withstand the forces that act during flight
  - Material science: study of the materials used to build aircraft
  - Avionics: design and programming of in-flight computer systems

TEACHING STRATEGIES

- **Begin the Lesson**—Explain the role of aeronautical engineers to students. Have students brainstorm a list of jobs/responsibilities an aeronautical engineer is likely to have.
  - As a class, go over the four design challenges given in the student textbook. Have students brainstorm ways to address or overcome these challenges before reading the passage.
- **During Teaching**—Draw students' attention to Figure 4.1 A and B on page 100. How are the aircraft and the dolphin similar in design? Why do students think it is beneficial for an aircraft to have a shape similar to that of a dolphin?



CHAPTER 4

Section 4.1 Designing Aircraft

Key Terms
wind tunnel
angle of attack

Designing aircraft is a complicated task. Aeronautical engineers are the ones who take on the challenges. They design, produce, and take care of aircraft, including their structure, systems, and engines. These engineers are given a different set of requirements for each aircraft they design. All aircraft have characteristics that are related to their function. This can provide interesting challenges for engineers, as shown in the following examples:

- The design of a jet fighter that goes faster than the speed of sound is very different from that of a small passenger plane. Wings that work well for slower-speed aircraft do not always work well at high speeds.
- A jet for an airline must be streamlined to reduce drag but have a wide shape to carry passengers.
- Unlike a jet plane, a Space Shuttle needs special protection to prevent it from burning up when it reenters Earth's atmosphere.
- The twirling blades of a helicopter *rotor* (propeller) would cause the rest of the helicopter to turn in the opposite direction if aeronautical engineers had not added a stabilizing rotor to the design.

Figure 4.1 The design of a streamlined, wide-bodied passenger jet (A) looks a lot like a dolphin (B).

Figure 4.2 The rotor at the rear of a helicopter stabilizes the aircraft.

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SPECIALIZED DESIGN

BACKGROUND INFORMATION

- The solar plane shown in Figure 4.3 on page 101 is the NASA *Pathfinder*. It is essentially a solar-powered flying wing that is remotely controlled from the ground. The plane can stay airborne for months and may eventually be one of many solar planes used to complete high-altitude, scientific research. The solar panels on the plane's wing provide power for its electric motor, computer, and communications system. The plane also has a back-up battery just in case. The *Pathfinder* flies at a very low airspeed, with a maximum speed of 40 km/h.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students if they have seen any specialized or unusual aircraft, either in person, on television or in films, or in books. Ask them to write a description of the aircraft in their logbooks. As a class, try to guess at the function the aircraft was designed to carry out. How might its design help it accomplish this function?

Specialized Design

Aeronautical engineers often design planes to do very specialized tasks. It is new technology that makes such specialized planes possible. The following aircraft provide examples of how design and technology work together to enable planes to carry out specific functions.

INTERNET CONNECT

www.mcgrawhill.ca/links/ns+science6

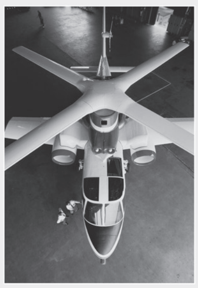
Have you ever seen a human-powered helicopter? The American Helicopter Society offers a prize for the first successful controlled flight of a helicopter that is powered solely by a human being. Learn more about human-powered helicopters and related aircraft. Go to the above web site and click on **Web Links** to find out where to go next.

Figure 4.3 This plane has a specialized function: to fly using only the Sun's energy.

Name of Aircraft
X-wing plane

Specialized Task
An X-wing plane can take off vertically and hover like a helicopter. It can also fly at high speeds like a jet. (Regular helicopters can only fly at limited speeds or flight vibration will damage the rotor.)

Design Features
Its rotor is used for takeoff and hovering, while its jet engines produce thrust for forward flight.



- **During Teaching**—Draw students' attention to Figure 4.3 on page 101. How do students think the Sun's rays make the aircraft fly? As a class, brainstorm a list of possible drawbacks to flying a solar-powered plane.
- **After Teaching**—*ICT Option:* You may wish to have students visit the web site of the Smithsonian National Air and Space Museum. The museum has a large array of unusual aircraft that are also shown on their web site. Students could also research one unusual aircraft and make a brief report on it to the class. A link can be found at www.mcgrawhill.ca/links/ns+science6.

Common Misconceptions

- Some students may believe that aircraft can only be powered by fossil fuels. Use Figure 4.3 on page 101 to start to explore other possibilities.

INTERNET CONNECT This prize is called the Sikorsky prize, after early helicopter pioneer Igor Sikorsky. Twenty thousand dollars will be awarded to the individual or team that flies the first human-powered helicopter at a minimum height of 3 m for 60 seconds or longer. So far, only two human-powered helicopters have even succeeded in getting off the ground in front of witnesses. These were the *Yuri I* and the *Da Vinci III*. The *Da Vinci III* was the first helicopter to lift off the ground under human power in 1989. It reached a height of about 20 cm for about 7 seconds. The *Yuri I* reached 20 cm for about 19 seconds in 1994.

X-WING PLANE FILE CARD INSET

BACKGROUND INFORMATION

- The manufacturer Sikorsky built the *X-Wing* aircraft shown on the file card for NASA as an experimental aircraft. The aircraft was designed purely for experimental research purposes. The conversion of rotor use during takeoff to jet-engine use during flight was not fully mastered during the test process. The aircraft has not been flown for the military or for other uses. It was envisioned for future use on missions that required the low-speed versatility of a helicopter as well as the high-speed horizontal flight of a jet plane.

TEACHING STRATEGIES

- **During Teaching**—For this series of file cards on unusual aircraft, divide students into groups of four. Have each student read one file card and describe the aircraft to the rest of the group.
- **After Teaching**—In groups, have students generate questions they would like answered about the *X-wing* plane. Then brainstorm the answers to each group's question as a class.

Common Misconceptions

- Many people believe that helicopters can fly at extremely high speeds, as often depicted on television. In reality, the maximum forward speed of a helicopter is about 400 km/h. The world speed record for a helicopter is 400.80 km/h, which was achieved in 1986. Speed is limited because of the stress airflow places on the rotor. Air velocity at the tips of the rotor becomes so high that shock waves develop.

F-117 FILE CARD INSET

BACKGROUND INFORMATION

- Physicists believed that the strength of return of a radar signal depended only on the edge configuration of an aircraft's design. The *F-117* is an extremely angular aircraft with flat wings and panels that scatter radar signals. The computer program used to keep the aircraft stable was designed especially for the plane. The aircraft also uses RAM (radar absorbent material). A special paint known as "iron ball" paint is used to coat the aircraft. It contains iron ferrite, which creates a magnetic field that dissipates radar signals. Heat-absorbing panels around exhausts decrease the risk of heat detection. The doors and panels on the aircraft also have serrated edges that reduce radar detection. The *F-117* was retired after 25 years of service.

TEACHING STRATEGIES

- **Begin the Lesson**—Have students discuss or write about possible ways the *F-117* could avoid radar detection.
- **During Teaching**—For this series of file cards on unusual aircraft, divide students into groups of four. Have each student read one file card and describe the aircraft to the rest of the group.
- **After Teaching**—Ask students what problems the unusual shape of this aircraft might present. How do they think the plane stays in the air?

RQ-4 GLOBAL HAWK FILE CARD INSET

BACKGROUND INFORMATION

- The *RQ-4 Global Hawk* is a remote-controlled surveillance aircraft used by the U.S. military. It has an extremely specialized system on board, including high-resolution radar that can obtain images through sandstorms and cloud cover. It can cruise for 36 hours without refueling. Its average cruise speed is 650 km/h.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask if any students have ever flown a remote-controlled plane or other remote-controlled vehicle. What difficulties did they experience during the process?

Name of Aircraft
F-117
Specialized Task
The *F-117* is a jet bomber that can drop bombs while remaining undetected by radar and other detection devices.
Design Features
Its unusual shape and special paint coating make it difficult to detect. The shape of the plane's exhausts hides heat generated by its engines.

Name of Aircraft
RQ-4 Global Hawk
Specialized Task
The *RQ-4 Global Hawk* is used for surveillance (monitoring military activity). It can record images through clouds and even sandstorms. The plane stays in the air for long periods of time.
Design Features
The *RQ-4 Global Hawk* is flown completely by remote computer control. Its instruments are operated the same way. Because the plane has no pilot, it can stay in the air for extended periods of time. It only needs to land to refuel. In 2003, it made the first unmanned flight across the Atlantic Ocean.

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- **After Teaching**—Ask students to apply the difficulties they discussed in their brainstorming activities to the *Global Hawk*. Would they encounter the same difficulties or different ones? What would the benefits and drawbacks of a remote-controlled plane be? What might happen if there was an emergency, and no one was on board to deal with it?

PROTEUS FILE CARD INSET

BACKGROUND INFORMATION

- The *Proteus* gets its name from a Greek god of the sea. In addition to completing high-altitude climate research, the plane may eventually be used to perform high-altitude communications tasks, replacing telecommunication satellites if necessary. It may also be used as a space launch platform to launch small satellites into orbit from high altitudes. Currently, the *Proteus* is a one-of-a-kind test plane. Its long wings provide agility in adverse wind conditions at high altitude. They also provide a high lift-to-drag ratio that allows the plane to reach high altitudes quickly. Its unusual design increases its stability. It can be flown by pilots or remotely if necessary.

Name of Aircraft
Proteus
Specialized Task
The *Proteus* carries out high altitude research and completes long distance flights. It is used to take measurements in the upper atmosphere and complete other scientific tasks.
Design Features
Its unusual design helps it remain stable over 20 000 metres above sea level.

Once a new design is completed, the aircraft must be tested. Models are often built and tested before a full-scale version of the aircraft is built. Can you think of one way that aeronautical engineers can test and research aircraft designs while still on the ground?

Find Out ACTIVITY 4–B

Wind Tunnel Presentation

How do aeronautical engineers design and test airplanes? In this activity, you will learn about wind tunnels and find out how they are used in aircraft design.

What You Will Need

Library books or the Internet

What to Do

1. Use library or Internet resources to research the use of wind tunnels in aircraft design and testing.
2. Use your research to create a presentation about wind tunnels. Include photos or illustrations of wind tunnels and various wind tunnel tests.

What Did You Find Out?

1. What is a wind tunnel?
2. How does a wind tunnel work?
3. How are wind tunnels used to design and test aircraft?
4. Why are wind tunnels helpful in this regard?

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TEACHING STRATEGIES

- **Begin the Lesson**—Have students brainstorm different ways high-altitude research is completed (satellites, weather balloons, planes). What are some of the main challenges in completing high-altitude research?
- **After Teaching**—Ask students how they think the design of the *Proteus* might help the plane complete its task. Could they improve the design?

FIND OUT ACTIVITY 4-B WIND TUNNEL PRESENTATION

Purpose

- Students research and complete a presentation on wind tunnels to find out how they are used to test aircraft designs.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 week before	– Book the library or computer facilities for student research.

MATERIALS
– Library books and/or Internet access

Suggested Time

- 30 min for research
- 30-60 min to create presentation (Some home time may be required to work on the presentation.)
- 5 min per presentation

HINTS & HELPS

- You may wish to provide a brief overview explaining what wind tunnels are before beginning the activity.
- Pre-select web sites and books for student research.
- Presentations may be in the form of an oral report, poster, 3-D panel display, a news-style report, a mock interview, wind tunnel model, or computer slide show presentation. Encourage each group to use a different medium.

Implementing the Activity

- This activity is best carried out in groups of three or four, depending on class size.
- This activity is not meant to take long. Be sure to tell students they will only have about 5 minutes per group for their presentations.

Adaptations

- Students with literacy difficulties may need assistance due to the amount of reading required to complete the activity. You may wish to use preferential grouping in such cases.

Activity Wrap-Up

- Discuss with students how they will be using wind tunnels to complete the next two investigations: Conduct an Investigation 4-C Wing Angle and Conduct an Investigation 4-D Wing Shape.

Assessment Option

- Use Learning Skills Rubric 5 Research Project and/or Learning Skills Rubric 6 Communication for Find Out Activity 4-B Wind Tunnel Presentation

What Did You Find Out? Answers

1. *Sample answer:* A wind tunnel is a special flight research tool. Aeronautical engineers use wind tunnels to learn how air moves around and over a solid object, such as an airplane.
2. *Sample answer:* Engineers use wind tunnels to understand how different forces act on aircraft at high speeds. A wind tunnel uses smoke, ribbons, or beams of light to show how air moves over the body of an aircraft. Because high speeds are necessary to generate and maintain lift in aircraft, wind tunnels that test aircraft must also generate such air speeds. Wind tunnels also help engineers understand how a plane will behave during different stages of flight, such as takeoff, cruising, and landing.

(continued) ➜

3. *Sample answer:* Wind tunnels are used to design and test aircraft in several ways. They vary in size. Some test small-sized models of aircraft; others are large enough to house a full-size airplane. Wind tunnels can create different wind speeds to see how an airplane reacts at different speeds. Some wind tunnels only achieve wind speeds that are below the speed of sound. Others reach speeds up to five times as great. Wind tunnels can also be designed to complete special tests. For example, some are used only to study wing design.
4. *Sample answer:* Wind tunnels are helpful tools when it comes to designing aircraft because they can show engineers if certain details of the design are not working well at different speeds.

TESTING AIRCRAFT DESIGNS

BACKGROUND INFORMATION

- Wind tunnels have been used to study airflow for quite a long time. The first wind tunnel was actually built in the eighteenth century to measure drag. It was quickly adopted for use by many early aviation pioneers, including the Wright brothers, to test early aircraft designs. The Wright brothers used a wind tunnel to test small model wings, helping them determine what the best wing shape would be. Understandably, most early wind tunnels were quite small. However, prior to and during WWII, German engineers forced air through large caves to create larger wind tunnels that greatly advanced German aviation at the time.

TEACHING STRATEGIES

- **Begin the Lesson**—Review students' discoveries from the previous activity, Find Out Activity 4-B Wind Tunnel Presentation.
- **During Teaching**—Draw students' attention to Figures 4.4 and 4.5. How would aeronautical engineers use these two wind tunnels differently?
- **After Teaching**—*ICT Option:* Several videos that show wind tunnel flight tests and explain how wind tunnels work can be found online. For links, go to www.mcgrawhill.ca/links/ns+science6.

Testing Aircraft Designs

A **wind tunnel** is a special flight research tool. Aeronautical engineers use wind tunnels to learn how air moves around and over a solid object, such as an airplane. This helps them understand how different forces act on aircraft at high speeds.

A wind tunnel uses smoke, ribbons, or beams of light to show how air moves over the body of an aircraft. The air travels at the high speeds that are necessary to generate and maintain lift. Because aircraft fly at such high speeds, wind tunnels that test aircraft must also generate such speeds. Some wind tunnels only achieve wind speeds that are below the speed of sound. Others reach speeds up to five times as great. Wind tunnels also help engineers understand how a plane will behave during different stages of flight, such as takeoff, cruising, and landing.

Wind tunnels vary in size. Some test only small-sized models of aircraft. Others are large enough to house an entire airplane. Wind tunnels can be designed to complete special tests. For example, some are used only to study wing design. How do you think the amount of lift a wing experiences changes if its angle changes? How could you use a wind tunnel to find out?

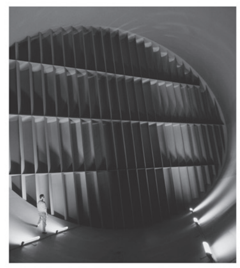

Figure 4.4 A wind tunnel at NASA's Langley Research Center. It is large enough to hold a full-sized airplane.

Figure 4.5 A wind tunnel shows how air moves around and over a solid object.

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CONDUCT AN INVESTIGATION 4-C WING ANGLE

Purpose

- Students test a wing in different positions in a wind tunnel to determine if the amount of lift a wing experiences changes if its angle changes.

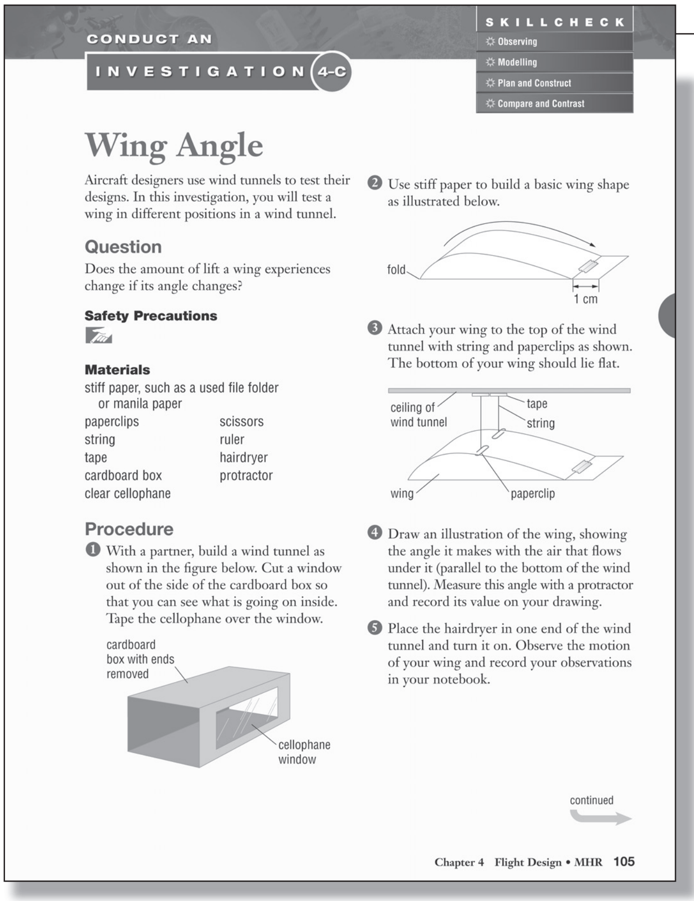
Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 week before	– Complete the investigation yourself to make sure it works with the material you have selected.
3 days before	– Gather a class set of materials.

MATERIALS	
Per group: – stiff paper, such as a used file folder or Manila paper – paperclips – string – tape – cardboard box	– clear cellophane – scissors – ruler – hair dryer – protractor

Suggested Time

- 60 min



CONDUCT AN INVESTIGATION 4-C

SKILLCHECK
- Observing
- Modelling
- Plan and Construct
- Compare and Contrast

Wing Angle

Aircraft designers use wind tunnels to test their designs. In this investigation, you will test a wing in different positions in a wind tunnel.

Question

Does the amount of lift a wing experiences change if its angle changes?

Safety Precautions

Materials

stiff paper, such as a used file folder or manila paper
paperclips
string
tape
cardboard box
clear cellophane
scissors
ruler
hairdryer
protractor

Procedure

1. With a partner, build a wind tunnel as shown in the figure below. Cut a window out of the side of the cardboard box so that you can see what is going on inside. Tape the cellophane over the window.

2. Use stiff paper to build a basic wing shape as illustrated below.

3. Attach your wing to the top of the wind tunnel with string and paperclips as shown. The bottom of your wing should lie flat.

4. Draw an illustration of the wing, showing the angle it makes with the air that flows under it (parallel to the bottom of the wind tunnel). Measure this angle with a protractor and record its value on your drawing.
5. Place the hairdryer in one end of the wind tunnel and turn it on. Observe the motion of your wing and record your observations in your notebook.

continued

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Safety Precautions

- Remind students to use caution when handling scissors.
- Advise students to set the hair dryer to the coolest setting to avoid burning themselves.

HINTS & HELPS

- Students can cut the ends out of rectangular cardboard boxes to make the wind tunnels in this investigation. However, if these are in short supply, students can tape together pre-cut cardboard panels.
- Students can cut a large flap in the top to make it easier to change wing designs. Tape it back down with a small piece of tape to minimize leakage of air around the cut.
- You may wish to have students build their wind tunnels the day before they complete the investigation.
- To measure the angle the wing makes with the air flowing below it, students can stack books to create a flat surface upon which they can place the edge of the protractor.
- Students may become frustrated when adjusting wing angle. If wing angle is too steep, advise students to move their paperclips towards the centre of the wing. If the angle is not steep enough, move the paperclips towards the rear of the wing or add more paperclips to the rear.
- If students are having trouble adjusting the wing within the wind tunnel, suggest that they cut out the bottom of the cardboard box and tape the sides onto the desk with easily removable tape. This way they can turn the wind tunnel upside down or on its side to adjust the wing. The wind tunnel will not be as sturdy, however.
- One student should handle the hair dryer while the other observes the wing through the cellophane window. Students could alternate so each one gets to carry out both roles.

Implementing the Investigation

- This investigation is best completed in partners.
- Review dependent, controlled and independent variables prior to this activity.
- Students should save their wind tunnels for use in the next investigation, Conduct an Investigation 4-D Wing Shape.
- There is an excellent and free wind tunnel simulator where students can adjust the angle of attack and choose a variety of shapes at the NASA web site. For links, go to www.mcgrawhill.ca/links/ns+science6.

Adaptations

- Students with fine motor difficulties should be partnered with a student who can help them participate in the investigation as fully as possible.

Investigation Wrap-Up

- Ask students to think of ways to alter the shape of their wing to increase lift. Explain that they will be experimenting with wing shape in the next investigation, Conduct an Investigation 4-D Wing Shape.
- Use this investigation to introduce angle of attack, which is covered on the next page of the student textbook.

Assessment Option

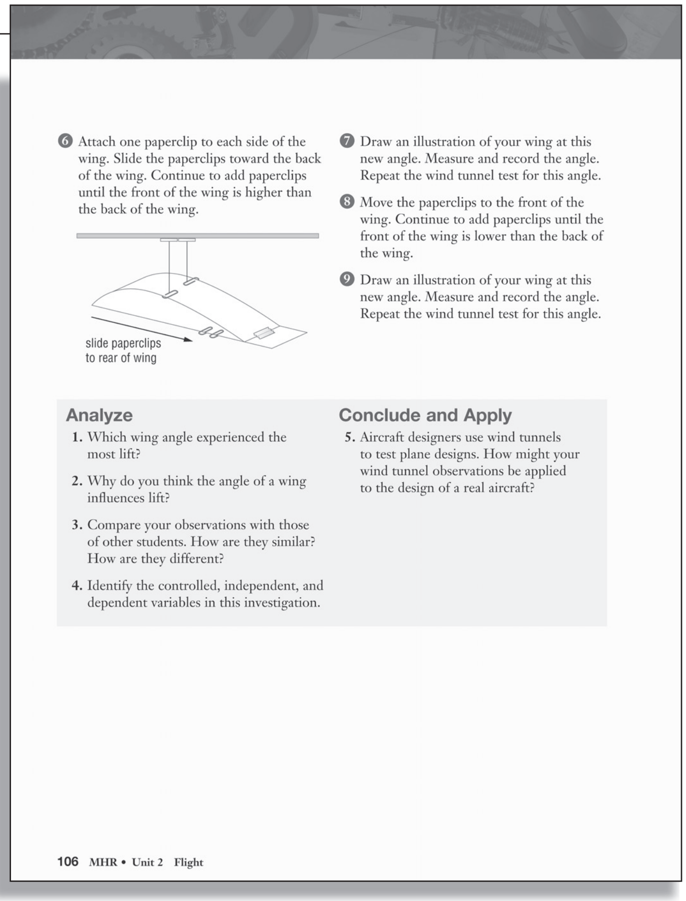
- Use Science Skills Rubric 19 Conduct an Investigation for Investigation 4-C Wing Angle.

Analyze Answers

1. Students will generally find that a moderate wing angle will generate the most lift. If the wing angle is too steep, more drag will result. This may cause the front of the wing to be forced backward, rather than causing the entire wing to lift.
2. Students may not recognize that the wing is deflecting air, which is in turn pushing against the wing with an opposite force that causes the wing to lift. However, they should be aware at least that the air striking the tilted surface plays a role here. When the wing angle changes, so does the amount of air it deflects.
3. *Sample answer:* We found that a small angle created more lift than a large angle. Most other groups found the same thing. One difference, though, was that some groups saw more lift at a certain angle. Other groups had their wing at the same angle and saw less lift. Answers should clearly compare similarities and differences between groups.
4. Controlled variables are the wing design (size, shape, and overall features), the material used to build the wing, the size and shape of the paperclips, the wind tunnel design, the placement of the wing in the wind tunnel, the wind speed generated by the hair dryer, the placement of the hair dryer, and the size and measurements of the protractor. The independent variable is the angle of the wing. The dependent variable is the amount of lift generated.

Conclude and Apply Answers

5. *Sample answer:* My wind tunnel observations could be applied to the design of aircraft in several ways. Engineers could use the observations to see how wind flowing around a wing affects lift. They would learn how different wing angles affect lift. Once the engineers observe how angle affects the wing's lift, they could change the wing angle of an aircraft to increase the aircraft's overall lift. They could also use the observations to change the design of the wing so the aircraft is safer, flies faster, and so on. They could also change the wind speeds to see how the wing design responds to faster or slower winds.



6. Attach one paperclip to each side of the wing. Slide the paperclips toward the back of the wing. Continue to add paperclips until the front of the wing is higher than the back of the wing.

7. Draw an illustration of your wing at this new angle. Measure and record the angle. Repeat the wind tunnel test for this angle.
8. Move the paperclips to the front of the wing. Continue to add paperclips until the front of the wing is lower than the back of the wing.
9. Draw an illustration of your wing at this new angle. Measure and record the angle. Repeat the wind tunnel test for this angle.

Analyze

1. Which wing angle experienced the most lift?
2. Why do you think the angle of a wing influences lift?
3. Compare your observations with those of other students. How are they similar? How are they different?
4. Identify the controlled, independent, and dependent variables in this investigation.

Conclude and Apply

5. Aircraft designers use wind tunnels to test plane designs. How might your wind tunnel observations be applied to the design of a real aircraft?

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Angle of Attack

A wing's angle is extremely important when it comes to lift. When you used a wind tunnel to investigate wing angle in the previous activity, you discovered that this measurement affects the amount of lift a wing experiences.

How do wings produce lift? In Chapter 3, you learned that curved wings produce lift due to a difference in air pressure as air travels over and under the wing. Wings also increase lift by deflecting air downward as it passes. This is done by tipping the front of the wing upward slightly. The angle that the wing makes compared to the flow of air is called the wing's **angle of attack**.

Figure 4.6 shows the angle of attack of a tilted wing. Notice that the front end of the wing is higher than the back. In such a case, the angle of attack is described as positive. A wing's angle of attack must be positive to increase lift. This is true for mechanical aircraft as well as flying organisms (see Figure 4.7).

As mentioned earlier, shape can also influence the amount of lift a wing experiences. What wing shape do you think will achieve the most lift?

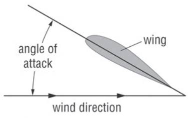

Figure 4.6 The angle that the wing makes compared to the flow of air is called the wing's angle of attack.

Figure 4.7 A bird's wing has a positive angle of attack.

READING Check

Explain how changes in a wing's angle of attack affect the amount of lift an aircraft experiences.

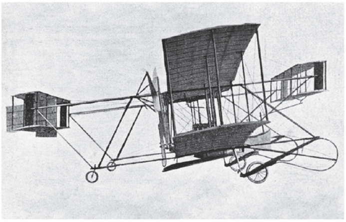

Figure 4.8 This early aircraft only rose a few metres off the ground. Note the angle of attack of its wings. How would you alter the angle of attack to increase the amount of lift this aircraft experiences?

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ANGLE OF ATTACK

BACKGROUND INFORMATION

- There is some controversy as to the role Bernoulli's principle and the angle of attack play in generating lift. While Bernoulli's principle plays a role for wings that are rounded in shape, there are many planes that have flat wings or wings that are rounded on both the top and bottom and also achieve lift. The angle of attack seems to play a significantly larger role here. You may wish to discuss this issue with students who ask how a flat-winged aircraft can fly.
- In general, a steep angle of attack increases lift, but it also increases drag. At a certain angle of attack, drag exceeds lift and the plane stalls. This critical angle is usually about 15 degrees. For this reason, most planes tend to have a moderate angle of attack.

TEACHING STRATEGIES

- **During Teaching**—Draw students' attention to Figure 4.8 on page 107 and ask them to answer the question posed in the caption: "How would you alter the angle of attack to increase the amount of lift this aircraft experiences?" They can explore possible answers with paper airplanes, investigating the adjustment that can be made manually to affect steep incline or the reverse.
- **After Teaching**—Ask students which angle of attack they think would generate the most lift. (They will probably choose the steepest angle.) Do they often see aircraft wings at this angle? Use the Background Information above to explain why a steep angle of attack does not always generate the most lift.

READING Check A wing must have a positive angle of attack to generate lift. Some students may also realize that if the angle of attack is too steep, there will be less lift, as drag starts to affect the wing as well.

Figure 4.8 on page 107
The angle of attack must be increased but not too much, or drag will also increase.

CONDUCT AN INVESTIGATION 4-D WING SHAPE

Purpose

- Students test different wing designs in a wind tunnel to determine if the amount of lift a wing experiences changes if its shape or materials change.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
3 days before	– Gather a class set of materials.

MATERIALS	
Per group:	
– stiff paper, such as a used file folder or Manila paper	– tape
– feathers	– glue
– straws	– scissors
– toothpicks	– ruler
– paperclips	– hair dryer
– wind tunnel from previous investigation	– protractor
	– string

Suggested Time

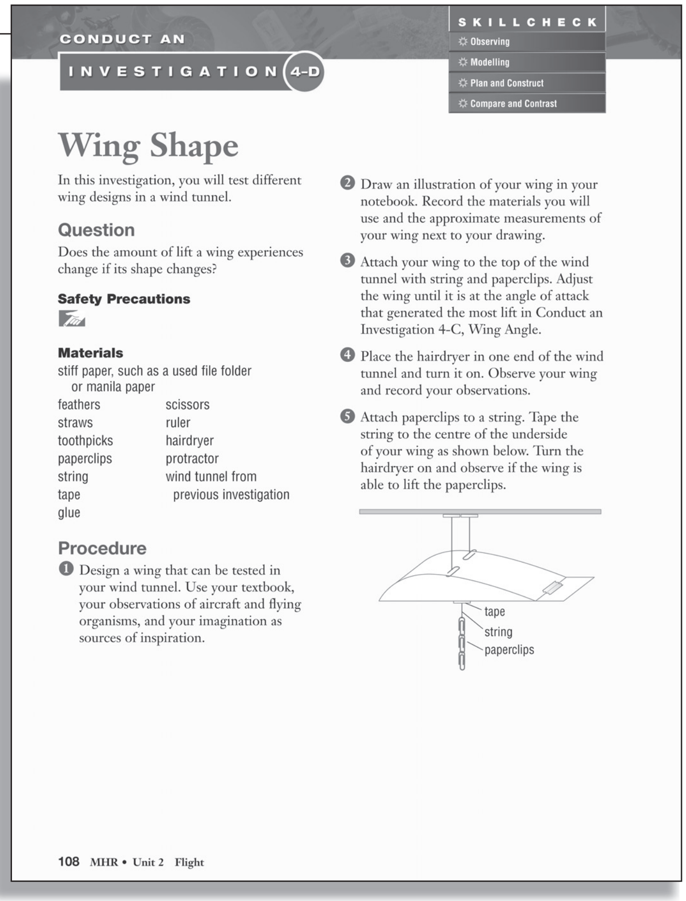
- 60 min

Safety Precautions

- Remind students to use caution when handling scissors.
- Advise students to set the hair dryer to the coolest setting to avoid burning themselves.

HINTS & HELPS

- Remind students that this is an exploratory investigation. Encourage them to make their wings any shape and to use any of the materials provided.
- Students could begin by writing or drawing different wing designs or angles of attack in their science logbooks.
- One student should handle the hair dryer while the other observes the wing through the cellophane window. Students could alternate so each one gets to carry out both roles.
- Students may need assistance attaching the wing to the wind tunnel. Students can also try cutting out the bottom of the cardboard box and taping the sides onto the desk with easily removable tape. This way they can turn the wind tunnel upside down to insert the wing.



CONDUCT AN INVESTIGATION 4-D

SKILLCHECK
- Observing
- Modelling
- Plan and Construct
- Compare and Contrast

Wing Shape

In this investigation, you will test different wing designs in a wind tunnel.

Question

Does the amount of lift a wing experiences change if its shape changes?

Safety Precautions

Materials

stiff paper, such as a used file folder or manila paper
feathers, straws, toothpicks, paperclips, string, tape, glue, scissors, ruler, hairdryer, protractor, wind tunnel from previous investigation

Procedure

1. Design a wing that can be tested in your wind tunnel. Use your textbook, your observations of aircraft and flying organisms, and your imagination as sources of inspiration.
2. Draw an illustration of your wing in your notebook. Record the materials you will use and the approximate measurements of your wing next to your drawing.
3. Attach your wing to the top of the wind tunnel with string and paperclips. Adjust the wing until it is at the angle of attack that generated the most lift in Conduct an Investigation 4-C, Wing Angle.
4. Place the hairdryer in one end of the wind tunnel and turn it on. Observe your wing and record your observations.
5. Attach paperclips to a string. Tape the string to the centre of the underside of your wing as shown below. Turn the hairdryer on and observe if the wing is able to lift the paperclips.

tape
string
paperclips

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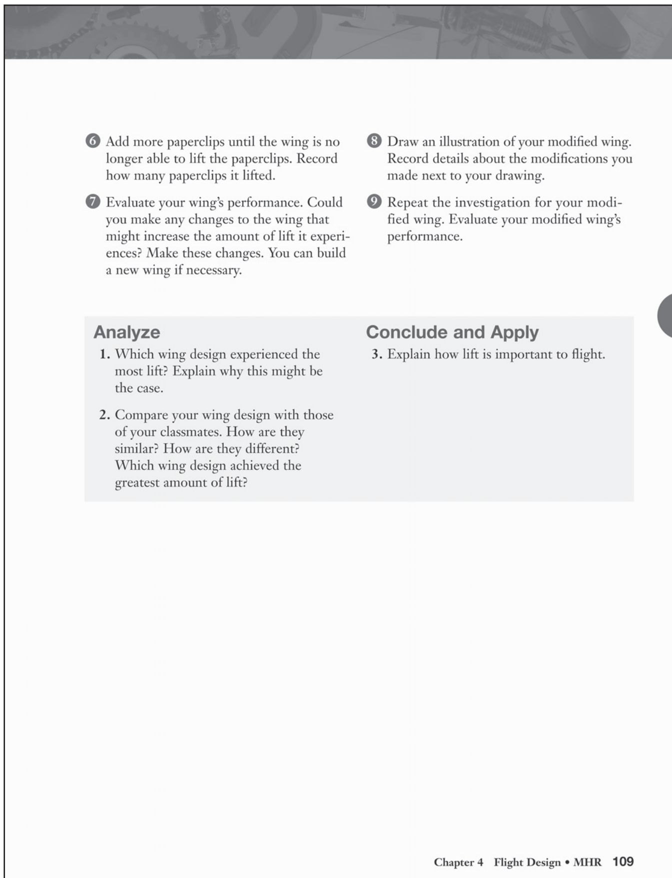
Implementing the Investigation

- This investigation is best completed in partners.
- Students should use their wind tunnels from the previous investigation, Conduct an Investigation 4-C Wing Angle.

Adaptations

- Students with fine motor difficulties should be partnered with a student who can help them participate in the investigation as fully as possible.


6 Add more paperclips until the wing is no longer able to lift the paperclips. Record how many paperclips it lifted.

7 Evaluate your wing's performance. Could you make any changes to the wing that might increase the amount of lift it experiences? Make these changes. You can build a new wing if necessary.

8 Draw an illustration of your modified wing. Record details about the modifications you made next to your drawing.

9 Repeat the investigation for your modified wing. Evaluate your modified wing's performance.

Analyze

1. Which wing design experienced the most lift? Explain why this might be the case.
2. Compare your wing design with those of your classmates. How are they similar? How are they different? Which wing design achieved the greatest amount of lift?

Conclude and Apply

3. Explain how lift is important to flight.

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Investigation Wrap-Up

- Display each group's wing(s) on a display board with the students' names and the number of paperclips the wing lifted. Have students visit each wing display to answer Analyze question 2.
- Use a carpet activity or whole-class discussion to encourage students to talk about their work.

Assessment Option

- Use Science Skills Rubric 19 Conduct an Investigation for Investigation 4-D Wing Shape.

Analyze Answers

1. Accept any logical, well-explained response. *Sample answer:* The wing with the most lift was our second design. I think it had the most lift because the wing was curved and the front of the wing was tipped up (like in the last investigation). Also, it was very strong. We used feathers in this design and that might have helped, too, because the wind might have caught the feathers and lifted the wing up more.
2. Accept any logical, well-explained response. *Sample answer:* Our wing was curved, had the front edge tipped up, and was built from stiff paper and feathers. Some students' wings also had these features, but none had all of them together in one wing. Everyone weighted the wings with paperclips like we did to tip the wing up. Some students used straws and toothpicks in their wings. We didn't use these. Some also used different types of paper. Our wing had the second most lift (three paperclips). Jan and Phillip's wing had the most lift of all (four paperclips). They used more feathers than we did. Also, I think the wing was more curved.

Conclude and Apply Answers

3. Lift is important to flight because it provides the force that moves an aircraft upward. Without lift, an aircraft could not fly.

SECTION 4.1 SUMMARY

Review the section summary as a class. Make sure that students update the flight section of their logbooks and key terms list. As a review, students could also make posters showing the different aircraft they reviewed in this section, explaining any unique aspects of their design and how these help the aircraft carry out their functions.

✓ ASSESSMENT OPTIONS FOR SECTION 4.1

- Collect and review science logbooks, using Learning Skills Rubric 2, Science Logbook.
- Use the following rubrics to assess student work:
  - Learning Skills Rubric 5 Research Project and/or Learning Skills Rubric 6 Communication for Find Out Activity 4-B Wind Tunnel Presentation
  - Science Skills Rubric 19 Conduct an Investigation for Investigation 4-C Wing Angle and Investigation 4-D Wing Shape

Check Your Understanding Answers

1. *Sample answer:* You could use a wind tunnel in several ways to determine how much drag an aircraft experiences. Some wind tunnels use smoke, ribbons, or beams of light to show how air moves around an aircraft. You could observe if these materials are moving smoothly as air flows around the aircraft. This would tell you if there is a lot of drag or just a little. This could also tell you if some parts of the aircraft are causing more drag than others. You could test models or full-sized aircraft. You could observe drag during takeoff, cruising, or landing. You could also test different wind speeds to see how drag changes when the airspeed changes, or focus on one part of the aircraft, like the wings.
2. The angle of attack is the angle the wing makes compared to the flow of air.
3. A wing's angle of attack must be positive (the front of the wing must be tipped up) for lift to occur.
4. Accept any reasonable suggestions. Some possibilities include being light in weight, having a very large fuel tank, having only a small area for crew so that there is more room for fuel, having a design that keeps its flight steady (because it is so lightweight, it could be easily tossed around in strong winds), and having an efficient motor that uses as little fuel as possible.

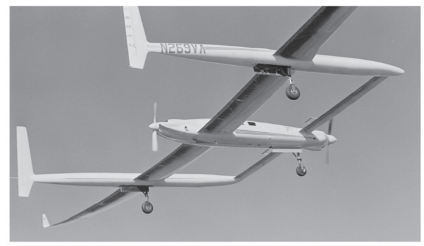
Section 4.1 Summary

All aircraft have characteristics that are unique to their function. This can provide challenges for the aeronautical engineers who design them.
- Once a new design is completed, the aircraft must be tested. Models are often built and tested before a full-scale version of the aircraft is built.
- Wind tunnels help aeronautical engineers design and test aircraft.
- The angle that the wing makes compared to the flow of air is called the wing's angle of attack. In order to increase lift, a wing's angle of attack must be positive.

Key Terms
wind tunnel
angle of attack

Check Your Understanding

1. Describe how you could use a wind tunnel to determine how much drag an aircraft experiences.
2. What is meant by the term "angle of attack?"
3. Explain how a wing's angle of attack affects the amount of lift it experiences.
4. The *Voyager* was the first and only plane to fly around the world on one tank of fuel. It has been designed specifically for fuel-efficiency. What design features might help this plane achieve its special function?



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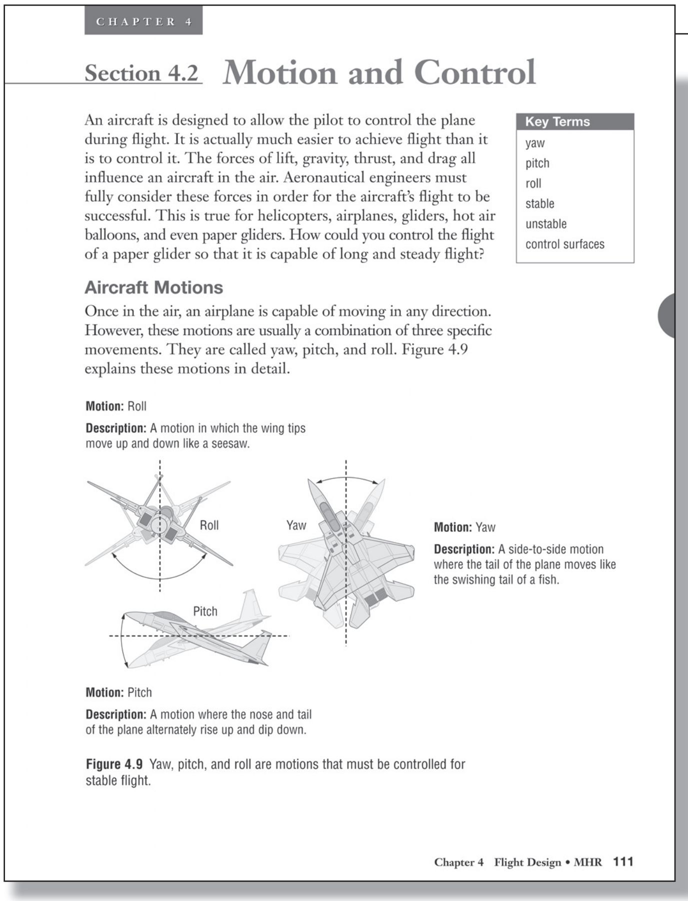
SECTION 4.2 MOTION AND CONTROL

What Students Do in Section 4.2

- describe the three basic aircraft motions that must be controlled during flight
- experiment with glider design to investigate how to control aircraft motion to increase stability and flight duration
- compare the designs of stable and unstable aircraft
- learn about control surfaces and how they help control an aircraft's motion during flight
- modify a paper glider to perform aerobatics by altering control surfaces

BACKGROUND INFORMATION

- Aircraft flight control systems consist of the control surfaces on the aircraft itself, the cockpit controls, links from the cockpit to the control surfaces, and any in-flight control computers. Control surfaces include exterior flaps that allow the pilot to directly control the aircraft's motion. Many fighter jets have limited control surfaces and must rely on in-flight computers to make adjustments that keep their flight stable.



CHAPTER 4

Section 4.2 Motion and Control

An aircraft is designed to allow the pilot to control the plane during flight. It is actually much easier to achieve flight than it is to control it. The forces of lift, gravity, thrust, and drag all influence an aircraft in the air. Aeronautical engineers must fully consider these forces in order for the aircraft's flight to be successful. This is true for helicopters, airplanes, gliders, hot air balloons, and even paper gliders. How could you control the flight of a paper glider so that it is capable of long and steady flight?

Key Terms
yaw
pitch
roll
stable
unstable
control surfaces

Aircraft Motions

Once in the air, an airplane is capable of moving in any direction. However, these motions are usually a combination of three specific movements. They are called yaw, pitch, and roll. Figure 4.9 explains these motions in detail.

Motion: Roll
Description: A motion in which the wing tips move up and down like a seesaw.

Motion: Yaw
Description: A side-to-side motion where the tail of the plane moves like the swishing tail of a fish.

Motion: Pitch
Description: A motion where the nose and tail of the plane alternately rise up and dip down.

Figure 4.9 Yaw, pitch, and roll are motions that must be controlled for stable flight.

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TEACHING STRATEGIES

- **Begin the Lesson**—Ask students to write a paragraph answering the questions "How do you think a pilot can control an airplane? What does a pilot need to control or manipulate?"
  - In small groups, have students brainstorm how different types of aircraft might be controlled during flight. Each group can be given a different aircraft to explore, such as a hot air balloon, a ram-air parachute, a helicopter, an airplane, and so forth.
- **After Teaching**—Ask students the question at the end of the text passage: How could you control the flight of a paper glider so that it is capable of long and steady flight? This question can be used to introduce the next activity, Find Out Activity 4-E My Flying Machine: Stable and Long-Flying.

Common Misconceptions

- Students may not realize that it is more difficult to keep a plane in the air than it is to get it up there in the first place. They may believe that once the plane is airborne, everything is "smooth sailing." You may want to ask if any students who have been on an aircraft have experienced "air turbulence" (invisible bodies or pockets of air that are moving vertically at different speeds than the surrounding air) or describe your own experiences during flight (for example, losing altitude) to show students that this is not the case.

AIRCRAFT MOTIONS

BACKGROUND INFORMATION

- Yaw, pitch, and roll are essentially different angles of rotation around an aircraft's centre of mass. Note that in Figure 4.9 on page 111 the centre of mass always remains in the same location during each motion.
- A plane with wings above the centre of gravity (a "high wing" seen in the passenger plane in Figure 4.10 A on page 113 and the *An–225 Cossack* on page 62) is less likely to experience roll. A plane with wings below the centre of gravity (a "low wing" seen in the *CT-114 Tutor* on page 98 and the *F-117* on page 102) is much more likely to experience roll. Low-wing planes are, however, more maneuverable.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students what kind of motions come to mind when they hear the terms yaw, pitch, and roll. Students will probably have a sense of the motion involved in pitching and rolling.
- **During Teaching**—BLM 4.2 Yaw, Pitch, and Roll is a BLM of Figure 4.9 on page 111. Use it as an overhead to help teach students the difference between yaw, pitch, and roll.

FIND OUT ACTIVITY 4-E MY FLYING MACHINE: STABLE AND LONG-FLYING

Purpose

- Students design stable, long-flying paper gliders. They test the gliders for flight time and smoothness and then modify them to determine the best way to increase flight duration and stability.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 week before	– Gather books and Internet sites on paper gliders and glider design. – Book the gym or larger area to test the paper gliders.
3 days before	– Gather a class set of materials.

MATERIALS	
Per group:	
– paper, a variety of textures and/or weights	– ruler
– tape	– scissors
– glue	– timer
	– books on paper gliders

Suggested Time

- 45 min

Safety Precautions

- Students should be warned not to throw their paper airplanes at other students. Some designs have a relatively hard, pointed nose area that could damage another student's eye.

HINTS & HELPS

- Try to have a wide variety of paper in different textures, sizes, and weights available. Possibilities include photocopy paper, Manila paper, used file folders, construction paper, and cardstock. Medium weight paper (20–60 lb weight) tends to make the best gliders. Photocopy paper is usually 20 lb weight, while Manila paper is heavier but still works well.
- Some students may think that if they throw a paper airplane with as much force as they can, it will fly further. Hurling the plane often results in it spiraling downwards. Remind students that a firm throw will help the plane remain stable during its flight.
- One of the secrets to a long and stable flight is to add weight to the nose of the glider. Adding a paperclip or two to the nose of the plane can achieve this. Have paperclips on hand for students who wish to try this trick. Bending the wings up to form a slight Y-shape will also improve stability.
- Review how to calculate the average time for all three trials with students before beginning the activity.

Find Out ACTIVITY 4–E

My Flying Machine: Stable and Long-Flying

In this activity, you will attempt to design and build a stable paper glider. A stable paper glider is one that remains steady during flight (does not wobble, spin, or turn in an uncontrolled way during flight). The more stable a glider is, the longer it will fly.

Safety Precautions

What You Will Need

paper, ruler, tape, scissors, glue, timer, books on paper gliders

What to Do

1. Use the books on paper gliders and your knowledge of flight to design a stable, long-flying glider.
2. Draw an illustration of your glider. Identify parts of the design that will help your glider remain stable during flight. Explain how the parts will work to stabilize your glider.
3. Fly your glider with a partner. Have your partner time how long your glider stays in the air while you observe its flight. Record your observations in your notebook. Then exchange roles as you time your partner's glider.
4. Repeat two more trials. Calculate the average time the glider stayed in the air for all three trials.
5. Evaluate your glider's performance. How stable was its flight? How long did it stay in the air? Are there any changes you think would improve its stability? Brainstorm a list of possible modifications with your partner. You can change the surfaces of your glider by cutting or gluing, or you can make a new glider.
6. Make and record these modifications.
7. Fly your modified glider. Record your observations in your notebook.
8. Repeat two more trials. Again, calculate the average time the glider stayed in the air for all three trials.

What Did You Find Out?

1. What characteristics do you think will result in the most stable glider? Support your opinion.
2. What other factors might have influenced your glider's performance?
3. How do you think you could change the design of your glider to make it perform an aerobatic maneuver, such as spinning or turning? Explain your reasoning.

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Implementing the Activity

- This activity should be completed in partners.
- Review students' response to Find Out Activity 3-F My Flying Machine: Flying Further What Did You Find Out? question 4 before beginning the activity. In this question, students suggested how they might make their gliders more stable.
- Ask students to create a table to keep track of the adjustments they make to their gliders and to record flight data.

Adaptations

- Use preferential grouping when organizing students to allow all students, including those with fine motor difficulties, to fully participate in the investigation.
- You may wish to pre-build a few different gliders for students who have trouble designing their own planes or reading instructions.

Activity Wrap-Up

- Ask each student to demonstrate his or her best design to see which plane stays in the air the longest. Examine the three gliders that stayed airborne the longest. How are they similar? How do they differ? What characteristics do they have that enabled them to fly the longest?

Yaw, pitch, and roll must be controlled if a pilot hopes to provide a safe, predictable flight for his or her passengers. Passenger aircraft are designed to control these three motions and correct their flight if air turbulence occurs. (Air turbulence can occur when wind speeds change suddenly.) These aircraft are **stable**.

Surprisingly not all planes are designed to be stable. Some aircraft are designed to overcorrect if air turbulence disrupts their flight. These planes have less control over yaw, pitch, and roll. They are referred to as unstable aircraft. Unstable aircraft may crash if the pilot is not able to bring the plane under control. Why would anyone want to fly an unstable aircraft? In some cases, being unstable can be a good thing. For example, fighter jets are **unstable**. The advantage of an unstable aircraft is that a pilot can maneuver it quickly—something that is helpful if a missile is coming toward you at high speed.

Sometimes a plane will demonstrate yaw, pitch, and roll on purpose in a controlled manner. This is known as *aerobatics*. How can yaw, pitch, and roll be mastered in a paper glider to perform an aerobatic maneuver, such as a spin or turn?

READING Check

Describe the three basic motions that must be controlled to maintain stable flight.

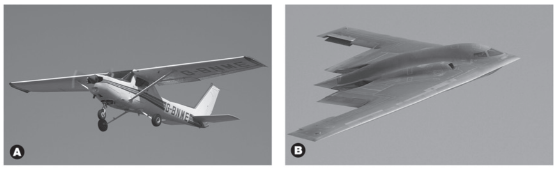


Figure 4.10 A passenger plane (A) is stable, while a fighter jet (B) is unstable.

Assessment Option

- Use Process Skills Rubric 11, Problem Solving for Find Out Activity 4-E My Flying Machine: Stable and Long-Flying.

What Did You Find Out? Answers

1. Accept any opinion that is supported by logical reasons. *Sample answer:* I think the most stable glider will be made out of stiff paper. This would keep it from flopping around during flight. I made my glider out of stiff paper, and it flew for a long time and didn't wobble. Also, I think flaps at the back of the wings make the glider more stable. I added these when I changed my design, and my glider flew longer.
2. Accept any logical opinions. *Sample answer:* I think how hard I threw the glider affected its flight. I thought if I threw it harder, it would stay in the air longer and fly more smoothly. Actually, the opposite happened. It wobbled and then crashed.
3. Accept any responses in which students support their reasoning. This question is designed to get students thinking, not necessarily to be correct. *Sample answer:* I think that if I turned the flap of one wing down and the flap of the other wing up, I could make my plane do a roll. The plane would roll because each wing would turn the plane in the same direction.

AIRCRAFT MOTIONS (CONTINUED FROM PAGE 4-111)

BACKGROUND INFORMATION

- Examples of unstable aircraft include the *F-117* on page 102 of the student textbook and the *B-2* bomber in Figure 4.10 B. Their nontraditional design is much less stable in the air than a passenger jet, for instance. However, unstable aircraft have a much greater degree of maneuverability in the air, a distinct asset for fighter jets. To avoid crashing, the flight of an unstable aircraft is monitored by an electrically signaled computer system known as a fly-by-wire system. This system responds to acutely changing aerodynamic conditions during flight. The pilot's commands are translated to electronic signals. The computer reads these signals and modifies them based on its software programs to ensure flight safety. Without a fly-by-wire system, most unstable aircraft will crash, making computer failure a serious concern.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students what they think of when they hear the words stable and unstable.
- **During Teaching**—Draw students' attention to Figure 4.10 on page 113. What design features make the plane in photo A more stable than the one in photo B? How do they think a stable aircraft would behave during flight? What about an unstable one?

READING Check The three basic motions that must be controlled for stable flight are: (1) roll: a motion in which the wing tips move up and down like a see-saw; (2) yaw: a side-to-side motion where the tail of the plane moves like the swishing tail of a fish; and (3) pitch: a motion where the nose and tail of the plane alternately rise up and dip down.

FIND OUT ACTIVITY 4-F
MY FLYING MACHINE: AEROBATICS

Purpose
- Students modify paper gliders to perform aerobatic maneuvers.

Advance Preparation

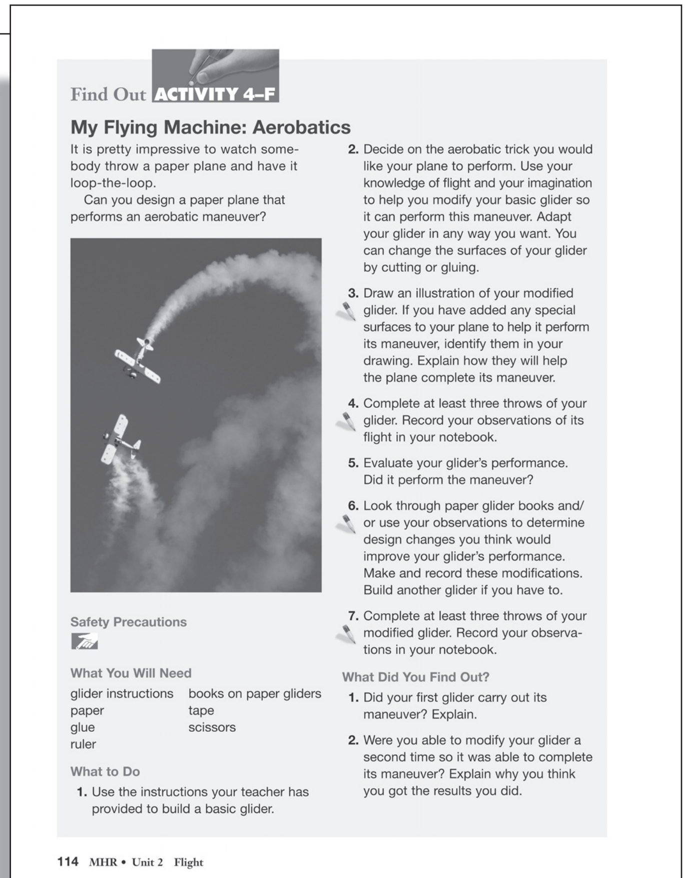
WHEN TO BEGIN	WHAT TO DO
1 week before	– Gather books or bookmark Internet sites on paper gliders and glider design. – Book the gym or larger area to test the paper gliders.
3 days before	– Gather a class set of materials.
1 day before	– Photocopy BLM4.4 Glider Instructions, My Flying Machine: Aerobatics for each student.

MATERIALS	
Per group:	
– glider instructions	– glue
– paper, a variety of textures, weights, sizes	– ruler
– tape	– scissors
	– books on paper gliders

Suggested Time
- 45 min

Safety Precautions
- Students should be warned not to throw their paper airplanes at other students. Some designs have a relatively hard, pointed nose area that could damage another student's eye.

HINTS & HELPS
- Remind students that they do not need to make their planes loop-the-loop. They can choose any aerobatic maneuver they wish, such as turns and barrel rolls. Try to provide a variety of books to inspire students.
- The following tips will help students perform aerobatics if they are having trouble:
  - To make the glider loop-the-loop, bend the back flaps up and throw the glider straight up. A more level, harder throw should also work.
  - To make a glider complete a barrel roll, fold the tip of the right wing downward and the tip of the left wing upward.
  - To spin the glider in the other direction, simply reverse the folds.
  - Adding flaps to the back of the plane generally improves overall stunt performance as it increases lift.


Find Out ACTIVITY 4–F

My Flying Machine: Aerobatics

It is pretty impressive to watch somebody throw a paper plane and have it loop-the-loop.

Can you design a paper plane that performs an aerobatic maneuver?

Safety Precautions

What You Will Need

glider instructions, books on paper gliders, paper, tape, glue, scissors, ruler

What to Do

1. Use the instructions your teacher has provided to build a basic glider.
2. Decide on the aerobatic trick you would like your plane to perform. Use your knowledge of flight and your imagination to help you modify your basic glider so it can perform this maneuver. Adapt your glider in any way you want. You can change the surfaces of your glider by cutting or gluing.
3. Draw an illustration of your modified glider. If you have added any special surfaces to your plane to help it perform its maneuver, identify them in your drawing. Explain how they will help the plane complete its maneuver.
4. Complete at least three throws of your glider. Record your observations of its flight in your notebook.
5. Evaluate your glider's performance. Did it perform the maneuver?
6. Look through paper glider books and/or use your observations to determine design changes you think would improve your glider's performance. Make and record these modifications. Build another glider if you have to.
7. Complete at least three throws of your modified glider. Record your observations in your notebook.

What Did You Find Out?

1. Did your first glider carry out its maneuver? Explain.
2. Were you able to modify your glider a second time so it was able to complete its maneuver? Explain why you think you got the results you did.

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Implementing the Activity
- This activity can be completed in partners.
- Review students' responses to Find Out Activity 4-E My Flying Machine: Stable and Long-Flying What Did You Find Out? question 3 before beginning the activity. In this question, students suggested how they might make their gliders complete aerobatics.
- Ask students to create a table to keep track of the adjustments they make to their gliders and to record flight data.

Adaptations
- Use preferential grouping when organizing students to allow all students, including those with fine motor difficulties, to fully participate in the investigation.
- You may wish to pre-build a few gliders that perform different aerobatics for students who have trouble designing their own planes or reading instructions.

Activity Wrap-Up
- Ask each student to enter his or her "best" design to see which plane completes the most impressive aerobatic. Examine the three gliders that completed the best loop-the-loop, turn, and barrel roll (or other aerobatic). How were the gliders modified to perform these tricks?

Control Surfaces

In the last activity, you found out that it is possible to create a paper glider that will perform aerobatics. How did you modify your paper glider to perform an aerobatic maneuver? You may have modified your design to create new surfaces on your plane. In order to control yaw, pitch, and roll, airplanes have special surfaces called **control surfaces** built into them. These surfaces work together to keep a plane under control during flight. They can also be used to perform aerobatics. Understanding how control surfaces work is the key to aerobatics. Pilots use their knowledge of control surfaces and the forces that act on an object in flight to perform aerobatic displays. They must also be highly skilled pilots.

Figure 4.12 on page 116 shows the different control surfaces on an airplane.

Figure 4.11 Canadian Snowbirds perform a wide variety of aerobatics at air shows.

INTERNET CONNECT

www.mcgrawhill.ca/links/ns+science6

Seattle's Museum of Flight and the Smithsonian Institution's National Air and Space Museum in the United States once sponsored an international paper airplane competition. People from all over the world entered. Over 5000 paper airplanes were flown. Prizes were awarded for the longest flight, longest time in the air, and aerobatics. The under-14 category was won by a 10-year-old boy. Learn more about current paper airplane competitions. Go to the above web site and click on **Web Links** to find out where to go next.

- Join with another class and hold an air show featuring different aerobatics.
- Introduce students to the concept of control surfaces and how they are used to control the motion of an aircraft during flight.

Assessment Option

- Use Process Skills Rubric 11, Problem Solving for Find Out Activity 4-F My Flying Machine: Aerobatics.

What Did You Find Out? Answers

1. Accept any reasonable answer. *Sample answer:* No, my first glider didn't complete its maneuver. I wanted to make it do a barrel roll, but it just crashed.
2. Accept any reasonable answer that provides a possible explanation for the observed results. *Sample answer:* Yes, it worked after I modified the glider. I had bent one wing up and one wing down, to make the plane do a roll. When I modified the plane, I bent the wings further and made a really strong crease to keep them in place. I think my bent wings unfolded when I flew my first design. After I modified the wings, the bends stayed in place when the glider flew. This time it did a barrel roll.

CONTROL SURFACES

BACKGROUND INFORMATION

- Control surfaces can be manipulated in a variety of different ways. They can be controlled manually through a series of cables, pulleys, and rods that link the aircraft controls directly to the control surfaces. This control system, called a mechanical system, is used in many small personal passenger planes, such as the plane in Figure 4.10 A on page 113. However, as the aircraft increases in size, manual control becomes problematic. In such cases, a hydro-mechanical system is used. Thanks to a system of hydraulic pumps, reservoirs, and pipes, the movement of control surfaces no longer relies on a pilot's muscle power. Hydro-mechanical systems are used on older jet planes and high-performance jets. Two shortcomings of manual and hydro-mechanical systems are that they (1) are very heavy and (2) do not allow for compensation for changing aerodynamic conditions. The latter means that the aircraft must have a very stable design or it may enter a spin or stall that the control system cannot alter. As a result, planes with less-stable designs use a computerized control system called a fly-by-wire system. The system modifies the pilot's commands as per its software program. Changing aerodynamic conditions are thus compensated for. Fly-by-wire systems are used in passenger airliners and less stable aircraft, such as fighter jets.

TEACHING STRATEGIES

- **Begin the Lesson**—Review Find Out Activity 4-F My Flying Machine: Aerobatics with students. How were the paper gliders modified to perform aerobatics? Use this discussion to introduce control surfaces.
- **During Teaching**—Draw students' attention to Figure 4.11 on page 115. The Snowbirds in the figure can fly upside down. What design modifications might make this possible?

INTERNET CONNECT If a paper airplane contest is not running when you are teaching this unit, you may wish to start one for your school or district. If you are unable to set up an actual contest, you can also use an online paper airplane simulator to run your contest.

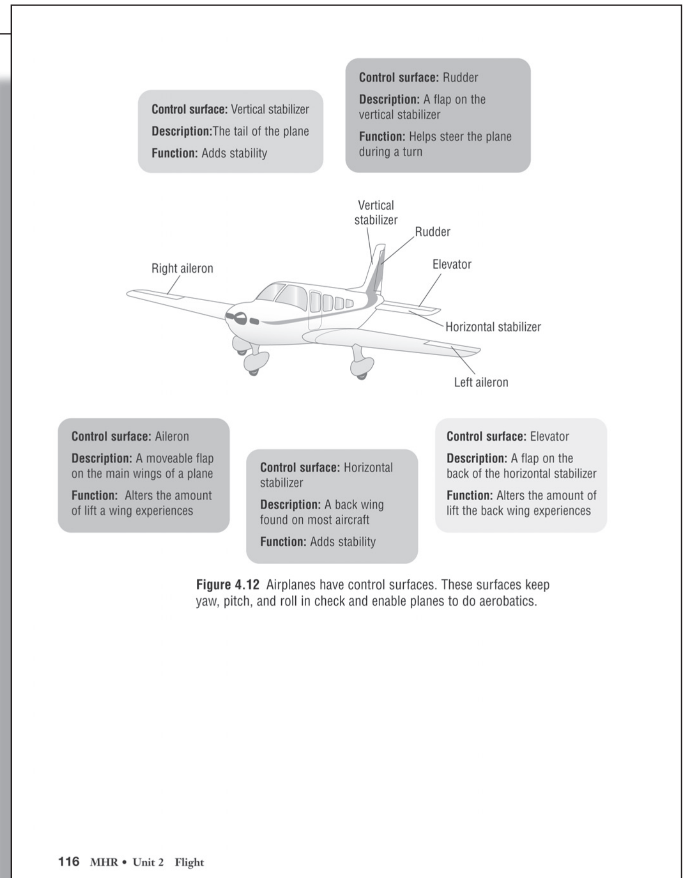
FIGURE 4.12 AIRPLANE CONTROL SURFACES ON PAGE 116

BACKGROUND INFORMATION

- The elevators on the horizontal stabilizer of the plane control pitch, the up and down motion of the nose of the plane. The rudder in the vertical stabilizer controls yaw, the side-to-side motion of the plane. The ailerons on the wings control roll, rotation around the plane's central axis.

TEACHING STRATEGIES

- **During Teaching**—BLM 4.5 Control Surfaces is an overhead of Figure 4.12. You may wish to use it as a teaching aid when explaining control surfaces to students.
- **After Teaching**—Arrange to bring in a model plane so that students can examine its control surfaces. If you have a small local airport nearby, you may also be able to arrange for students to examine the control surfaces on a small passenger plane.


Control surface: Vertical stabilizer
Description: The tail of the plane
Function: Adds stability

Control surface: Rudder
Description: A flap on the vertical stabilizer
Function: Helps steer the plane during a turn

Control surface: Aileron
Description: A moveable flap on the main wings of a plane
Function: Alters the amount of lift a wing experiences

Control surface: Horizontal stabilizer
Description: A back wing found on most aircraft
Function: Adds stability

Control surface: Elevator
Description: A flap on the back of the horizontal stabilizer
Function: Alters the amount of lift the back wing experiences

Figure 4.12 Airplanes have control surfaces. These surfaces keep yaw, pitch, and roll in check and enable planes to do aerobatics.

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THINK & LINK INVESTIGATION 4-G COMPARING AIRCRAFT DESIGNS

Purpose

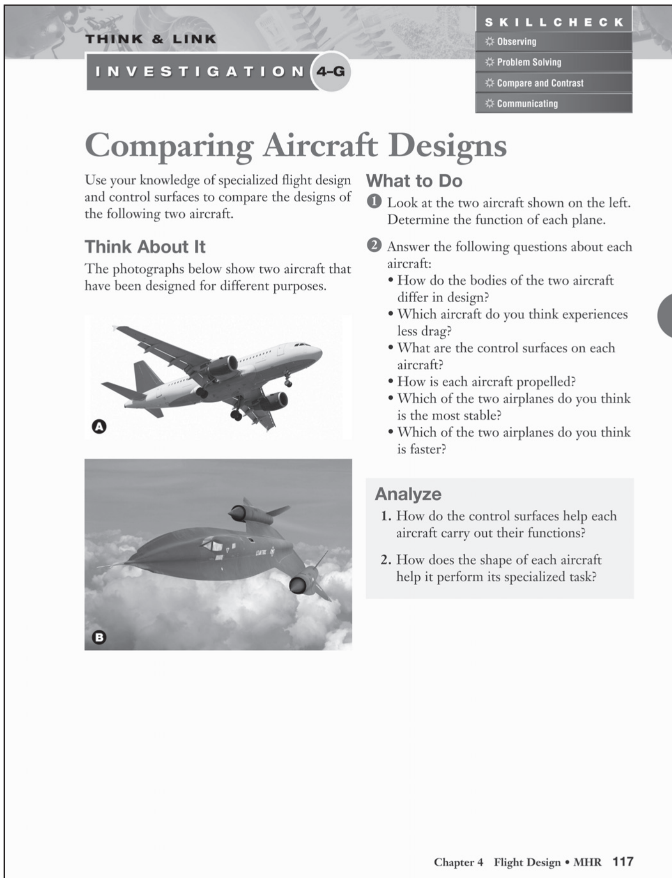
- Students compare the designs of two aircraft to analyze control surfaces and other aspects of aircraft design.

Suggested Time

- 20 min

HINTS & HELPS

- The plane in illustration A is a passenger jet. The plane in illustration B is a *SR-71 Blackbird* reconnaissance aircraft. Reconnaissance planes must fly quickly and at high altitude, avoiding radar detection and enemy fire. It is used for military surveillance.
- Have students compare the planes in this investigation to the control surfaces shown in Figure 4.12 on page 116.



THINK & LINK

INVESTIGATION 4-G

SKILLCHECK
- Observing
- Problem Solving
- Compare and Contrast
- Communicating

Comparing Aircraft Designs

Use your knowledge of specialized flight design and control surfaces to compare the designs of the following two aircraft.

Think About It

The photographs below show two aircraft that have been designed for different purposes.

A

B

What to Do

1. Look at the two aircraft shown on the left. Determine the function of each plane.
2. Answer the following questions about each aircraft:
   - How do the bodies of the two aircraft differ in design?
   - Which aircraft do you think experiences less drag?
   - What are the control surfaces on each aircraft?
   - How is each aircraft propelled?
   - Which of the two airplanes do you think is the most stable?
   - Which of the two airplanes do you think is faster?

Analyze

1. How do the control surfaces help each aircraft carry out their functions?
2. How does the shape of each aircraft help it perform its specialized task?

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Implementing the Investigation
- This investigation can be completed alone or in partners. It can also be completed as a class discussion.

Adaptations
- You may want to provide students who are visually impaired with enlargements of the images of the two planes. Working with a partner who can describe the images may also be beneficial.

Investigation Wrap-Up
- The Analyze questions for this investigation may be answered as part of a class discussion to wrap up the activity.

Assessment Option
- Use Science Skills Checklist 15, Making Observations and Inferences for Think & Link Investigation 4-G Comparing Aircraft Designs.

What to Do Answers

1. The function of the passenger jet is to transport people and cargo at a reasonable speed and a high level of safety. The function of the reconnaissance jet is to fly quickly at high altitude, avoid radar detection, avoid enemy fire, and carry out military surveillance.
2. (a) The passenger jet has a heavier, larger, bulkier, and less streamlined body than the reconnaissance jet.
   (b) The reconnaissance jet experiences less drag.
   (c) The passenger jet has a rudder, vertical stabilizer, horizontal stabilizer, elevators, and ailerons. The rudder and elevators are difficult to see in the photograph. The reconnaissance jet has a horizontal stabilizer but no other obvious control surfaces.
   (d) Each aircraft is propelled by jet engines.
   (e) The passenger jet is the most stable.
   (f) The reconnaissance jet is faster.

Analyze Answers

1. The passenger jet has numerous control surfaces that help it control its flight, allowing it to maintain stable flight and safely transport passengers. The reconnaissance jet has fewer control surfaces. This allows it to have a highly streamlined design so it can travel more quickly.
2. The passenger jet is large and bulky so it can carry a lot of passengers. Its control surfaces make it stable so the passengers arrive safely. The reconnaissance jet has an unusual shape that helps it avoid radar, which is important in its function as a military jet. Its streamlined shape lets it fly quickly and maneuver easily.

SECTION 4.2 SUMMARY

Review the section summary as a class. Make sure that students update the flight section in their logbooks and key terms list. As a review, students could design a graphic organizer that explains the motions that occur during flight and how they are controlled. BLM 4.6 Control Surfaces is a fill-in-the-blank version of Figure 4.12 on page 116. You may wish to have students fill in the missing information to review control surfaces.

✓ ASSESSMENT OPTIONS FOR SECTION 4.2

- Collect and review science logbooks, using Learning Skills Rubric 2, Science Logbook to evaluate them.
- Ask students to complete BLM 4.3. Aircraft Motions Review, a student review on yaw, pitch, and roll.
- Ask students to complete BLM 4.6, Control Surfaces Review, a fill-in-the-blanks version of Figure 4.12 on page 116 of the student textbook.
- Use the following rubrics to assess student work:
  - Process Skills Rubric 11, Problem Solving for Find Out Activity 4-E My Flying Machine: Stable and Long-Flying and Find Out Activity 4-F My Flying Machine: Aerobatics
  - Science Skills Checklist 15, Making Observations and Inferences for Think & Link Investigation 4-G Comparing Aircraft Designs

Check Your Understanding Answers

1. Stable aircraft are designed to control yaw, pitch, and roll and correct their flight if air turbulence occurs, providing a safe, predictable flight. To do this, they have different built-in control surfaces. A passenger aircraft is an example of stable aircraft. Unstable aircraft have fewer control surfaces than stable aircraft. As a result, they have less control over yaw, pitch, and roll than stable aircraft. They are not as safe as stable aircraft and are more likely to overcorrect and crash if air turbulence occurs. However, because they have fewer control surfaces, they can be more streamlined. This means they can fly more quickly. An unstable aircraft can also maneuver more quickly. Some students who are interested in fighter planes may know that in unstable aircraft an onboard computer guides the pilot's controls, making maneuvers possible. A fighter jet is an example of an unstable aircraft.

Section 4.2 Summary

Flight control is essential to maintain flight stability and complete aerobatic maneuvers successfully and safely.

- Once in the air, a plane can move in all directions. These directions are a combination of three basic motions: yaw, pitch, and roll.
- A stable plane self-corrects in air turbulence. An unstable plane does not. However, an unstable plane can maneuver much more quickly and easily than a stable plane can.
- Control surfaces help control the motion of a plane during flight.
- The control surfaces of a plane help a pilot perform aerobatic maneuvers.

Key Terms
yaw
pitch
roll
stable
unstable
control surfaces

Check Your Understanding

1. Describe the differences between a stable and an unstable aircraft. Give an example of each.
2. Describe the three basic motions that must be controlled to maintain stability during flight.
3. Explain how aerobatics and control surfaces are linked.
4. Do you think that large airplanes such as passenger jets are able to complete aerobatics? Explain your reasoning.

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2. The three basic motions that must be controlled to maintain stability during flight are: (1) roll: a motion in which the wing tips move up and down like a see-saw; (2) yaw: a side-to-side motion where the tail of the plane moves like the swishing tail of a fish; and (3) pitch: a motion where the nose and tail of the plane alternately rise up and dip down.
3. Control surfaces work together to keep a plane under control during flight. Pilots that perform aerobatics need to have a high degree of control over their planes to perform tricky maneuvers. Control surfaces help them do this.
4. Accept any well-reasoned answer. *Sample answer:* Yes, I think passenger jets could perform aerobatics if they weren't carrying any passengers. They have a lot of control surfaces, so a skilled pilot should be able to use these to complete maneuvers.

CHAPTER 4

Section 4.3 Flight—From the Past Into the Future

Key Terms
spaceplane

Since humans first observed flying animals, they have wanted to soar. Over time, their observations of airborne organisms and the forces that act on objects during flight helped their designs become airborne. Only a few attempts were successful at first. However, early *aviators* (people who design, build, and operate aircraft) learned from early successes and failures. Eventually human beings began to build flying machines that could stay in the air for more than a few seconds.

Learning how to control aircraft during flight was the next important advance. Many early aviators had focused more on the dramatic factors of power and speed than on flight control. Pilots had little control over the plane when it was in the air and were mostly along for the ride. The Wright brothers invented the first plane that was under the pilot's control. In 1903, the plane, known as the *Wright Flyer*, made its first successful flight.

The timeline in Figure 4.14 shows the development of aircraft from early human flight to modern aircraft, some of which you have already learned about in this Unit. How do you think living things may have inspired past and present aircraft design?

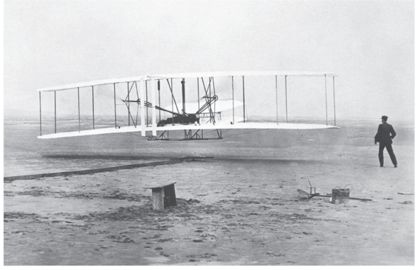

Figure 4.13 *The Wright Flyer* made its historic controlled flight in Kitty Hawk, North Carolina on December 17, 1903. The Wright brothers focused on controlling their aircraft, while other aviators focused on power or speed.

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SECTION 4.3 FLIGHT—FROM THE PAST INTO THE FUTURE

What Students Do in Section 4.3

- determine how living things may have inspired past and present aircraft design
- discover how aircraft changed over the course of history
- define spaceplanes and learn how they differ from rockets and the Space Shuttle
- learn how aircraft and spacecraft differ and determine how certain features of both types of crafts are combined in the Space Shuttle

BACKGROUND INFORMATION

- Early aviators learned most of what they knew about flight by observing nature. The greatest source of inspiration was the flight of birds. Leonardo da Vinci studied birds closely, both observing them in flight and studying their bones and muscles. Despite early designs of human-powered ornithopters (aircraft that fly by flapping wings), da Vinci quickly learned that human muscles were too weak to flap a pair of wings for long. His observations of birds soon inspired him to change his path and design a glider that required less energy and strength to fly. Da Vinci went on to imitate the designs of nature in many of his flying machines.
- In 1907, the Aerial Experiment Association was formed in Baddeck, Nova Scotia. It was led by Dr. Alexander Graham Bell and financed by his wife Mabel. Dr. Bell worked with John McCurdy, Frederick Baldwin, and Glenn Curtis to build and test the first successful aircraft in the British Empire. Known as *The Silver Dart*, the plane's first flight was on February 23, 1909.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students to write a paragraph in their logbooks about why people might have wanted to fly and what may have inspired them. This can be done as a Language Arts connection.
  - In class discussion, ask students what they already know about the early days of flight, both through the atmosphere and space. They may have already heard about the Wright brothers, for instance, or know that humans landed on the moon.
- **During Teaching**—Draw students' attention to Figure 4.13 on page 119 showing the Wright brothers' first flight. Have them note the pilot's unusual position on the plane and the fact that the plane has two sets of wings. They may be surprised to learn that in this historic first flight, the *Wright Flyer* flew only a few metres above the ground.
- **After Teaching**—Ask students the question that ends this text passage: "How do you think living things may have inspired past and present aircraft design?" to introduce Think & Link Investigation 4-H Living Things and Flight Design.

Common Misconceptions

- Students may incorrectly believe that the Wright brothers built the first plane that ever flew. In fact, several other aviation pioneers built planes that flew before the Wright brothers did; however, the Wright brothers' was considered the first fully controlled flight.

FIGURE 4.14 A TIMELINE OF AIRCRAFT HISTORY ON PAGES 120–121

BACKGROUND INFORMATION

- Although this timeline of the history of aircraft begins with Leonardo da Vinci's drawings of flying machines, he never actually tested these designs to determine if they were capable of flight. Recently, two of da Vinci's designs were actually built and flown: his parachute (in 2000) and his hang-glider (in 2002). The aircraft were mainly built from materials that would have been available when da Vinci was alive. For example, the frame of the hang-glider was made from bamboo, which was steamed so that it could be bent into shape.

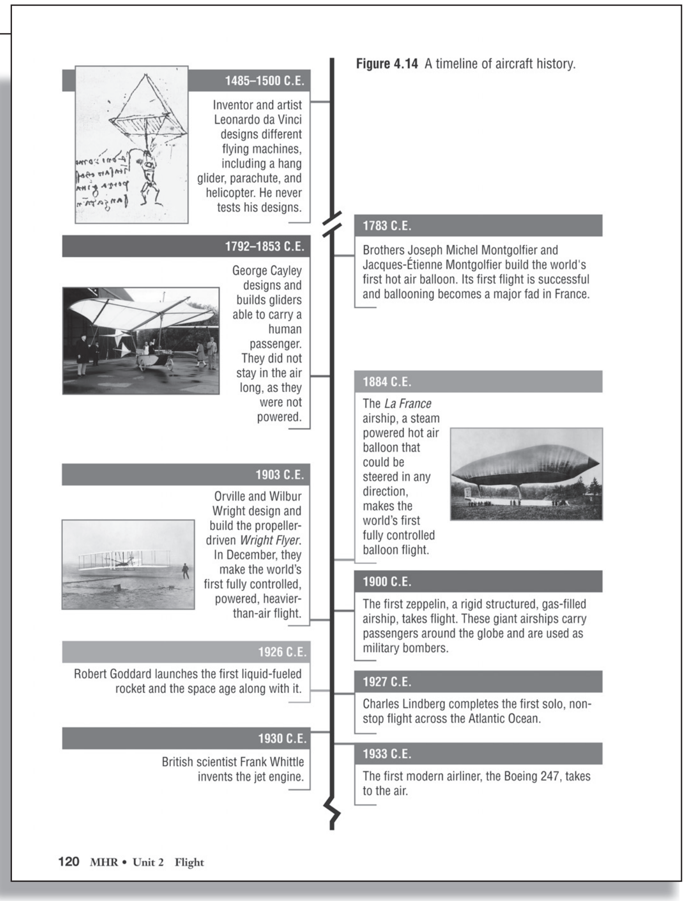

Figure 4.14 A timeline of aircraft history.

1485–1500 C.E.
Inventor and artist Leonardo da Vinci designs different flying machines, including a hang glider, parachute, and helicopter. He never tests his designs.

1783 C.E.
Brothers Joseph Michel Montgolfier and Jacques-Étienne Montgolfier build the world's first hot air balloon. Its first flight is successful and ballooning becomes a major fad in France.

1792–1853 C.E.
George Cayley designs and builds gliders able to carry a human passenger. They did not stay in the air long, as they were not powered.

1884 C.E.
The *La France* airship, a steam powered hot air balloon that could be steered in any direction, makes the world's first fully controlled balloon flight.

1903 C.E.
Orville and Wilbur Wright design and build the propeller-driven *Wright Flyer*. In December, they make the world's first fully controlled, powered, heavier-than-air flight.

1900 C.E.
The first zeppelin, a rigid structured, gas-filled airship, takes flight. These giant airships carry passengers around the globe and are used as military bombers.

1926 C.E.
Robert Goddard launches the first liquid-fueled rocket and the space age along with it.

1927 C.E.
Charles Lindberg completes the first solo, non-stop flight across the Atlantic Ocean.

1930 C.E.
British scientist Frank Whittle invents the jet engine.

1933 C.E.
The first modern airliner, the Boeing 247, takes to the air.

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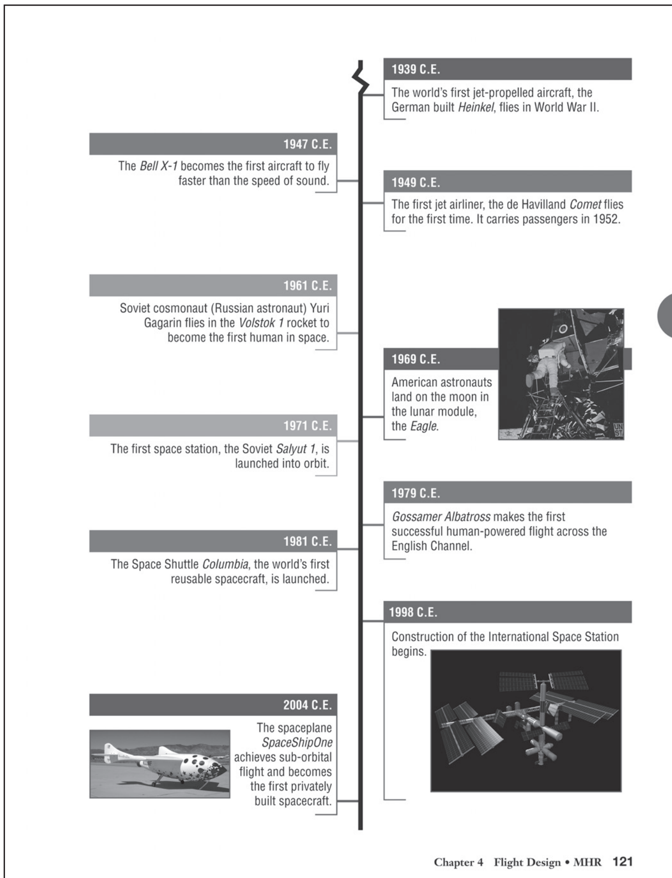

1939 C.E.
The world's first jet-propelled aircraft, the German built *Heinkel*, flies in World War II.

1947 C.E.
The *Bell X-1* becomes the first aircraft to fly faster than the speed of sound.

1949 C.E.
The first jet airliner, the de Havilland *Comet* flies for the first time. It carries passengers in 1952.

1961 C.E.
Soviet cosmonaut (Russian astronaut) Yuri Gagarin flies in the *Volstok 1* rocket to become the first human in space.

1969 C.E.
American astronauts land on the moon in the lunar module, the *Eagle*.

1971 C.E.
The first space station, the Soviet *Salyut 1*, is launched into orbit.

1979 C.E.
Gossamer Albatross makes the first successful human-powered flight across the English Channel.

1981 C.E.
The Space Shuttle *Columbia*, the world's first reusable spacecraft, is launched.

1998 C.E.
Construction of the International Space Station begins.

2004 C.E.
The spaceplane *SpaceShipOne* achieves sub-orbital flight and becomes the first privately built spacecraft.

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TEACHING STRATEGIES

- **Begin the Lesson**—*Leonardo's Dream Machines*, a documentary of the process involved in building a hang-glider based on da Vinci's design, is currently available.
  – *ICT Option:* Photographs of the aircraft are also available on the Internet for students to see. For links, go to www.mcgrawhill.ca/links/ns+science6. Both options can be used to get students excited about the history of aircraft.
- **During Teaching**—(optional teaching tool) BLM 4.7 Aircraft Timeline provides the timeline of aircraft history that can be copied as an overhead for use as a teaching tool.

THINK & LINK INVESTIGATION 4-H LIVING THINGS AND FLIGHT DESIGN

Purpose
- Students compare photos of airborne organisms and aircraft from different time periods to investigate how observations of living creatures may have inspired flight design.

Suggested Time
- 20 min

HINTS & HELPS
- Students may have some trouble determining whether the ornithopter (B) is related to the eagle (C) or the flying fish (F). Draw students' attention to the fact that both the eagle and the ornithopter flap their wings. Conversely, the flying fish actually glides over the water. Despite its misnomer, it does not truly fly. It has the most in common with the glider (E).

Implementing the Investigation
- Students can complete this investigation on their own or with a partner.
- This investigation can also be completed as a class discussion.
- You may wish to have students classify other aircraft and airborne organisms based on their classification schemes.

Adaptations
- You may want to provide students who are visually impaired with enlargements of the images in this investigation. Working with a partner who can describe the images may also be beneficial.

Investigation Wrap-Up
- Have students share their classification schemes with the class. Have a discussion about the importance of classification schemes in science. Advise them that they will be learning more about how scientists classify organisms in Unit 4.

Assessment Option
- Use Learning Skills Checklist 15, Making Observations and Inferences for Think & Link Investigation 4-H Living Things and Flight Design

What to Do Answers
1. A and G: both look like flying wings (an aircraft that hardly seems to have a body) and have a flat design; B and C: both have wings that flap by using muscle power; D and H: both have thin blades that turn to provide lift instead of wings; E and F: both have similar shaped wings that glide through the air (do not flap).
2. Accept any logical classification schemes that focus on each aircraft or organism's characteristics.


THINK & LINK
INVESTIGATION 4-H

SKILLCHECK
- Observing
- Problem Solving
- Compare and Contrast
- Classify

Living Things and Flight Design

Observations of airborne organisms have helped inspire aircraft design in the past and the present.

Think About It

Several photos of living things that fly and aircraft from different time periods are shown below.

What to Do

1. Match each living organism with the aircraft it may have inspired. Next to each organism-aircraft pair, describe the feature(s) that they share.
2. Classify the aircraft and flying organisms shown based on their different characteristics.

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FIND OUT ACTIVITY 4-I AIRCRAFT DESIGN OVER TIME

Purpose
- Students investigate how aircraft design has changed by researching and preparing a poster on a specific aircraft.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 week before	– Book library or computer resources if using. – Pre-select appropriate books for students to use in their research.

MATERIALS
Per student/group: – student textbook – library books or the Internet

Suggested Time
- 90 min

HINTS & HELPS
- Try to get some students interested in researching Canadian-designed aircraft (e.g., McCurdy and the *Silver Dart*; the *Avro Arrow*).
- You may wish to pre-select aircraft that are evenly spaced throughout history. Have students choose aircraft from the list, or assign each student or pair of students an aircraft to research.

Find Out **ACTIVITY 4–I**

Aircraft Design Over Time

How have aircraft changed throughout history?

What You Will Need

textbook
library books or the Internet

What to Do

1. Decide on a flying machine from any time in history that interests you. Confirm your topic with your teacher.
2. Create a list of questions you have about your aircraft. Use your textbook, library books, or the Internet to research your aircraft. Find the best and most complete answers to your questions.
3. Use a combination of text and illustrations to create an information page about your aircraft. Write the name of your aircraft and the date when it was designed on the top of the page. When you are finished, combine your pages with those of other students to create a timeline of aircraft history.

What Did You Find Out?

1. Explain how the aircraft you researched played an important role in the history of flight.
2. Review the class aircraft timeline. Write a short paragraph that describes an aircraft that you did not research.

Space Flight

Once humans were able to master flight through the air, they quickly turned their thoughts to space travel. The development of rockets and rocket engines has allowed us to realize our dreams of journeying into space for several reasons.

- A rocket engine is the only type of propulsion that works in both Earth's atmosphere and in the vacuum of space. Unlike a jet engine, it does not require air to operate.
- Rocket engines are able to provide the enormous amount of thrust needed to overcome Earth's gravitational pull and reach space.
- Rockets and the Space Shuttle are specially designed to reduce drag while they are travelling through Earth's atmosphere. Once they enter space, however, drag is no longer an issue. There is no air in space to cause drag.

DidYouKnow?

The Chinese first used rockets in fireworks displays over 1000 years ago, long before they were used for space travel.

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Implementing the Activity

- Pre-select books and web sites that have information and illustrations/photographs on a wide variety of historical and modern aircraft.
- This activity can be completed alone or with a partner.
- Once students have completed their posters, post them around the classroom in the form of a timeline. Use coloured, removable tape to create a continuous line around the room. Add dates to the timeline in 10-year intervals. Tape students' posters near the appropriate dates on the timeline.

Adaptations

- You may wish to pre-select simpler, highly visual materials for students with literacy difficulties ahead of time.

Activity Wrap-Up

- Create a video documentary on the timeline of aircraft design. Have each student present his or her poster and capture it on video. Then take the clips and create a running documentary you can show students.

Assessment Option

- Use Learning Skills Rubric 5, Research Project for Find Out Activity 4-I Aircraft Design Over Time.

What Did You Find Out? Answers

1. Accept any answers that include a basic overview of the role the aircraft played in the history of flight. *Sample answer:* My aircraft, the *Bell X-1*, played an important role in the history of flight. The plane was a top-secret military plane. The pilot called it the *Glamorous Glennis* after his wife. In 1947, it was the first plane to fly faster than the speed of sound. This was important in history because no plane had flown this fast before. Also, this success led the way for the U.S. to develop more flight technology. It was soon the world leader in aviation.
2. Accept any answers that include a moderately detailed overview of the chosen aircraft. *Sample answer:* The *Silver Dart* was the plane that made the first motorized flight in Canada and the British Empire. It took off from Baddeck Bay, Nova Scotia, in 1909. The flight involved some famous people in history. John McCurdy, who later became lieutenant governor of Nova Scotia, flew the plane. He worked with Alexander Graham Bell, who invented the telephone, to design and build the aircraft. The *Silver Dart* was made from steel tubes, tape, wire, wood, and bamboo. Its wings were covered in silk cloth. It flew over 35 km during its first flight. It won an award for the first flight over a mile long in North America. The plane crashed in its fifth and last flight when its wheel hit uneven ground when it was landing. There is a full-size model of the plane at the Canadian Aviation Museum in Ottawa.

SPACE FLIGHT

BACKGROUND INFORMATION

- Students will be interested to learn that the first astronauts were non-human. In order to determine that humans could safely travel in space, animals took all the risks. The first animals in space were fruit flies. They were used to test for radiation exposure at high altitudes. The first monkey to enter space was named Albert II. He was launched into space in 1949. Unfortunately, he died upon impact when the parachute failed to open upon landing. However, many dogs entered space and returned to Earth successfully in the next 10 years, before the first human orbited the planet in 1961.

(continued) ➜

TEACHING STRATEGIES

- **Begin the Lesson**—Show a video or DVD on space flight to get students excited about space-craft and space travel.
- **During Teaching**—Ask students what other special factors engineers need to consider when designing crafts that enter space and return to Earth again.
- **After Teaching**—Discuss students' responses to the "during reading" strategy to introduce the next activity, Think & Link Investigation 4-J Aircraft Versus Spacecraft. In this investigation, students compare the differences and similarities between spacecraft and aircraft. They then try to determine how the Space Shuttle combines features of both.

DidYouKnow? While the Chinese first used rockets in firework displays for religious ceremonies and festivals, the first historically documented use of rockets was in 1232 during warfare between the Chinese and the Mongols. The Chinese defeated the Mongols by using "fire arrows." These were essentially bamboo tubes that were closed at one end and filled with gunpowder.

FUTURE FLIGHT

BACKGROUND INFORMATION

- The new Space Shuttle Orion will replace the current Space Shuttle, which is scheduled for retirement in 2010. Orion's first flight is scheduled for 2014. It will eventually play a key role in human trips to the Moon and Mars.

TEACHING STRATEGIES

- **After Teaching**—*ICT Option:* There are some interesting "spaceplanes of the future" web sites that students may enjoy looking at. For links, go to www.mcgrawhill.ca/links/ns+science6.

INTERNET CONNECT The Canadian Space Agency web site has some interesting information about Canada's role in space, including information on NASA's *Phoenix Mars Lander*, which carried a Canadian meteorological station to Mars. The *Phoenix Lander* touched down on the Martian surface on May 25, 2008. It will study the Martian Arctic. For links, go to www.mcgrawhill.ca/links/ns+science6.

INTERNET CONNECT
www.mcgrawhill.ca/links/ns+science6
Did you know that Canada has an extensive space program? Find out more about Canadians and Canadian technology in space. Go to the above web site and click on **Web Links** to find out where to go next.

Spacecraft and aircraft differ not only in the engines they use, but in other aspects of design as well. However, the Space Shuttle is unique in that it combines features of both types of craft. What features do you think the Space Shuttle shares with aircraft? How about with spacecraft?

Future Flight

How far will aircraft and spacecraft design take human beings? Will we one day travel to nearby planets? Will we leave our own solar system? As flight design continues to advance, the sky is no longer the limit. One of the current focuses is on affordable space travel. Aeronautical engineers are designing cost-effective, reusable space aircraft, known as **spaceplanes**. Spaceplanes are rocket-powered. However, they differ from the Space Shuttle in that all their components are completely reusable. For example, the *SpaceShipOne* has already achieved extremely high-altitude flight. However, it has not yet achieved true orbit. It also requires a special launch. The spaceplane is piggybacked on a jet and lifted to a high altitude. At this point the spaceplane launches into space. Engineers hope that one day spaceplanes will be able to achieve takeoff on their own.

Despite these efforts to create spaceplanes, the Space Shuttle program has not been abandoned. However, the current Space Shuttle will soon be retired, as the new *Orion* design is expected to be ready for space flight in 2014. You will learn more about space in the next unit.

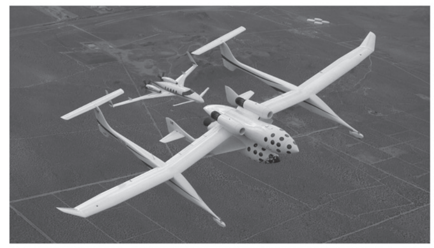

Figure 4.15 *SpaceShipOne* launches into space from the back of a jet.

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THINK & LINK INVESTIGATION 4-J AIRCRAFT VERSUS SPACECRAFT

Purpose

- Students investigate how the characteristics of spacecraft and aircraft differ. They then determine how certain features from both types of crafts are combined in the Space Shuttle.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 day before	– Photocopy BLM 4.8 Aircraft Versus Space Craft and BLM 4.9 Space Shuttle.

MATERIALS
Per student: – activity handouts

Suggested Time

- 60 min

THINK & LINK

INVESTIGATION 4–J

SKILLCHECK
- Research
- Problem Solving
- Compare and Contrast
- Communicating

Aircraft Versus Spacecraft

Think About It

Aircraft and spacecraft have their own unique characteristics. They are designed to travel in certain environments. The Space Shuttle, on the other hand, combines features from both air and space design. It is a unique craft. In this investigation, you will learn how the characteristics of spacecraft and aircraft differ. Then you will determine how certain features from both types of crafts are combined in the Space Shuttle.

What to Do

1. Read the handout that describes features of aircraft and spacecraft. As a group, brainstorm how the two types of crafts differ.
2. Read the handout on the Space Shuttle. Explain how the Space Shuttle uses features of both types of crafts in its design.
3. With your group, create a poster that illustrates the results of your research.

Figure 4.16 A Space Shuttle launches into space with the help of rocket engines. Notice the aerodynamic shape of the rocket and the shuttle.

Analyze

1. Explain why the Space Shuttle needs features of both an aircraft and a spacecraft.

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HINTS & HELPS

- Be sure to provide each student in the group with a copy of each BLM so they can read it to themselves to begin with. You may also wish to go over these BLMs as a class.
- Remind students that the photograph of the Space Shuttle in the student textbook may be helpful when considering the design of the Space Shuttle.
- You may want to provide students with extra books on the Space Shuttle for more photographs and information.

Implementing the Investigation

- This activity works best when completed in groups of three or four.

Adaptations

- Due to the amount of reading in this investigation, you may want to use preferential grouping so students with literacy difficulties can be fully involved in the project. Encourage such students to focus on the visual design features of spacecraft, aircraft, and the Space Shuttle.

Investigation Wrap-Up

- Analyze question 1 can be answered as part of an activity wrap-up.
- Ask each group to present their poster to the class.

Assessment Option

- Use Learning Skills Checklist 5, Poster and/or Learning Skills Rubric 3, Co-operative Group Work for Think & Link Investigation 4-J Aircraft Versus Spacecraft

Analyze Answers

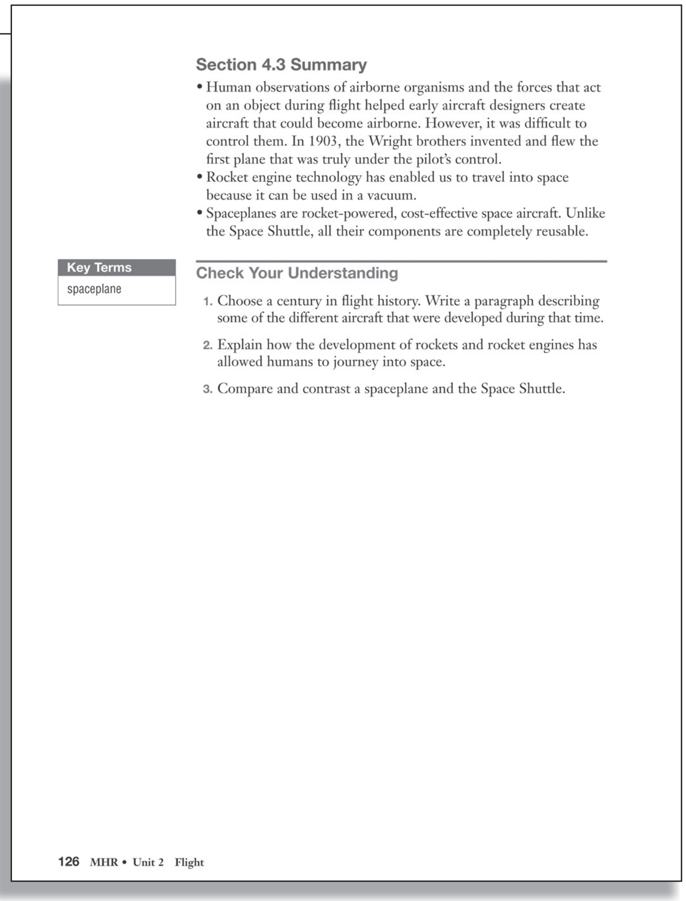
1. The Space Shuttle needs to have the features of an aircraft because it is a reusable spacecraft. To land, it has to fly through the atmosphere like a jet. The features of an aircraft, such as its wings and control surfaces, help make its flight stable. The Space Shuttle needs to have the features of a spacecraft, too, however, as it needs to fly in space. For this, it needs rocket engines, since jet engines cannot work in the vacuum of space. It also needs to be made from special materials that protect it from space debris and heat during re-entry into the atmosphere.

SECTION 4.3 SUMMARY

Review the section summary as a class. Make sure that students update the flight section of their logbooks and key terms list. As a review for the entire chapter, students could design quiz questions that cover the concepts they have learned. The questions could be used in a class discussion.

✓ ASSESSMENT OPTIONS FOR SECTION 4.3

- Collect and review science logbooks, using Learning Skills Rubric 2, Science Logbook to evaluate them.
- Use the following rubrics and checklists to assess student work:
  - Learning Skills Checklist 15, Making Observations and Inferences for Think & Link Investigation 4-H Living Things and Flight Design
  - Learning Skills Rubric 5, Research Project for Find Out Activity 4-I Aircraft Design Over Time
  - Learning Skills Checklist 5, Poster and/or Learning Skills Rubric 3, Co-operative Group Work Rubric for Think & Link Investigation 4-J Aircraft Versus Spacecraft



Section 4.3 Summary

- Human observations of airborne organisms and the forces that act on an object during flight helped early aircraft designers create aircraft that could become airborne. However, it was difficult to control them. In 1903, the Wright brothers invented and flew the first plane that was truly under the pilot's control.
- Rocket engine technology has enabled us to travel into space because it can be used in a vacuum.
- Spaceplanes are rocket-powered, cost-effective space aircraft. Unlike the Space Shuttle, all their components are completely reusable.

Key Terms
spaceplane

Check Your Understanding

1. Choose a century in flight history. Write a paragraph describing some of the different aircraft that were developed during that time.
2. Explain how the development of rockets and rocket engines has allowed humans to journey into space.
3. Compare and contrast a spaceplane and the Space Shuttle.

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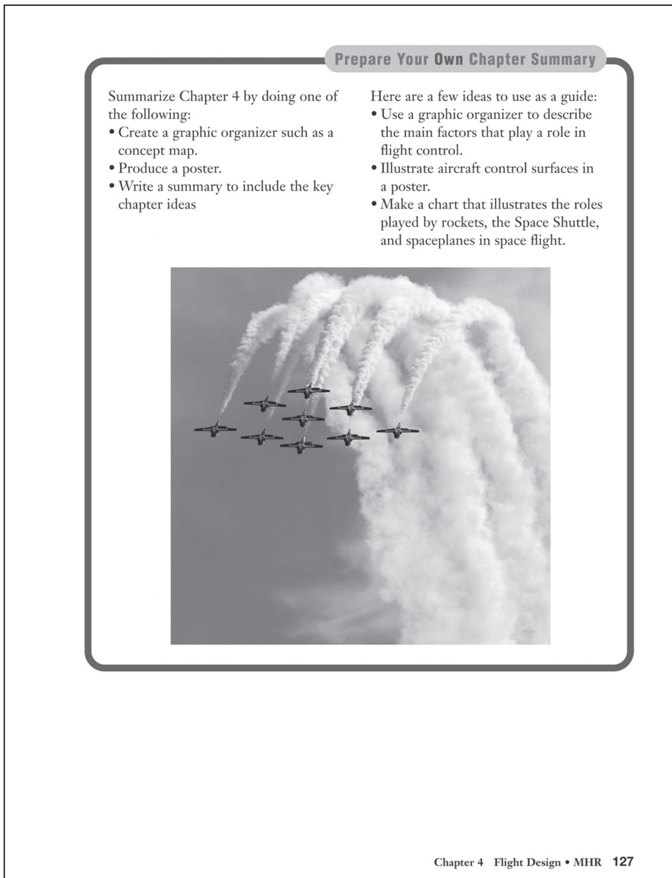
Check Your Understanding Answers

1. Accept any response that provides a good overview of the century in question. *Sample answer:* During the twenty-first century, most new developments in aviation were actually in space flight. The International Space Station was completed. It is now orbiting Earth as a working space station. SpaceShipOne made the first sub-orbital flight in 2004. It was the world's first privately built spacecraft. Also, the new Space Shuttle Orion is being designed and will fly in 2014.
2. The development of rocket engines helped people travel into space because these engines can operate in a vacuum, unlike jet engines, which require air to work. Rockets helped people journey into space by providing oxygen to breathe and protection from radiation in space, space debris, the cold of space, and the heat of re-entry into the atmosphere.
3. Both the Space Shuttle and spaceplanes are powered by rocket engines. Right now, the Space Shuttle can travel into space, but spaceplanes have only reached really high altitudes, not true orbit. The Space Shuttle is a lot more expensive to run than a spaceplane. All the parts of a spaceplane are totally reusable. Some parts of the Space Shuttle are not reusable. The Space Shuttle takes off from the ground, while a spaceplane needs to take off from a plane that is already flying at a high altitude. The Space Shuttle has been operating a lot longer than spaceplanes.



Prepare Your Own Chapter Summary

Summarize Chapter 4 by doing one of the following:
- Create a graphic organizer such as a concept map.
- Produce a poster.
- Write a summary to include the key chapter ideas

Here are a few ideas to use as a guide:
- Use a graphic organizer to describe the main factors that play a role in flight control.
- Illustrate aircraft control surfaces in a poster.
- Make a chart that illustrates the roles played by rockets, the Space Shuttle, and spaceplanes in space flight.

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Prepare Your Own Chapter Summary

Student summaries should incorporate the following main ideas:

- Aeronautical engineers design, produce, and take care of aircraft.
- New aircraft designs are tested in wind tunnels to determine how air moves around and over the aircraft.
- The angle that a wing makes compared to the flow of air is called its angle of attack. To increase lift, the angle of attack must be positive.
- Once in the air, an airplane's motions are usually a combination of three specific movements: yaw, pitch, and roll.
- Stable aircraft are designed to control yaw, pitch, and roll. Unstable aircraft have less control over these motions, but the pilot can maneuver these aircraft more quickly.
- During aerobatics, a plane will demonstrate yaw, pitch, and roll on purpose in a controlled manner.
- In order to control yaw, pitch, and roll, airplanes have special surfaces called control surfaces. These surfaces also help planes perform aerobatics.
- Most early aviators had little control over their aircraft. The Wright brothers invented the first plane that was under the pilot's control.
- Airborne organisms have inspired past and present aircraft design.
- Spacecraft and aircraft differ in many different ways, including the design of their engines. Rocket engines can work in the vacuum of space while jet engines cannot.
- Spaceplanes are rocket-powered, reusable space aircraft that can achieve extremely high-altitude flight and may one day travel into space.

You may wish to put a few key words on the board or on an overhead or data screen to help guide students in creating their own summary.

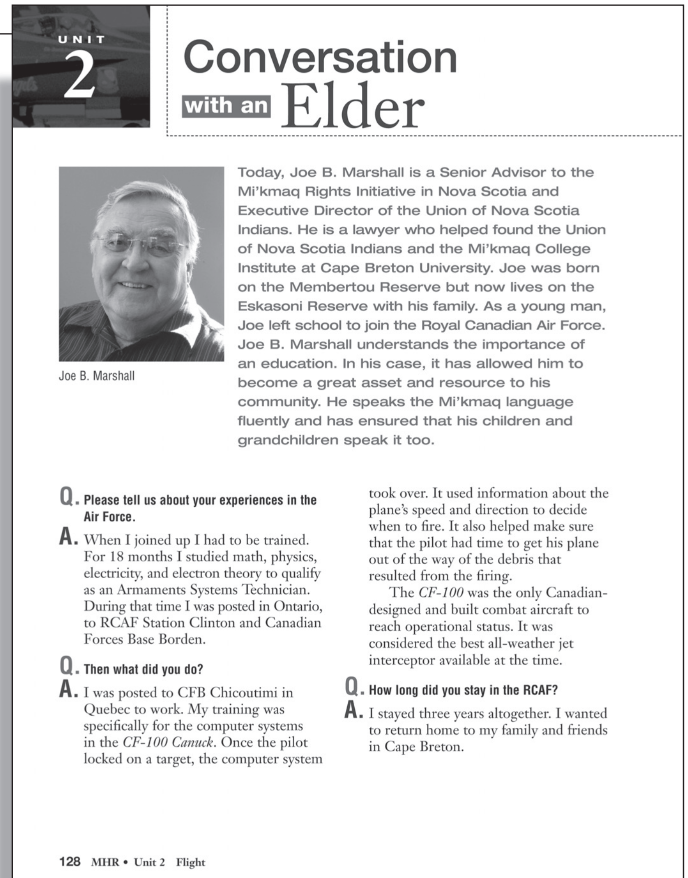
CONVERSATION WITH AN ELDER JOE B. MARSHALL

BACKGROUND INFORMATION

- The *CF-100 Canuck* made its first flight in 1950. It was designed to meet the need for a fighter plane that could monitor Canada's north in all weather conditions during the Cold War. It was the only Canadian-designed fighter jet to enter mass production. Nearly 700 *CF-100* Canucks were produced. Both the Canadian Air Force and the Belgian Air Force used the plane. While the plane could not technically break the sound barrier, a test pilot did fly faster than the speed of sound during a dive from a height of 10 000 metres.

TEACHING STRATEGIES

- **Begin the Lesson**—Ask students if anyone in their family has served in the Canadian Air Force. Do they have any experiences they can share with the class? Are any students interested in joining the Air Cadets themselves? Students can join once they are 12 years old.
- **During Teaching**—Draw students' attention to the figure of the *CF-100 Canuck* in the top right-hand corner of page 129. Explain that the symbol of the red maple leaf in the blue circle is an international symbol that tells pilots that the plane is Canadian. Military planes from different countries all use different symbols. Why are these symbols important?
- **After Teaching**—If possible, have a Canadian Air Force pilot come in and speak to your students about the experience.



UNIT 2

Conversation with an Elder

Joe B. Marshall

Today, Joe B. Marshall is a Senior Advisor to the Mi'kmaq Rights Initiative in Nova Scotia and Executive Director of the Union of Nova Scotia Indians. He is a lawyer who helped found the Union of Nova Scotia Indians and the Mi'kmaq College Institute at Cape Breton University. Joe was born on the Membertou Reserve but now lives on the Eskasoni Reserve with his family. As a young man, Joe left school to join the Royal Canadian Air Force. Joe B. Marshall understands the importance of an education. In his case, it has allowed him to become a great asset and resource to his community. He speaks the Mi'kmaq language fluently and has ensured that his children and grandchildren speak it too.

Q. Please tell us about your experiences in the Air Force.

A. When I joined up I had to be trained. For 18 months I studied math, physics, electricity, and electron theory to qualify as an Armaments Systems Technician. During that time I was posted in Ontario, to RCAF Station Clinton and Canadian Forces Base Borden.

Q. Then what did you do?

A. I was posted to CFB Chicoutimi in Quebec to work. My training was specifically for the computer systems in the *CF-100 Canuck*. Once the pilot locked on a target, the computer system took over. It used information about the plane's speed and direction to decide when to fire. It also helped make sure that the pilot had time to get his plane out of the way of the debris that resulted from the firing.

The *CF-100* was the only Canadian-designed and built combat aircraft to reach operational status. It was considered the best all-weather jet interceptor available at the time.

Q. How long did you stay in the RCAF?

A. I stayed three years altogether. I wanted to return home to my family and friends in Cape Breton.

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The CF-100 Canuck was a twin-engine jet interceptor. It was used by the RCAF for more than 30 years, from 1950 to 1981. It was also known as the "Clunk" because of the noise the landing gear made when it was retracted into the nose of the aircraft.

Q. What did you do after you left the military?

A. I went back to high school and finished grade 11, then went to St. Francis Xavier University in Antigonish, to the Coady International Institute. When I graduated with a diploma in Social Leadership, I worked in various jobs for the Department of Indian Affairs. Later, I decided I wanted more education, so I moved to Halifax to study law at Dalhousie University.

Q. How did you become involved with Mi'kmaq organizations?

A. As a lawyer, I was a founding member of the Union of Nova Scotia Indians at Membertou. Later I wanted to further the Mi'kmaq people and culture so I worked alongside others to establish the Mi'kmaq College Institute at Cape Breton University. I taught there for several years.

Q. What are you doing now?

A. I recently retired from Cape Breton University as an Associate Professor. I'm still working with the Mi'kmaq Rights Initiative, negotiating treaty rights with the Nova Scotia government.

EXPLORING Further

If you are interested in airplanes and flying, you might like working in the aviation industry. The industry includes not only air travel, but also air freight, air ambulances, emergency services, and the military. All depend on the facilities and services supplied in airports.

Only about 20 percent of people who work in the aviation industry actually do their work in the air. The other 80 percent have jobs on the ground. There are entry-level jobs such as baggage-handler, skilled jobs such as ticket agent, jobs for certified trades-people such as mechanics, and professional jobs such as flight engineer or pilot.

Research jobs in the aviation industry. Select one that interests you, and find out (a) what a person in that job does during their workday, and (b) how much general education and how much special training the position requires. Prepare a short report to be included in a school career resources binder so others can find out about the job.

Unit 2 Conversation with an Elder • MHR 129

EXPLORING FURTHER

Purpose

- Students investigate different careers in the field of aviation.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 week before	– Book library and/or computer resources for student use.

Suggested Time

- 60 min

HINTS & HELPS

- You may wish to provide students with a list of pre-selected, student-friendly web sites that contain information on aviation-related careers.
- Students can use their science logbooks to write up what they learned and list some occupations that involve working with an aspect of flight.

Implementing the Activity

- This activity can be done alone or in partners.

Adaptations

- This activity relies heavily on reading skills. Students with literacy difficulties should work with a partner who can help them master the activity.

Activity Wrap-Up

- Students could present their reports to the class.
- Have someone who works in the aviation industry come in and speak with your students about the job he or she does.

Assessment Option

- Learning Skills Rubric 5 Research Project and/or Learning Skills Rubric 6 Communication for Exploring Further activity.

ASK A COMMERCIAL PILOT: BEP HARDY-MATTERN

BACKGROUND INFORMATION

- The first step to becoming a commercial pilot is to earn your Commercial Pilot's Certificate. This can be obtained in Nova Scotia if you are 18 years of age or older.
- Approximately 5 percent of commercial pilots are female. The first female commercial-airline pilot was hired in North America in 1973. Air Canada hired Rosella Bjornson, a Canadian pilot from Alberta. Bjornson played a large role in changing regulations that allowed pregnant women to fly. She was inducted into the Canadian Aviation Hall of Fame in 1997. She is still a captain of a commercial airliner today and an active supporter of aviation careers for women.

TEACHING STRATEGIES

- **After Teaching**—Invite a commercial pilot or co-pilot to come in and speak with your class. You may also wish to take your students on a tour of a commercial airport, if possible.

UNIT 2

Ask a Commercial Pilot

Bep Hardy-Mattern

Bep Hardy-Mattern was born and grew up in the Netherlands. Her father worked as a captain with Royal Dutch Airlines (KLM). She moved to Canada in 1976, finishing high school in Ottawa and attending Carleton University to earn a degree in teaching. In the summer of 1979, she took the required training to get her Private Pilot's Licence. She then continued her training to get her commercial pilot's licence. By 1981, she was also qualified to be a flight training instructor.

Q: What do pilots need to know and understand about flight?

A: When you train to be any kind of pilot, you have to complete a lengthy ground school education, including training in aerodynamics and navigation and weather studies. This is because when you fly an aircraft, you have many forces and changing aerodynamic situations to deal with. If something happens, it's not like driving a car: you cannot just slow down and get off the road. You have to get the aircraft down safely. And to be a pilot for an airline, you need a commercial license with a multi-engine instrument rating.

Q: What else is involved?

A: Students need to know that it takes a lot of hard work to become a commercial pilot. There are many skills to learn and many hours to fly before you can make your living as a pilot. Pilots not only need a lot of training to get their licences, they continue to train to keep up their skills throughout their careers.

Pilots also need to be in good physical condition. They must have a valid medical certificate that shows they do not have any medical conditions that might disable them during a flight or need to take many medications. The Class 1 Medical Certificate commercial pilots need is hard to get and maintain. If you fail your medical, you lose your pilot's licence, without exception. You need to work very hard to get it back.

There are also basic requirements related to having good vision. Now a pilot can fly while wearing glasses, but when I was in training it was more difficult to find a job if you wore them.

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Q: What does a pilot do before a flight?

A: The pilot of a single-engine plane has to prepare a flight plan and measure the mass of the aircraft before every flight. The pilot needs to calculate how much fuel will be required and what route to follow in order to arrive safely—all of that information depends on the destination. Before every flight the pilot must check the weather. A strong wind will affect the route pilots plot to get to their destination. They also need to check for "NOTAMS," which are "notices to airmen" that may affect the airport they are headed to. Everything a pilot does involves a concern for safety. Pilots try to rule out any surprises because they are more difficult to deal with in the air.

I flew from 1979 to 1986 and made it my full-time profession for four years. I flew more than 2400 hours, mostly as pilot-in-command. I have a commercial license, a float rating, and a multi-engine rating.

Q: How does flying inspire you?

A: I enjoy the space and freedom when I lift off the ground. Once I became a pilot, I was fascinated with being in the air and dealing with the elements like weather, the mechanics of the aircraft, runway conditions, and the adventure of flying into new places. The world looks quite different from up there!

I enjoyed teaching people how to fly, which was a close match to my background as a teacher. Flying, like teaching, is much more than a job. It is fascinating and exciting, and you will find pilots flying for the major airlines who, like me, started their careers in other professions but were caught by the "flying bug" and changed their career path.

EXPLORING Further

Many Canadian pilots first went up in the air during World War I (1914–1918). They flew as part of the British Air Services and eventually made up one-third of the force. After the war, those who had fallen in love with flying came home hoping to find ways to put their new skills to work. In the following decades, bush pilots and their small planes played an important role in mapping Canada's north, surveying and managing its forests, and getting access to rich mining and oil resources.

Inventors, including Wallace Turnbull of New Brunswick, worked hard to improve the aircraft. Turnbull is famous for perfecting the first practical variable pitch propeller. Visit **www.mcgrawhill.ca/links/ns+science6** to find out answers to the following questions:

1. What is a variable pitch propeller?
2. How does it work?
3. How does it help a plane's performance?

EXPLORING FURTHER

Purpose

- Students investigate Canada's role in aircraft history, specifically Wallace Turnbull's improvement of the propeller.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
1 week before	– Book library or computer resources for student use.

Suggested Time

- 30 min

HINTS & HELPS

- You may wish to provide students with a printout of the appropriate materials from the McGraw-Hill web site. For links visit www.mcgrawhill.ca/links/ns+science6.

Implementing the Activity

- This activity can be completed alone or in partners.

Adaptations

- Students with literacy difficulties or comprehension problems may benefit from extra assistance during this activity.

Activity Wrap-Up

- You may want to wrap up this activity with a discussion of Canadian aviation firsts. Some firsts mentioned in this Teacher's Resource include McCurdy's flight (the first motorized flight in the British Commonwealth) and Rosella Bjornson (the first female airline pilot in North America).

Assessment Option

- Use Learning Skills Rubric 5 Research Project and/or Learning Skills Rubric 6 Communication for Exploring Further activity.

Exploring Further Answers

1. Pitch refers to adjusting the angle of attack of the propeller blades into or out of the wind. A variable pitch propeller has blades in which the pitch can be changed.
2. The pitch of the propeller is changed automatically to generate different levels of thrust and air speed.
3. It makes the propeller more efficient and keeps the plane from stalling. It can also generate reverse thrust to make the plane go backward or to help the plane slow down when braking.

UNIT 2 PROJECT FLIGHT IN THE YEAR 2030

Purpose

- Students use their knowledge of the unit to create a model of an aircraft or spacecraft for the future.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO
3 days before	– Gather enough materials for the whole class.

MATERIALS
Per group: – cardboard, Manila and construction paper – papier-mâché materials – plastic bottles – tape – glue – drinking straws – toothpicks – Popsicle™ sticks – aluminum foil – paint – modelling clay – scissors

Suggested Time

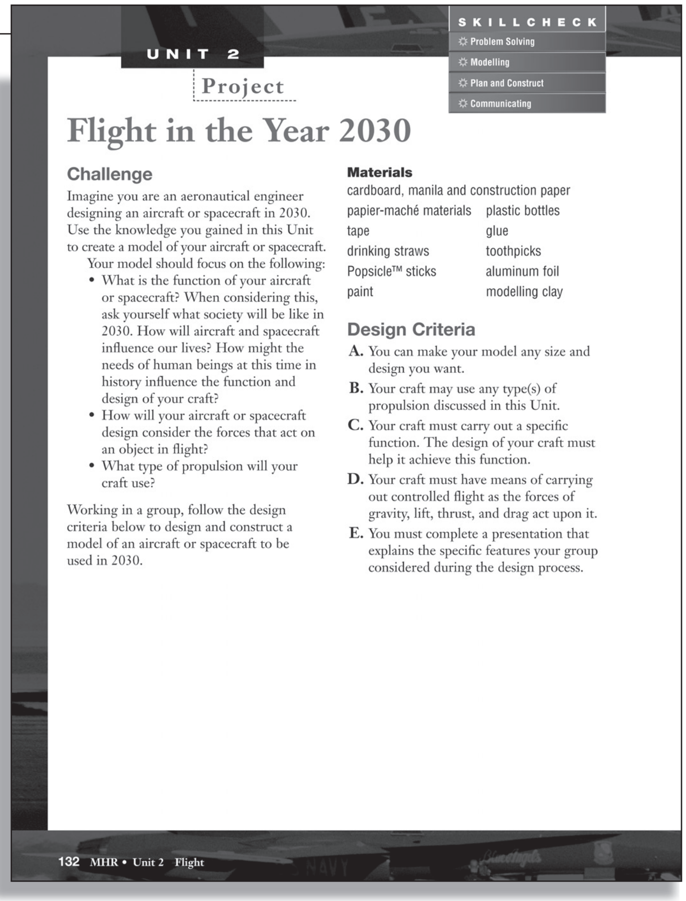
- 2 hours (Some out-of-class time will be required to prepare or practise the presentation.)

Safety Precautions

- Remind students to use caution when handling scissors.

HINTS & HELPS

- Supply students with any other arts and crafts materials you have around the classroom.
- Have each group assign one student as recorder ahead of time.
- Remind students that they must show their illustration and design plan to you and get your approval before proceeding to build their model.


UNIT 2

Project

SKILLCHECK
Problem Solving
Modelling
Plan and Construct
Communicating

Flight in the Year 2030

Challenge

Imagine you are an aeronautical engineer designing an aircraft or spacecraft in 2030. Use the knowledge you gained in this Unit to create a model of your aircraft or spacecraft.

Your model should focus on the following:
- What is the function of your aircraft or spacecraft? When considering this, ask yourself what society will be like in 2030. How will aircraft and spacecraft influence our lives? How might the needs of human beings at this time in history influence the function and design of your craft?
- How will your aircraft or spacecraft design consider the forces that act on an object in flight?
- What type of propulsion will your craft use?

Working in a group, follow the design criteria below to design and construct a model of an aircraft or spacecraft to be used in 2030.

Materials

cardboard, manila and construction paper
papier-maché materials, plastic bottles, tape, glue, drinking straws, toothpicks, Popsicle™ sticks, aluminum foil, paint, modelling clay

Design Criteria

A. You can make your model any size and design you want.
B. Your craft may use any type(s) of propulsion discussed in this Unit.
C. Your craft must carry out a specific function. The design of your craft must help it achieve this function.
D. Your craft must have means of carrying out controlled flight as the forces of gravity, lift, thrust, and drag act upon it.
E. You must complete a presentation that explains the specific features your group considered during the design process.

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Implementing the Project

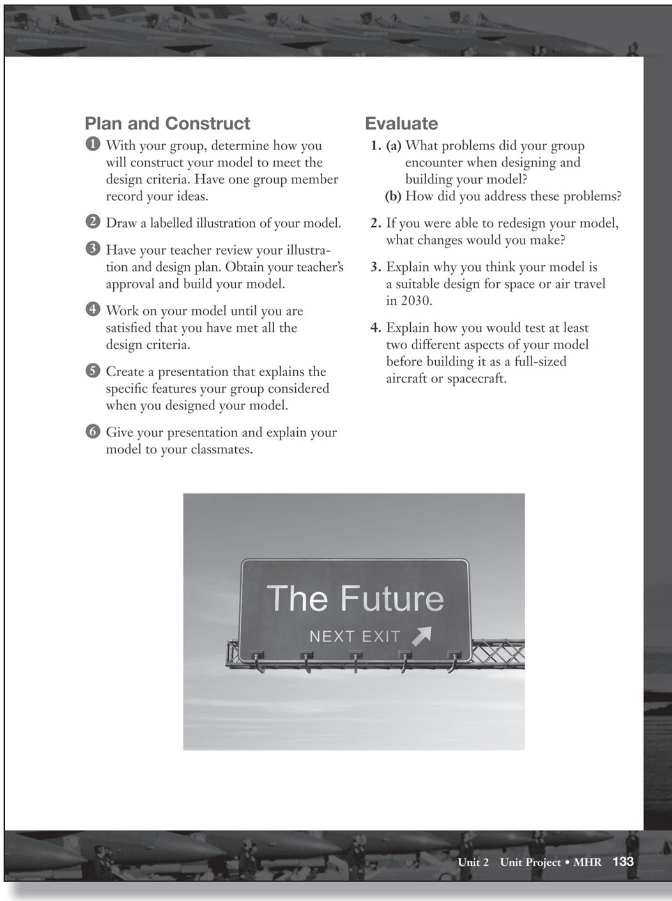
- Groups of three or four students work best for this project. This may be a project where assistance from home would be suitable.
- Students can choose any medium to present their project. This may include a standard oral presentation, a news-style interview of the team who designed the aircraft, a video documentary or computer slide show presentation, for example. Encourage students to be creative.

Adaptations

- Use preferential grouping to ensure that students with fine motor difficulties are able to participate in the project fully.

Project Wrap-Up

- Arrange to have the models displayed in the classroom or in a school display area.



Plan and Construct

1. With your group, determine how you will construct your model to meet the design criteria. Have one group member record your ideas.
2. Draw a labelled illustration of your model.
3. Have your teacher review your illustration and design plan. Obtain your teacher's approval and build your model.
4. Work on your model until you are satisfied that you have met all the design criteria.
5. Create a presentation that explains the specific features your group considered when you designed your model.
6. Give your presentation and explain your model to your classmates.

Evaluate

1. **(a)** What problems did your group encounter when designing and building your model?
   (b) How did you address these problems?
2. If you were able to redesign your model, what changes would you make?
3. Explain why you think your model is a suitable design for space or air travel in 2030.
4. Explain how you would test at least two different aspects of your model before building it as a full-sized aircraft or spacecraft.

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✓ ASSESSMENT OPTIONS FOR UNIT 2 PROJECT

- Consider using the following rubrics to assess student work:
  - Learning Skills Checklist 2, Developing Models and/or Process Skills Rubric 8, Developing Models
  - Learning Skills Checklist 12, Project Group Assessment and/or Learning Skills Rubric 3, Co-operative Group Work Rubric
  - Learning Skills Checklist 3, Oral Presentation or 4, Computer Slide Show Presentation; Learning Skills Rubric 6, Communication or 7, Multimedia Presentation

Evaluate Answers

1. (a) Accept any answers that clearly identify the problems encountered. *Sample answer:* We had a lot of problems in designing our model because it is a spaceplane. This means that it has to be able to fly all the way into space and return to Earth again. It also can't be damaged in the flight because it is supposed to be reusable. Our spaceplane takes off from the ground so it needs to be able to carry a lot of fuel. At the same time, it can't weigh too much. This was our biggest problem.
   (b) Accept any answers that clearly identify how the problems were addressed. *Sample answer:* We addressed our fuel/weight problem by creating a new fuel for the year 2030 that could be squished into a small space and is very light in weight. People are trying to come up with new fuels all the time now to reduce pollution, so they will probably come up with such a fuel by 2030.
2. Accept any reasonable answer. *Sample answer:* If we change our model, I think we should also design a special lightweight but strong material. This would make our plane weigh less so it could carry more fuel.
3. Accept any well-explained answer. *Sample answer:* Our model is a spaceplane. I think our model will be good for travel in 2030 because it is designed to travel in both air and space, which a lot of people will want to do by then. Also, it is totally reusable, which will be important in the future because more and more people will be concerned about waste. Also, it uses a special fuel that does not cause a lot of pollution, which will help keep our planet clean.
4. Possible means of testing the aircraft or spacecraft as a model include the following: testing a small-scale model of the craft in a wind tunnel; testing components of the craft, such as its wings, in a wind tunnel; testing the materials used to build the craft for their ability to stand up to heat, abrasion, and so forth; testing the craft for functionality, for example, to see if the control surfaces and means of propulsion operate properly.