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.

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.

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.

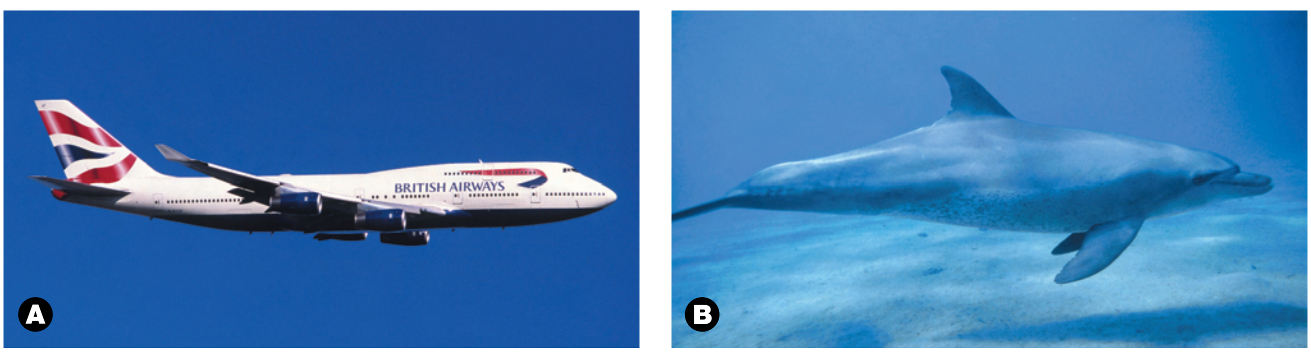


Figure 4.1 The design of a streamlined, wide-bodied passenger jet (A) looks a lot like a dolphin (B).

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

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.

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

Name of Aircraft

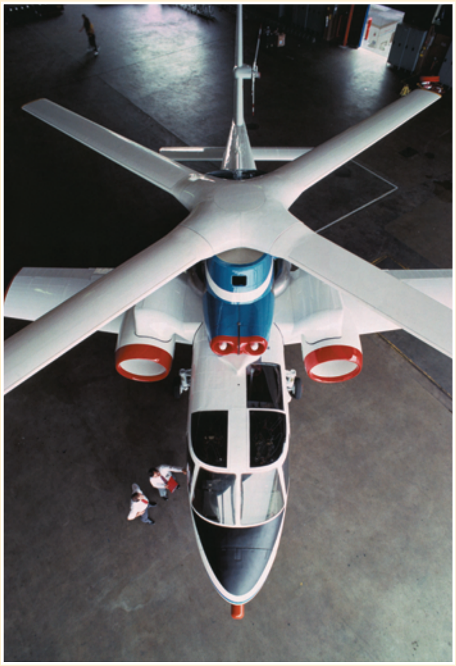
X-wing plane

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.



INTERNET CONNECT

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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.

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.

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?

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?

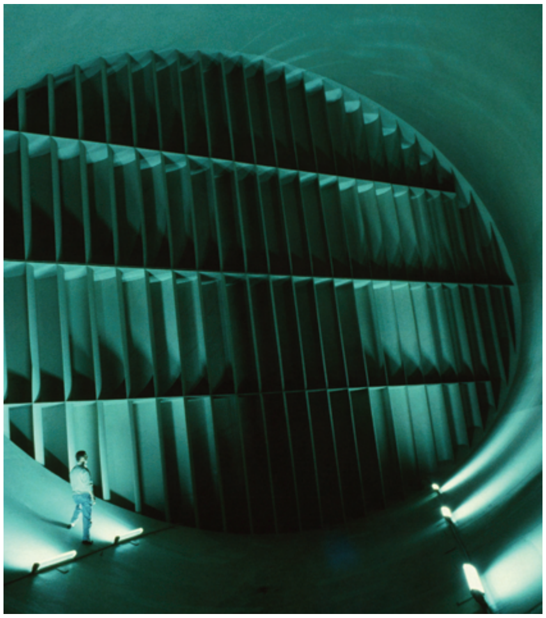


Figure 4.4 A wind tunnel at NASA's Langley Research Center. It is large enough to hold a full-sized airplane.

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

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

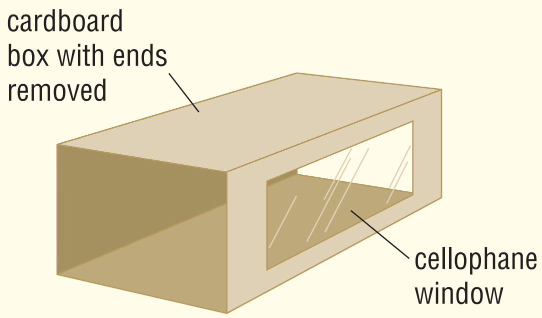
Materials

stiff paper, such as a used file folder or manila paper

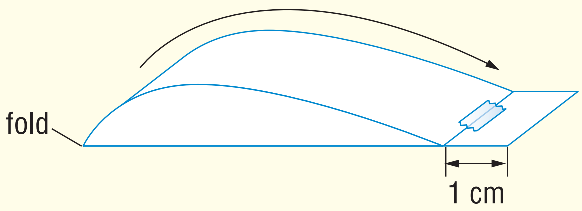
paperclips	scissors
string	ruler
tape	hairdryer
cardboard box	protractor
clear cellophane	

Procedure

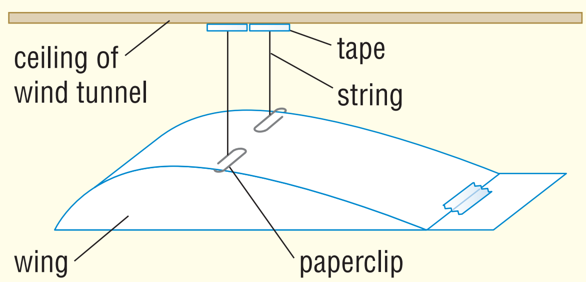
1. With a partner, build a wind tunnel as shown in the figure below. Cut a window out of the side of the cardboard box so that you can see what is going on inside. Tape the cellophane over the window.



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.

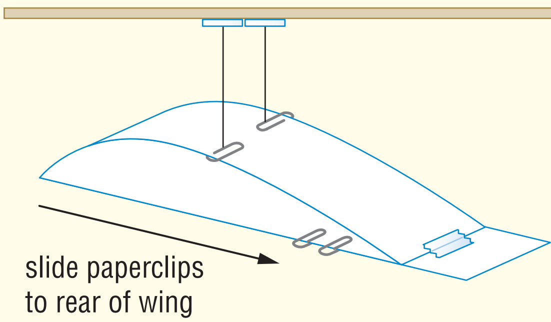


4. Draw an illustration of the wing, showing the angle it makes with the air that flows under it (parallel to the bottom of the wind tunnel). Measure this angle with a protractor and record its value on your drawing.

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

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?

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?

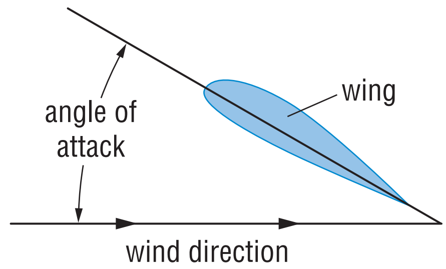


Figure 4.6 The angle that the wing makes compared to the flow of air is called the wing's angle of attack.

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

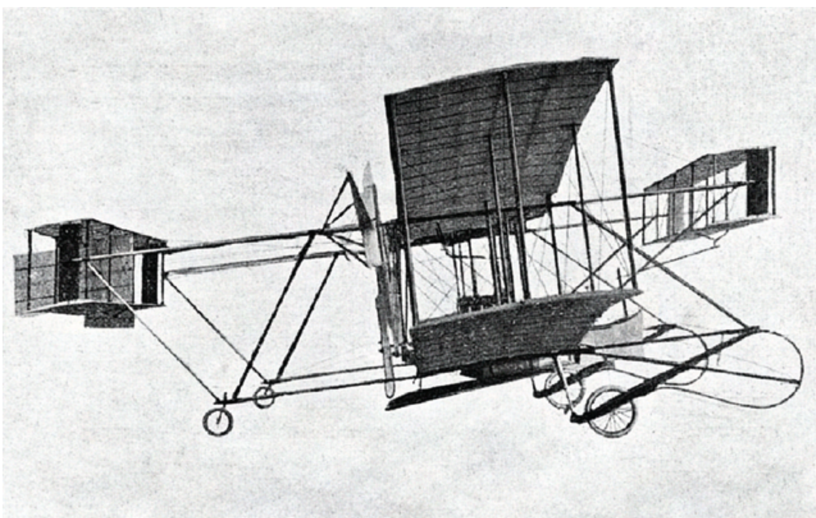


Figure 4.8 This early aircraft only rose a few metres off the ground. Note the angle of attack of its wings. How would you alter the angle of attack to increase the amount of lift this aircraft experiences?

READING Check

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

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?

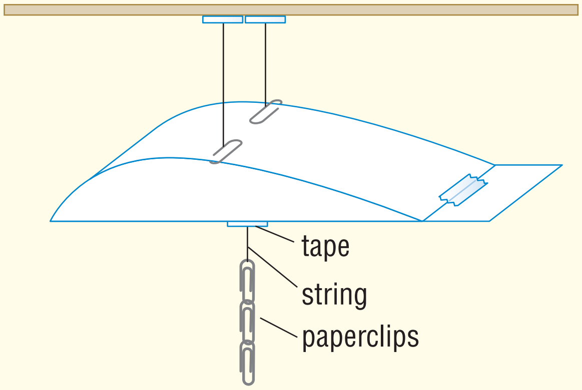
Safety Precautions

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.



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.

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.

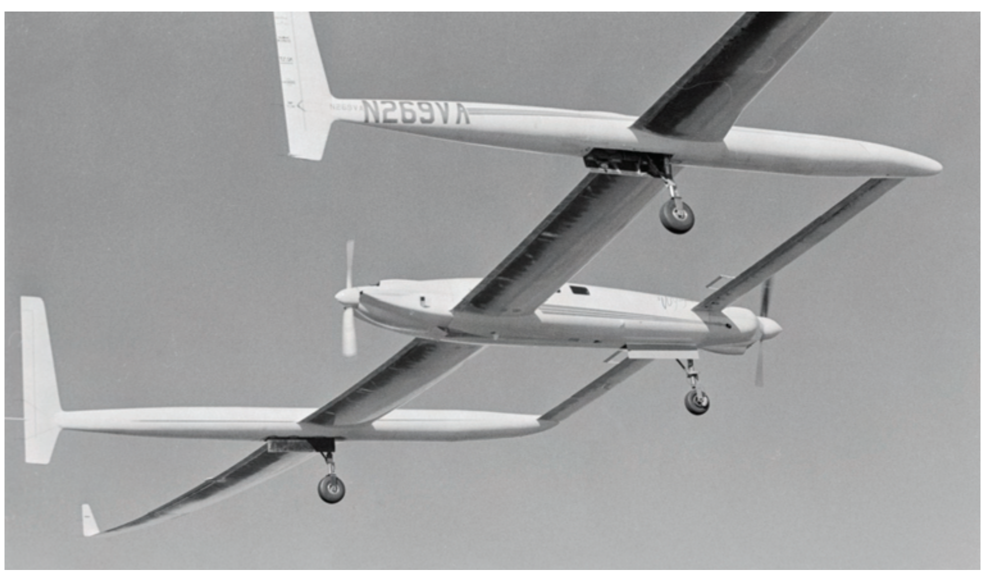
Key Terms

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?



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

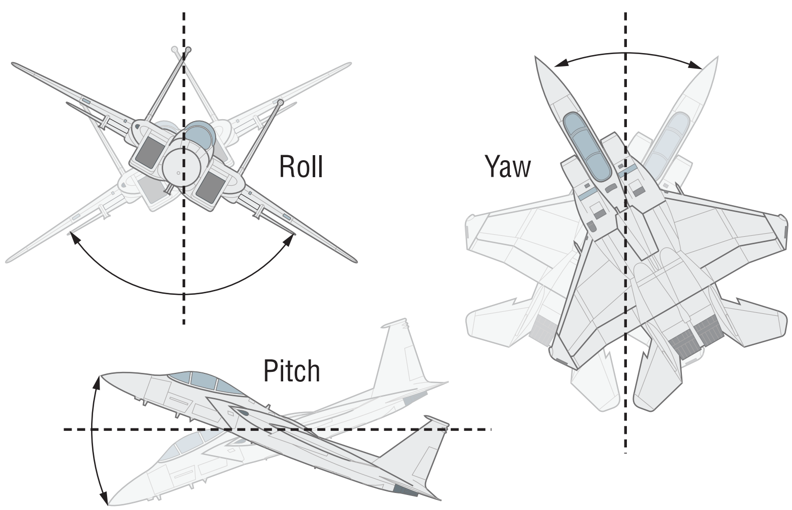
yaw
pitch
roll
stable
unstable
control surfaces

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

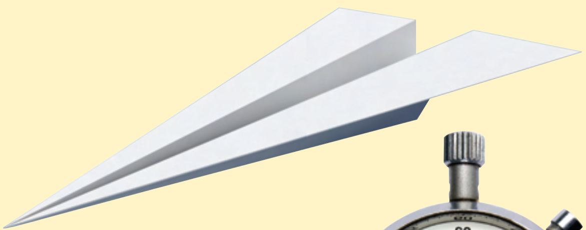
Description: A motion where the nose and tail of the plane alternately rise up and dip down.

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

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.

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.

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
paper
glue
ruler
books on paper gliders
tape
scissors

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.

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.

Control surface: Vertical stabilizer

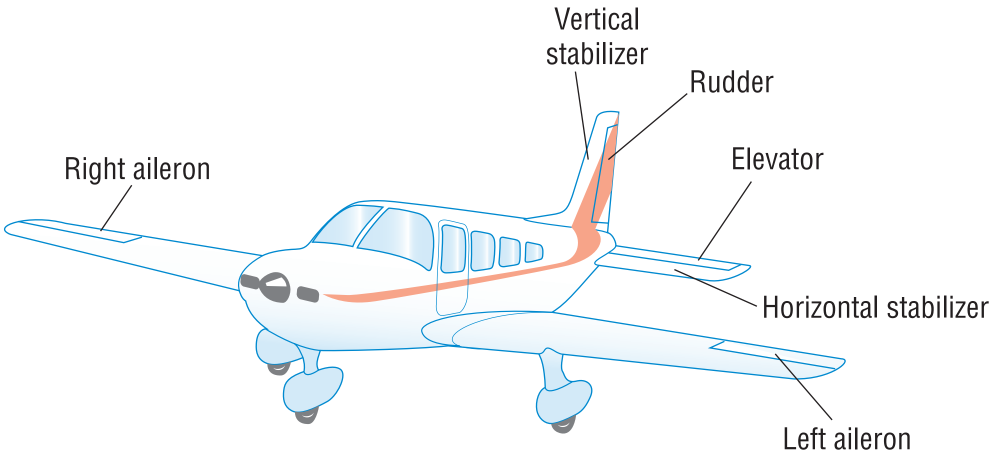
Description: The tail of the plane

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.

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?

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.

Section 4.3 Flight—From the Past Into the Future

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?

Key Terms

spaceplane

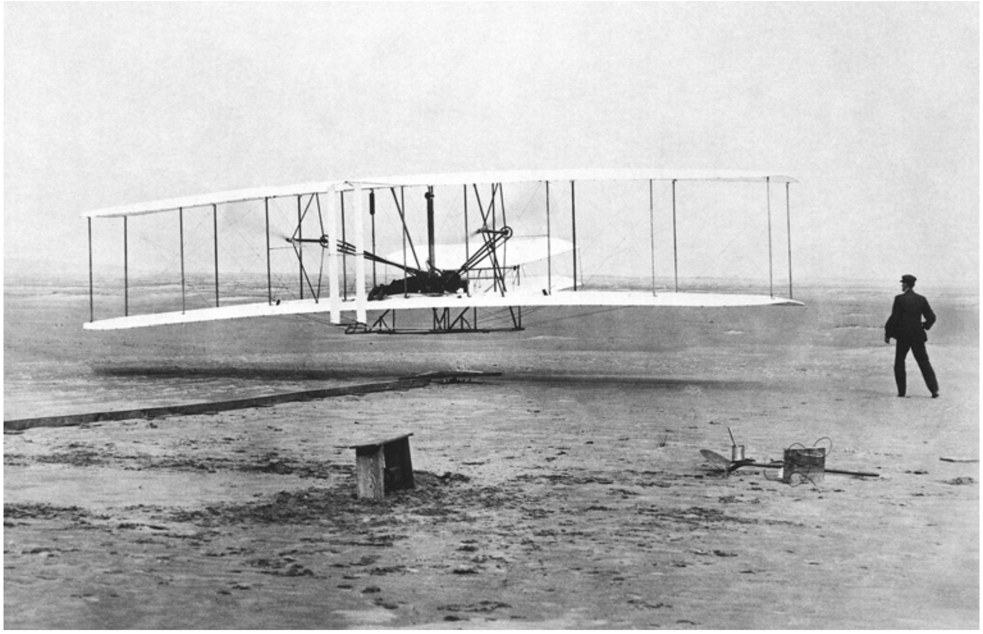


Figure 4.13 *The Wright Flyer* made its historic controlled flight in Kitty Hawk, North Carolina on December 17, 1903. The Wright brothers focused on controlling their aircraft, while other aviators focused on power or speed.

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.

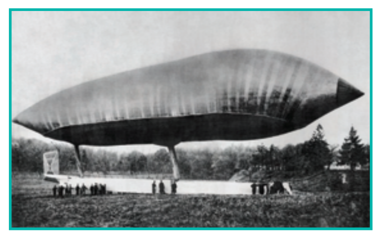
Brothers Joseph Michel Montgolfier and Jacques-Étienne Montgolfier build the world's first hot air balloon. Its first flight is successful and ballooning becomes a major fad in France.

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.

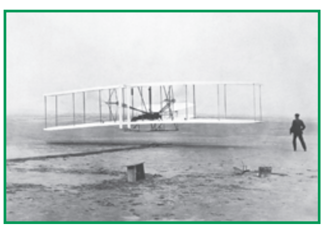
The *La France* airship, a steam powered hot air balloon that could be steered in any direction, makes the world's first fully controlled balloon flight.



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.

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.

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.

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.

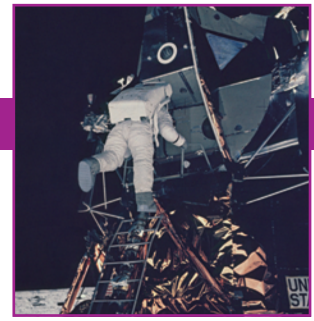
The first jet airliner, the de Havilland *Comet* flies for the first time. It carries passengers in 1952.

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.

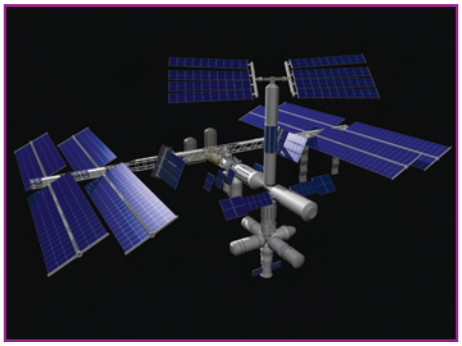
Gossamer Albatross makes the first successful human-powered flight across the English Channel.

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.

THINK & LINK

INVESTIGATION 4-H

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

Living Things and Flight Design

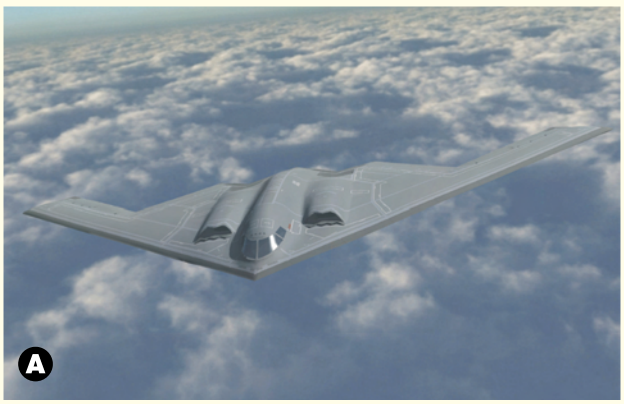
Observations of airborne organisms have helped inspire aircraft design in the past and the present.

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.



Find Out **ACTIVITY 4–1**

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.

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.

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.

Analyze

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

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.

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.

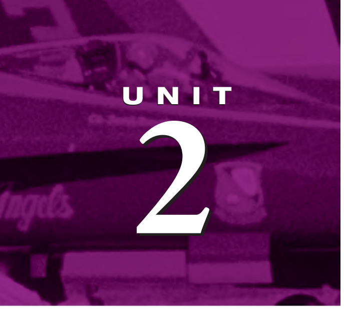
Prepare Your Own Chapter Summary

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.



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.

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

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.

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?

Project

Flight in the Year 2030

SKILLCHECK
- Problem Solving
- Modelling
- Plan and Construct
- Communicating

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.

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.