



# How Do Aircraft Fly?



**Susan Markowitz Meredith**

Science and Curriculum Consultant: Debra Voegel, M.A.  
Science Curriculum Resource Teacher



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by **Susan Markowitz Meredith**

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# Air All Around Us

**G**o outside on a windy day. You will soon discover just how strong air is. It can lift a kite high in the sky and grab onto a balloon and carry it away. But even when the air is calm, you can feel its strength when you move. Think about riding a bike, for example. As you go fast, the air presses hard against your face and body. Stretch out your hand—palm slightly forward—and the moving air lifts it up.



Maybe we can't see air, but it is all around us. In fact, this mix of **gases** surrounds Earth like a big blanket. These gases, like all **matter**, are made up of very tiny particles called **molecules**.

As this girl enjoys racing down a hill on her bike, she can feel the air pressing against her face and body.

Air molecules are always in motion. They also move out of our way as we pass. But air pushes back on us from all sides, too. Air molecules have weight.

### **Designed to Fly**

For centuries, people have understood how air behaves. But **aircraft** builders understand something else. They know that their structure, or aircraft, must be designed in a certain way. When it is, the aircraft flies smoothly through the air. When it isn't, the craft never leaves the ground.



Born to fly, this seagull uses its wings to soar through the air.

### **DID YOU KNOW ?**

#### **Nature's Flyers**

Many animals and plants use the air to get around. Birds, bats, and many insects have wings for flying. Even animals such as flying squirrels glide from tree to tree. Plants, too, can spread their seeds through the air. Elm tree seeds, for example, have wing-like coverings and can be carried by the wind.

## Two Types of Aircraft

All aircraft are designed to fly through the air. But not all of them fly the same way. In fact, there are two types of aircraft. One is called “lighter-than-air.” The other is known as “heavier-than-air.”

A lighter-than-air craft is able to float. It can become lighter in weight

than the air around it. A circus balloon is a simple example of this type of craft. Before it gets filled, the balloon doesn’t move. Its weight keeps it down. But fill the bag with helium gas, and the balloon lifts up. Why does this happen? The reason is that helium is much lighter than air.

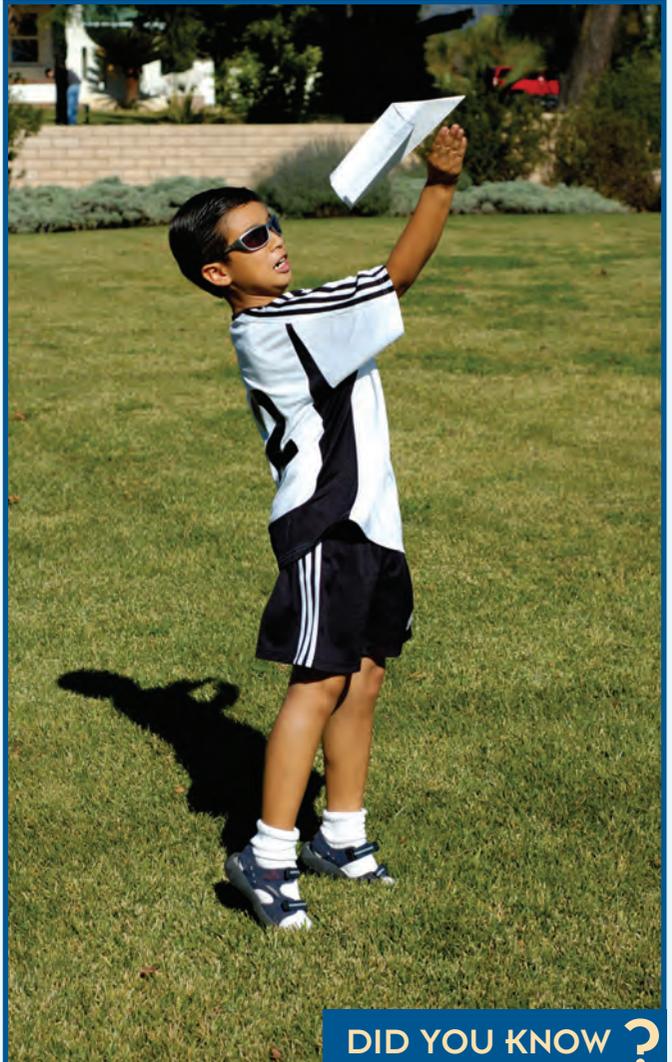


A kite is heavier than air. But on a windy day, air moving under the kite can lift it high in the sky.

## Why Kites Fly

A heavier-than-air craft is different. It always stays heavier than the air around it. This type of craft flies for another reason. Its surfaces cause moving air to lift up the craft. A simple heavier-than-air craft is a kite. Kites come in many shapes and sizes. But they are all made to lift up in the wind.

The kites people around the world fly for fun are named after the kite bird. This type of bird is also found all over the world.



**DID YOU KNOW ?**

### Just Fold and Fly

One heavier-than-air craft that's easy to make is a paper airplane. It starts out as a flat sheet of paper. When launched, a flat sheet of paper slowly falls to the floor. But after only a few folds, the paper becomes an aircraft. With its new shape, the paper lifts up and flies across the room.

# Hot-Air Balloons

**M**ost of us have seen them. Big and colorful, hot-air balloons carry people for long rides through the air. How do they do it?

These lighter-than-air craft work in several ways. First, every hot-air balloon has an air-filled bag, or envelope. Because of its large size, the bag can move aside a lot of air. But air moved to another place pushes back. In fact, this **displaced** air presses so hard that it keeps the bag afloat. In other words, the bag is **buoyant**.

But the basket tied to the bag stays on the ground. Its cargo of equipment and people is heavy.

A brightly colored hot-air balloon floats over the Napa Valley in California.



## Heating and Cooling Air

To make the hot-air balloon go up, the pilot turns on a burner under the bag. The burner creates a flame. Hot air quickly rises into the huge bag. This heats up the air molecules inside. They start moving faster. Also, some of them escape through the bottom of the bag. That leaves fewer molecules inside. They are farther apart, too. The inside air, then, is less **dense** than the air outside, and it weighs less. The result? The hot-air balloon rises.

To lower the hot-air balloon, the pilot turns off the burner. The air inside the bag gets cooler. That means the air molecules slow down. They also move closer together. Soon there's room for outside air to re-enter the bag. More air molecules inside make the air in the bag denser—and heavier. So the craft comes down.

### DID YOU KNOW ?

#### First Hot-Air Balloon Ride

In 1783, two French brothers made history. Joseph and Jacques Montgolfier built a silk bag and filled it with hot air from a straw fire. They attached a cage to it and watched their hot-air balloon float away. The first riders were a duck, a chicken, and a sheep. Soon after, the first human passengers made a flight in a Montgolfier balloon—floating over Paris for almost a half hour.

# Floating Airships

**H**ot-air balloons can fly, but they cannot be **steered**. They simply float in whatever direction the wind takes them. An airship is a lighter-than-air craft, too. But unlike a hot-air balloon, the airship has an engine and fins. These allow the ship to be steered in the direction where the pilot wants it to go.

The envelope of an airship is long and rounded. Usually helium gas is

An airship flies past the Empire State Building in New York City.



used to inflate it. The helium is sealed inside. It cannot escape. Since helium is lighter than air, the envelope stays afloat. It is buoyant.

### **Lifting the Engine and Cabin**

But the airship's engine is heavy. So is the cabin, which holds people and supplies. How, then, does the craft rise up?

For most airships today, the answer is **ballonets**. They are small pockets for air inside the envelope. Air can be pumped in or out of them. When air is pumped out, the pockets deflate. The ship gets lighter than the outside air. So it rises. To lower the airship, air is pumped back into the ballonets. More air means more weight. The ship gets heavier than the outside air. So it sinks down.



**DID YOU KNOW ?**

### **Not All Gases Are Alike**

The *Hindenburg* was the first airship to take large groups of people across the Atlantic Ocean. The huge ship was 804 feet (245 meters) long. Its envelope contained hydrogen gas. Hydrogen is lighter than air. But unlike helium, which does not catch fire, hydrogen can catch fire easily. That's what happened on May 6, 1937. The *Hindenburg* exploded. Many of its passengers were killed. The photo above shows the wreck of the airship.

# Heavier- Than-Air Craft: The Basics

**H**eavier-than-air craft are unable to float. They always weigh more than the air around them. Still, these craft can become **airborne**. To do it, they need fast-moving air and surfaces with the right shape.

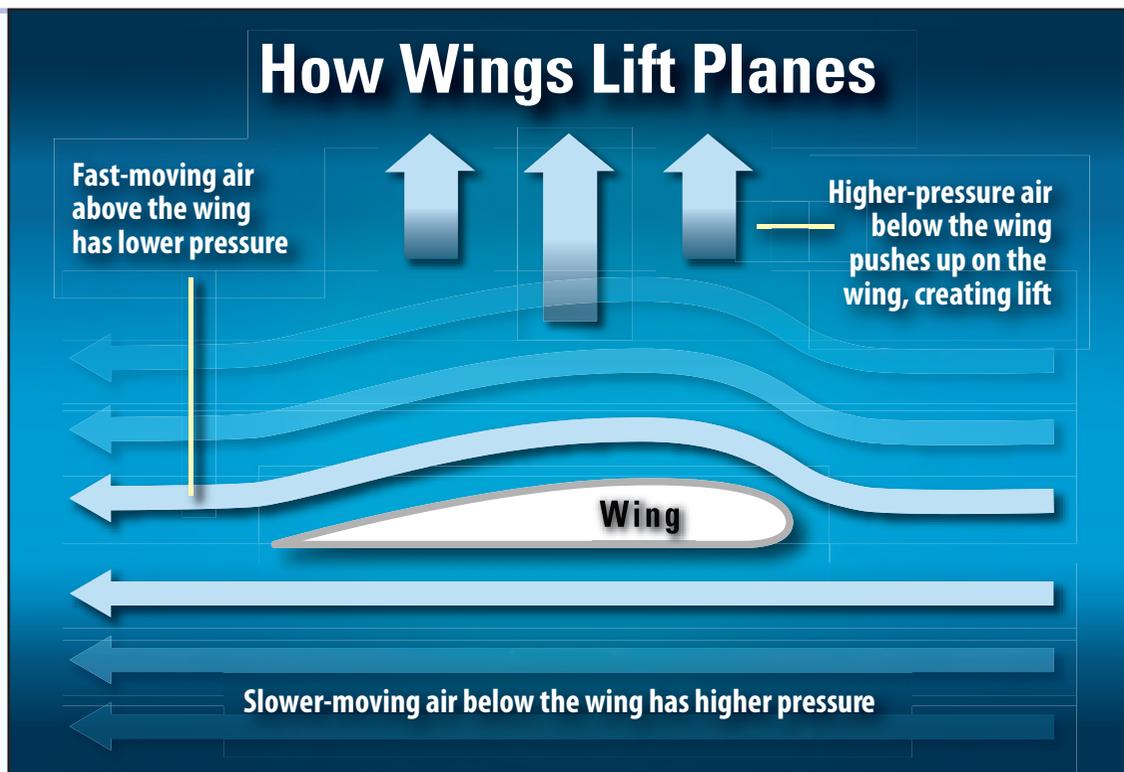
An airplane wing is made so that it has the perfect shape for flight. Its upper surface is curved. Also, its front edge is thicker than the back edge. The wing's bottom surface is almost flat. Something with this shape is called an **airfoil**.

When a heavier-than-air craft moves forward fast, air molecules hit the front of each of the plane's wings. Some of the molecules move over the wing. Others move under it. The two groups of air molecules meet again behind the wing at the same time.

## **Fast-Moving Air**

The molecules passing over the wing have farther to go—over the curve—than the molecules passing under the wing's flat bottom. So the over-the-wing air must move faster. And when air moves faster, the molecules

# How Wings Lift Planes



spread out. They become less dense. This air has lower **pressure**.

But the air under the wing has not gotten less dense or lost any pressure. So the air under the wing is pushing up on the wing with more force than the air above is pushing down. This greater force pushing up from underneath is called **lift**. Lift is what makes an airplane get off the ground.

The shape of an airplane's wings creates the lift that makes the plane leave the ground.

## DID YOU KNOW ?

### Tunnels of Wind

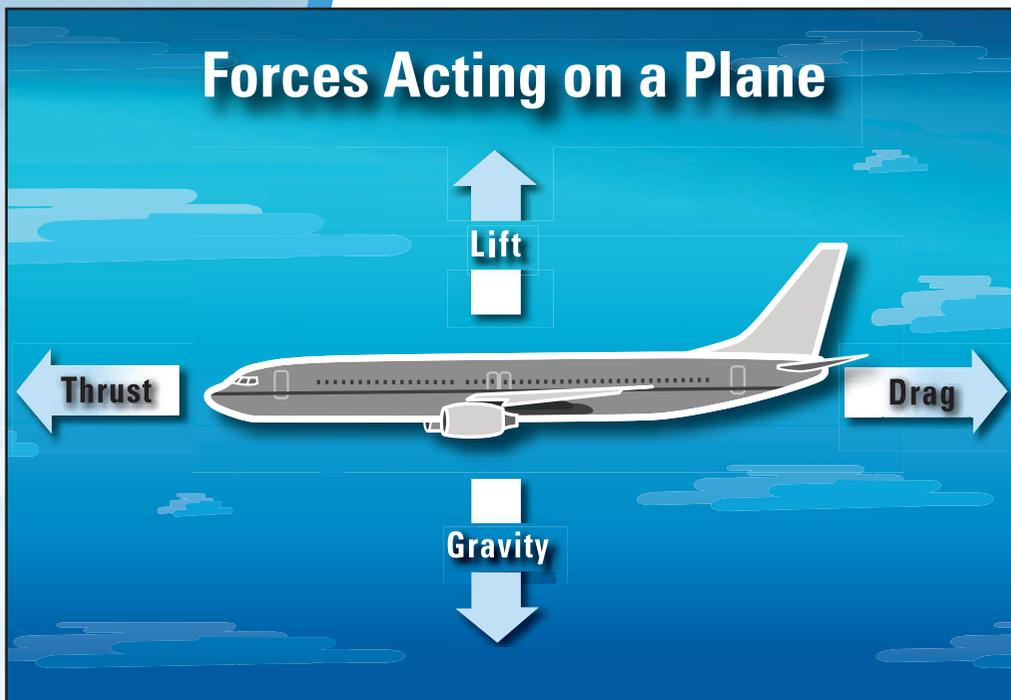
To watch how air flows around an aircraft, scientists use wind tunnels. Inside the tunnel, a powerful stream of air blows against the craft. Testers often add smoke or dyes to the air so they can see the flow.

# Four Forces at Work

For a plane to fly through the air, the lift from its wings must be stronger than the force of gravity, and the forward thrust from its engines must be stronger than the force of the air, or drag, pushing back.

You can see lift in action if you watch planes on an airport runway. An airplane ready to take off picks up speed quickly. Its engines move the plane forward faster and faster. For a while, the force of **gravity** still holds the heavy craft on the ground. Finally, though, the plane moves fast enough to lift off. At that moment, the force of lift is strong enough to overcome the force of gravity.

Once the plane is airborne, its engines work hard to push, or **thrust**, the aircraft forward. But the air



also pushes back on, or resists, the plane. This resisting force is called **drag**. It slows down whatever is moving through air. If an aircraft slows down, there will be less lift to overcome the force of gravity. To keep the plane in the air and moving forward, the engines work harder.



Once this plane has completed its take-off, the pilot will fold up the wheels to reduce drag while the plane flies.

### **What a Drag!**

Aircraft builders know a lot about drag. They know that air resists some shapes more than others. That's why designers **streamline** their aircraft. A streamlined craft has a shape that lets air flow smoothly around it. An aircraft that is not streamlined keeps the air molecules swirling in one place. The result is more drag to slow the craft down.

### **DID YOU KNOW ?**

#### **Folding Up the Wheels**

The way an airplane's wheels are designed is a good example of streamlining. The wheels are needed for take-off and landing, but they stick out when the plane is flying. So the air constantly rams into the wheels and swirls around. It cannot flow past them smoothly. To solve this problem, most planes today have devices that fold up the wheels during flight.

# Flying an Airplane

**A**n airplane is a heavier-than-air craft with fixed wings (that is, wings that don't move) and one or more engines. In many airplanes, the engine turns a **propeller**. Propellers are found mostly on a plane's wings or nose.

The propeller is made of several blades around a center, or hub. The front surface of each blade is rounded. It has an airfoil shape. As the propeller rotates, it causes air to move faster in front of the blades than behind them. The air pressure, then, is lower in front than in back. This difference pulls the propeller forward. The airplane is pulled forward, too.

But there's more to flying than moving forward. An airplane pilot also needs to steer the craft. For this, the plane has "control surfaces." These are moveable flaps on the plane's wings and tail.

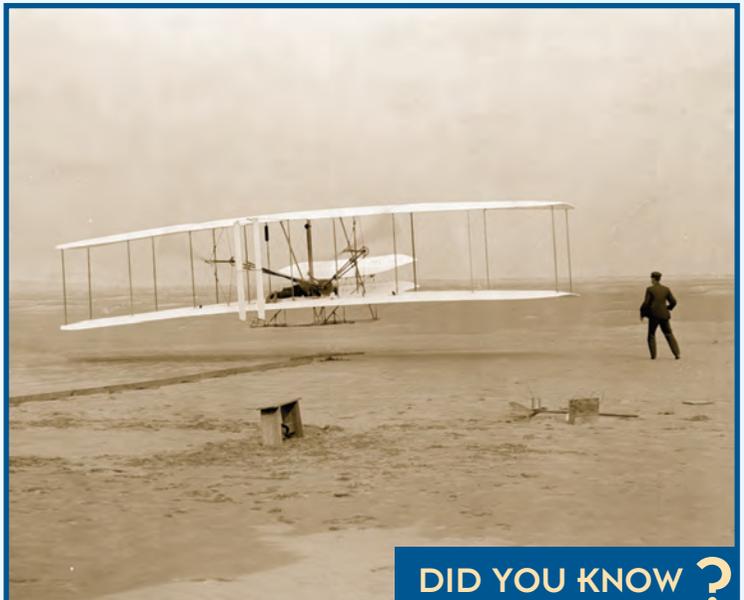
## What the Flaps Do

The flap on each wing is called an **aileron**. The two ailerons work in

opposite directions. When one wing's aileron is raised up, the other one is lowered. The pilot uses them to tilt the plane to one side or another. This motion is known as "roll."

The tail area flaps move the plane in other ways. The **rudder**, which stands upright at the back of the tail, can jut out from the tail to the left or to the right. The pilot uses the rudder to turn the plane left or right. "Yaw" is another name for this motion.

Flaps called **elevators** also are in the tail area. The pilot raises or lowers these two flaps. They make the plane climb up or dive down. This motion is known as "pitch."



**DID YOU KNOW ?**

### **The Wright Brothers**

Two brothers from Ohio, Wilbur and Orville Wright, built the first powered airplane that could roll, yaw, and pitch. Their small aircraft, called the Flyer, made its first flights on December 17, 1903, near Kitty Hawk, North Carolina. In this photo taken that day, Orville flies the plane as Wilbur looks on.

# Staying Aloft Without Power

**N**ot all fixed-wing aircraft have engines. A glider has no onboard power at all. To get off the ground, it is towed on the runway by an airplane. When the plane goes fast enough, both aircraft lift up.

High in the air, the airplane releases the glider. From then on, the glider flies on its own. With its long, thin wings, the glider soars smoothly through the air. The ride is very quiet, too.

But with no engine, the glider can't keep pushing forward through the air. Slowly, it loses lift, and gravity pulls the craft to the ground.

## Looking for Rising Air

Glider pilots like to stay airborne as long as they can, though. To do this,

This glider is about to land. Without an engine, a glider gradually loses lift and is brought down to the ground by gravity.





they look around for waves of rising air. Sometimes warm air rises from a plowed field below. Sometimes there's an upward wind near a mountain or ridge. These waves of air lift up the glider, too. Most glider flights last from one to five hours.

The pilot of this hang glider is looking for rising air over plowed fields, in order to stay airborne as long as possible.

#### DID YOU KNOW ?

### **Flying at 14**

When it comes to gliders, you don't need to be an adult to fly. Student pilots can fly solo at age 14. But they have to work hard before that. They need to go on thirty to forty flights with a teacher. They also must learn a lot about gliding.

To become a licensed glider pilot, students have to be 16 years old. The Federal Aviation Administration (FAA) gives out these licenses.

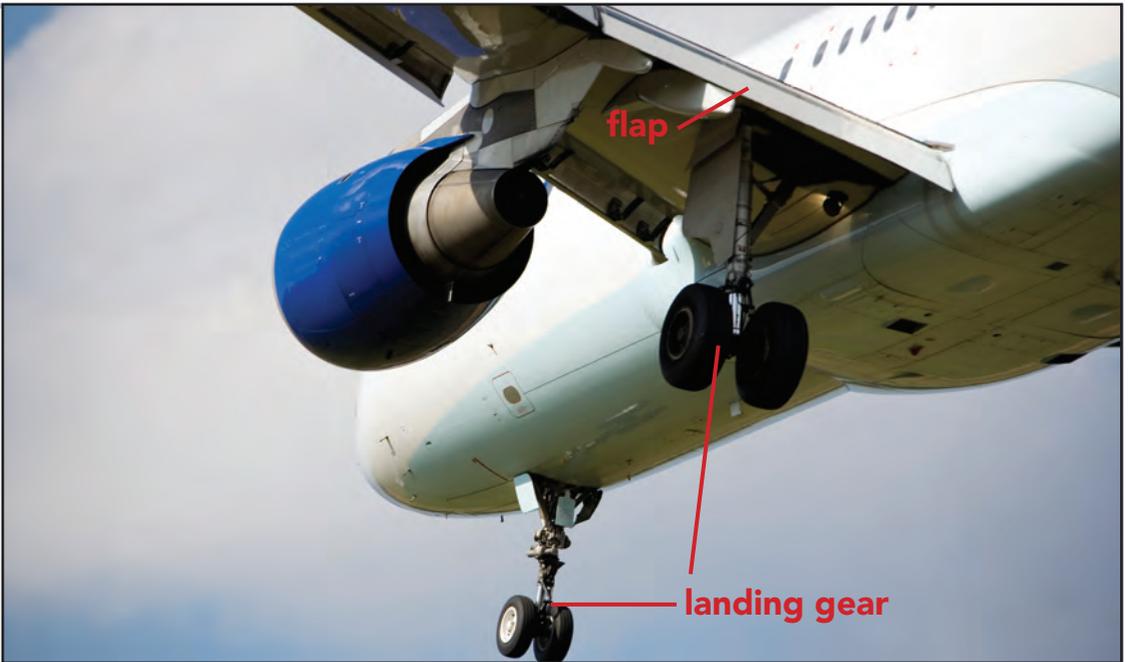
# Airliners

**A**irliners and travel go hand-in-hand. People fly on these large planes all over the world. There's a good reason for that. Airliners move fast. They can reach speeds of 500 to 600 miles per hour (800 to 960 kilometers per hour). Their jet engines help them do it.

A jet engine burns a special kind of fuel that creates hot gases. The gases shoot out the back of the engine with great force. This force is strong enough to thrust the huge plane forward.

## **Controlling a Huge Plane**

Because an airliner is very large, its pilot needs more ways to control it. That's why the aircraft has extra wing flaps. During take-off, movable flaps come out in front and back to make the wings bigger. The purpose is to give the wings more lift. With more lift, the heavy airliner can get off the ground. Once the plane is airborne, though, the flaps tuck back in. Why? Large wings produce more drag in the air. They are not stream-



lined enough. But when the plane lands, the flaps come out again. They help the airliner touch down smoothly.

An airliner has another type of wing flap called a “spoiler.” Spoilers are raised to slow down the aircraft. One spoiler is used just for flight. A second type is for landing.

This airliner coming in for a landing is using its wing flaps to slow down and has unfolded its landing gear.

#### DID YOU KNOW ?

### **The Concorde, Built For Speed**

In 2003, a famous airliner retired. Its name was the Concorde. This aircraft flew more than twice as fast as other airliners. At 1,355 miles per hour (2,180 kilometers per hour), it flew faster than the speed of sound. At 60,000 feet (18,300 meters), it flew almost twice as high as other airliners, too. The Concorde performed this well because of its special shape and powerful jet engines. But it was very expensive to operate and could not carry very many people. So the airlines that had Concorde's stopped flying them because they could not make enough money from Concorde flights.

# Helicopters

Like airplanes, helicopters are heavier-than-air craft. But the wings on a helicopter are not fixed. Its wings, or blades, connect to a pole. The whole unit is called a **rotor**. The rotor whirls around on top of the craft. An engine turns the rotor.

Helicopter blades are airfoils, just like wings. They are curved on top and flat below. When they turn, air flows around them. Air molecules passing over the blades move faster

than those going under. So the air pressure on top is less. The result? The whirling rotor lifts up—and so does the helicopter attached to it. This aircraft doesn't need a runway to get off the ground.



While this rescue helicopter hovers, a worker hanging from the craft looks for survivors at the site of a landslide.

## Useful Rotors

But the rotor does more than lift. It gives the helicopter thrust. In other words, the rotor powers the craft to keep it moving in the air.

The whirling rotor also controls the aircraft. The pilot steers by tilting the rotor in different ways. The blades can all tilt at the same angle. Or their tilt can change as they circle around. A skilled pilot can fly a helicopter forward, backward, up, and down. The pilot can move it sideways, too. This craft can also hover, or hang in the air without moving. That's because the rotor keeps lifting the aircraft and powering it to stay up—even in the same place.



**DID YOU KNOW ?**

### Twice the Lift

Not all helicopters have one main rotor. Many large helicopters have two. The extra rotor gives the craft twice as much lift and power. Twin-rotor helicopters are used to carry more cargo and people than a single-rotor craft could. This twin-rotor Navy helicopter can lift a small boat.

# Military Aircraft

**I**t might be an airship or an airplane. It could be a glider or a helicopter. The U.S. military has used them all. Some of its aircraft are built for combat. Other types carry troops and supplies. Still others are designed to take pictures.

Whatever the aircraft, it is built for a certain job. For instance, the military needs planes that can land and take off in small areas. V/STOL (vertical/short take-off and landing) craft do this. One type has propellers on its two wing tips. During take-off, these propellers face upward. So the aircraft lifts up like a helicopter. Once airborne, though, the propellers turn forward. Now the craft can fly like an airplane. Another V/STOL craft uses jet engines instead. During take-off, the jets' hot gases shoot down. This action thrusts the plane straight up. Once the craft is airborne, the jet engines turn forward.

## **Planes with Special Wings**

For combat missions, the military needs many aircraft. Each has a



different task. One fighter plane, for example, is designed to fly at high and low speeds. To do this, its wings change position. During high-speed flight, the wings are swept back. This streamlines the aircraft. But at lower speeds, the wings stick straight out from the sides of the plane. The plane lands and takes off with the wings in this straight-out position.

This B-2 Spirit “stealth” bomber is hard for an enemy to detect.

#### DID YOU KNOW ?

##### **Where Is It?**

The B-2 Spirit is a special type of military bomber. When in flight, the plane is hard to observe. That’s why it is called a “stealth” (secret) bomber. Its shape, and the materials used to make it, keep the plane hidden in the air. This allows the B-2 Spirit to launch weapons in enemy territory with low risk of being shot down by enemy fire.

# “Green” Designs

**M**any aircraft today are unfriendly to the environment. They use fuels that pollute the air. Their engines use lots of it, too. But aircraft builders are working hard to change that.

For the future, companies are designing many types of “green” aircraft. These craft will use cleaner fuels, and less of them. They also will make less noise. But even now, planes are getting a little greener. One device that’s helping is the “winglet.” This small strip is added to a plane’s wingtip. It makes the wing bend up at the edge. The new shape causes air to flow more smoothly around it. So there is less drag on the plane. That means the

This airliner has winglets on the ends of its wings to help it use less fuel.



engines don't need to work as hard to thrust the plane forward. An engine working less hard burns less fuel.

### **Powered by the Sun**

NASA (the National Aeronautics and Space Administration) is testing green aircraft, too. One is called Pathfinder. Its wings and body are combined into one. When flying, the craft looks like a long, thin rectangle. Solar panels are built right into it. They turn sunlight into electricity that runs the craft's electric motors. The motors turn the propellers.

This unusual craft also has no pilot. Instead, people at ground stations control its movement. Currently, the Pathfinder can stay airborne all day. In the future, solar-powered aircraft may stay up for weeks or even months at a time. Scientists will use them for research. Even the military has plans for their use.



A solar-powered Pathfinder on a NASA test flight over California.

### **DID YOU KNOW ?**

#### **Calling All Students**

Once a year, NASA invites high school and college students to design aircraft for the future. The challenge changes each year. But NASA doesn't change one thing. It always reminds students to make their designs environment-friendly.

# Flying Machines Everywhere

**T**hey come in different sizes and shapes. They fly at various speeds. They also have different jobs to do. These are today's aircraft. Hundreds of thousands of them are flying everyday. Our lives would not be the same without them.

Both lighter-than-air and heavier-than-air craft are flying all the time. New designs make them better and better. But the basics of how they work stay the same. Lighter-than-air craft must become lighter than the air around them. Heavier-than-air craft must get enough lift from their airfoils to get off the ground.

Whatever the flying machine, it makes use of the air to get around. Air is the silent partner for every aircraft. In fact, air is the partner for everything that flies.

## **A Flying Legend**

From the time of the earliest planes, some people have always loved to fly. One of them was Amelia Earhart. She was born in 1897. As a young woman, she loved everything about

aircraft. She took flying lessons and even bought her own plane. She became a fine pilot.

In 1932, she was the first woman to fly across the Atlantic Ocean alone. Her biggest dream, though, was to fly around the world. In 1937, she had her chance. Starting in California, she flew across the United States. A **navigator** joined her.

The two continued their journey for thousands of miles. Along the way they made stops to refuel. But their final stop was not planned. It was over the Pacific Ocean. Earhart's plane had run out of fuel. Rescuers searched the area for a long time. But no one found the plane—or its passengers.



Amelia Earhart stands in front of her plane before a 1937 flight.

#### DID YOU KNOW ?

### The Joy of Flying

Talking about the thrill of flying, Amelia Earhart once said:

“You haven’t seen a tree until you’ve seen its shadow from the sky.”

# Glossary

**aileron**—Movable flap on a plane's wing. When one wing's aileron is raised, the other one is lowered. This motion tilts, or rolls, the plane to one side or the other.

**airborne**—Flying through the air.

**aircraft**—Any machine made to fly in the air.

**airfoil**—A part, such as a wing, that has a curved surface. Airfoils are designed to keep an **aircraft** up.

**ballonets**—Small pockets within an airship's envelope. Air pumped out of them makes the airship rise; air pumped in causes the ship to go down.

**buoyant**—Floating.

**dense**—Close together. The density of air in a balloon, for instance, is the number and closeness of **molecules** inside it.

**displaced**—Moved from its place.

**drag**—The resisting force of air on objects that move through it.

**elevators**—Two movable flaps in the tail area of a plane. They make the plane climb up or dive down, which is also called "pitch."

**gas**—A substance that is not a liquid or a solid and that has no shape or size of its own.

**gravity**—The force that pulls everything to Earth. This force gives everything weight.

**lift**—The force that pushes up on an **airfoil** and makes an **aircraft** leave the ground.

**matter**—What all things are made of.

**molecules**—Tiny particles found in all **matter**.

**navigator**—A person who decides the course taken by a plane (or other craft).

**pressure**—A force, such as the force of air pushing against an object.

**propeller**—A group of **airfoil**-shaped blades attached to a center, called a hub. As the propeller turns, it moves the craft forward.

**rotor**—A unit made of **airfoil**-shaped blades on a pole. An engine turns the rotor.

**rudder**—A movable flap on the tail that turns the plane to the left or right. This movement is called "yaw."

**steered**—Guided on a certain course.

**streamline**—To shape a body, such as an airplane, so that air flows smoothly around it.

**thrust**—The force that pushes something forward.

# To Learn More

## Read these books:

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O'Brien, Patrick. *Fantastic Flights: One Hundred Years of Flying on the Edge*. New York: Walker & Company, 2003.

Thomson, Sarah L. *Extreme Aircraft! Q&A*. New York: HarperCollins, 2007.

## Look up these Web sites:

**The Franklin Institute (“The Challenge of Flight” and “Forces of Flight”)**

<http://www.fi.edu/flights/own2/index.html>

**Fun Paper Airplanes**

<http://www.funpaperairplanes.com>

**PBS Kids, “Wayback” Flight**

<http://pbskids.org/wayback/flight/index.html>

**Young Eagles**

[http://www.youngeagles.org/questions/default\\_askexpert.asp](http://www.youngeagles.org/questions/default_askexpert.asp)

## Key Internet search terms:

aircraft, airplane, airship, hot-air balloon, flight, helicopter

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## About the Author

Susan Markowitz Meredith likes to find out the how and why of things. She especially enjoys sharing what she discovers with young readers. So far, she has written more than 35 books on some very interesting topics. Meredith also has produced quite a few TV shows for young thinkers.