Check and uncheck as needed to select sections to print. Then select print preview to view your selections and print:

Print section(s) of

Airplane

Table of Contents

How to Cite This Article

The airplane has had a greater impact on our lives than any other modern invention. The ability to fly has dramatically increased the speed at which we can travel and decreased the time it takes to receive mail, food, and other goods from far-off places. It has brought us into closer contact with people in other parts of the world, and it has drastically changed the way we wage war.

Yet, until the beginning of the 20th century, the idea of a practical flying machine was only a dream. Balloons and gliders had been flown before 1900, but they were unreliable and could not carry a person over a long distance and land at a chosen destination. It was not until Orville and Wilbur Wright invented and successfully flew the first powered, controllable aircraft that the dream of flight became a reality. On December 17, 1903, the Wrights' plane, the *Flyer*, took off at Kitty Hawk, North Carolina, and flew 120 feet (37 meters).

The airplane has changed greatly since 1903. The wingspan of a modern jumbo jet is longer than the entire distance flown on the Wright brothers' first flight. That flight lasted only 12 seconds; in 1986 a plane named *Voyager* was flown around the world in nine days without stopping or refueling. Airplanes have been flown at more than 4,500 miles (7,300 kilometers) per hour and to altitudes of almost 70 miles (110 kilometers) above the earth. But no matter how fast, high, or far airplanes fly, they are still subject to the same basic principles of flight as the Wright *Flyer*.

How an Airplane Flies

An airplane is a heavier-than-air craft that can fly only if air flows over its wings fast enough to produce an upward force called **lift**. The force of lift must be strong enough to overcome **gravity**, the force that pulls objects toward the ground. A third force, called **thrust**, is required to move the plane through the air. It is produced by the plane's engine and must overcome another force, called **drag**. Drag is the resistance of the air to anything moving through it. Lift, gravity, thrust, and drag act on every airplane.

These four forces can be experienced while riding a bicycle. The rider pedals, providing the bicycle's thrust. The sensation of air pushing against the rider can be compared to the force of drag. If the rider holds out one hand with the palm down and slightly tilted to face the oncoming air, the hand will rise. This is similar to the way a wing reacts to lift. Gravity keeps the rider earthbound.

Of the four forces, lift is perhaps the least familiar. It is caused by the way gases and liquids behave when they are in motion. This behavior is described by a basic law of physics known as Bernoulli's principle. According to this principle, the faster a gas or liquid moves, the less pressure it exerts. This principle describes how air flows around an airplane wing. Air that flows over a wing moves faster than air that flows below. Thus the air over the wing exerts less pressure than the air below the wing. This difference in pressure accounts for a net upward force on the wing. This is lift. (For more information, read Aerodynamics.)

Air moves this way because of the wing's **angle of attack**. This is simply the tilt of the wing. Just as the bicyclist's palm must be tilted to produce lift, so must the wing of an airplane. As the wing moves through the air, its front edge is tilted upward. When the angle of attack is increased, the differences in air speed and pressure above and below the wing are increased. Lift, too, is increased.

A tilted wing has another effect: When it moves through the air, a tilted wing pushes air downward. Air is pushed downward whether it passes above or below the wing. If the angle of attack is increased, more air is pushed downward. The greater the volume of air that is pushed downward, the greater the upward pressure of lift. This is described by Newton's third law of motion, another law of physics. It states that for every action there is an equal and opposite reaction. More air is pushed downward when an airplane moves faster. Thus the faster the airplane moves through the air, the greater the lift.

To improve the airflow over the wing, some airplanes have wings with a curved top surface. However, some airplanes have wings that are flat, top and bottom. And even airplanes with curved upper wing surfaces are able to fly upside-down. To fly upside-down, the airplane's pilot must keep the front edge of the wings higher than the back edge. Also, the pilot must keep the airplane moving fast enough. Both actions maintain lift.

☑ Structure

The design of modern airplanes is based on the same aerodynamic principles used by the Wright brothers. But modern airplanes are built with stronger materials and more powerful engines. They fly faster and carry heavy loads or many passengers. They may be single-engine (one-engine) or multi-engine airplanes. Some are owned by large airlines or corporations, while others are owned by individuals. Airplanes are used for business, pleasure, and sports, such as racing or aerobatics. Other airplanes are military fighters, bombers, or transports that carry soldiers, tanks, or other equipment.

All of these aircraft, as different as they may seem, work on the same aerodynamic principles and are made up of the same structural components (parts): the **fuselage**; the **wings**; the **tail assembly**, with **vertical** and **horizontal stabilizers**; and the **landing gear**. All of these components together are called the **airframe**. The other main component of an airplane is the engine, which provides the power.

☑ Fuselage

The purpose of the fuselage, or body of the plane, is to carry the pilot, passengers, and cargo. The oldest fuselage design, the **truss type**, consists of a welded steel framework (truss) covered with tightly stretched fabric, metal, or composites which is painted to provide a smooth surface. The framework absorbs the stresses encountered in flight. The popular Piper Cub, first built in the 1930's and still flown today, has a fuselage of this type, as do many sport, recreational, and utility airplanes still being produced.

A second type of airplane fuselage is **monocoque**. Monocoque is a French word meaning "single shell." No truss is needed because the shell is made of metal or other strong material, such as composites (compounds) of plastic, fiberglass, and carbon fiber. These are strong enough to absorb the forces of normal flight. Small airplanes are often built with monocoque construction to save weight. But monocoque construction is not strong enough or rigid enough for large cargo planes or airliners. Therefore, most modern commercially built airline aircraft are manufactured using the **semi-monocoque** method, in which bracing and stiffeners of metal or other materials are added to the shell.

Modern airliners and military aircraft can fly at extremely high altitudes, where lower air pressure and oxygen content make breathing difficult. Also, the rapid changes in air pressure that occur when changing altitude can cause extreme physical discomfort. Therefore, the passenger cabin and cockpit of modern passenger jets are pressurized. Like the hull of a submarine, the fuselage of a pressurized aircraft is airtight. The air pressure inside the cabin and cockpit is increased by air compressors as the jet gains altitude. In this way, air pressure inside the plane is almost as high as pressure at ground level.

Wings

Airplane wings are designed to be very strong. Beneath the skin, or surface material, of the wing is a framework consisting of one or more **spars**, and **ribs**, **stringers**, and **formers**. The spars run from the wing root (the part of the wing attached to the fuselage) to the wing tip. Ribs run from the leading edge (front) of the wing to the trailing edge (back) of the wing. This framework provides the wing with its shape and its strength.

The distance from the leading edge to the trailing edge of the wing is called the **chord**. The distance from wing tip to wing tip is the **wingspan**.

Because the wing is an airfoil and thus produces lift, it is relatively flat on the bottom and curved on the top. This curve is called **camber**. Camber is the amount of curvature of the airfoil from the leading edge to the trailing edge of the wing. Thus a wing can have more or less camber, or curve, depending on the purpose for which it is designed.

The design and location of airplane wings vary according to the purpose of the airplane. Many modern airplanes have low wings—that is, wings attached near the bottom of the fuselage. Airplanes that operate out of rough, unpaved airfields often have wings attached near the top of the fuselage. High wings are less likely to hit the ground as the airplane bumps over the rough airfield. High-wing planes include the two-seat Piper Cub and the C-130, a large military plane that carries troops and equipment into grass or dirt air fields.

On most airplanes the wings are attached at a slight angle, so that when viewed from the front they form a shallow V. This angle is called the **dihedral**, and it reduces the plane's tendency to roll from side to side.

The shape and thickness of the wing are determined by the speed at which the airplane will be flown. Slower-flying planes have wings that extend straight out from the fuselage, with a very visible curve on the top surface. This provides lift at slow speeds. Faster airplanes have thinner wings. Because the air flows faster over these wings, less curve is needed to create lift. On very high speed jet fighters, the wing appears almost flat on top and is shorter. Such wings are also very thin so they create less drag at high speeds.

Wings on high-speed planes are usually **swept** (angled back). On some planes the two swept wings together form a triangle called a **delta wing**.

Planes with thin, short, swept wings must land at much higher speeds than straight-wing airplanes in order to maintain lift until the plane is on the ground. The F-14 Tomcat, a jet fighter, has variable wings, which can be changed from straight to swept. This allows it to be more easily maneuvered at both low and high speeds.

On each wing of an airplane are hinged movable sections called **control surfaces** with which the pilot controls the movement of the plane. **Ailerons** are control surfaces located on the trailing edge of the wing, near the wing tip. The pilot controls the ailerons by moving the control stick or wheel of the airplane. If the pilot moves the stick or turns the wheel to the right, the right aileron moves up and the left aileron moves down. Air pushing against the upturned right aileron forces the right wing down, while, at the same time, air pushing against the downturned left aileron pushes the left wing up. This causes the airplane to turn and **bank**, (tilt) to the right. A left movement of the stick or wheel causes the ailerons to move in the opposite directions, and the airplane banks to the left.

Many airplanes also have other control surfaces on the wings, called **flaps**. Flaps are usually located on the trailing edge between the aileron and the wing root. Flaps move at the same time in the same direction. When the pilot puts the flaps down, the camber of the wings is increased, thus increasing lift and permitting the airplane to fly at slower speeds. Flaps are put down primarily when landing. Because having the flaps down also creates drag, they are put up for normal flight.

Tail Assembly

The tail assembly, or **empennage**, of an airplane has two purposes: to provide stability and to control direction.

In most situations, a pilot prefers to keep the plane stable, or steady, in straight and level flight. In most aircraft, this stability is provided by surfaces called stabilizers. A fixed vertical stabilizer prevents the airplane from **yawing** (swinging from side to side). The horizontal stabilizer prevents **pitching** (up and down movement of the nose). On some planes the horizontal stabilizer is located near the nose. Then it is called a **canard**.

Directional control is provided by two control surfaces in the tail. These are the **rudder** and the **elevator**. The rudder is a hinged surface attached to the vertical stabilizer. The pilot moves the rudder by pushing foot pedals. When the pilot pushes the right rudder pedal, the rudder moves to the right. The pressure of the airflow against the rudder pushes the airplane's tail to the left. This, in turn, pushes the nose of the airplane to the right. When making a turn, the pilot uses both the ailerons and the rudder. This is called a co-ordinated turn.

Elevators are the movable control surfaces hinged to the horizontal stabilizer. When the pilot pushes the control stick or wheel forward, the elevators go down. The airflow pushes on the elevators, which makes the tail move up and the nose point down. Pulling the stick or wheel back puts the elevator up so the airflow pushes the tail down and the nose up. These movements are called changing the **pitch** of the airplane. On some airplanes, the function of the elevator is served by a horizontal stabilizer that can be moved up or down to control pitch. A horizontal stabilizer designed in this manner is called a **stabilator**.

Most airplanes also have **trim tabs**—small hinged sections of the elevator and rudder. These can be adjusted to stick out into the airflow to exert pressure on the control surface, causing it to move. In situations where a certain amount of pitch or yaw must be maintained for a period of time, the pilot can set the trim tab to hold the control surface in one position, such as a long, steady descent. Thus the pilot is better able to concentrate on other aspects of controlling the plane.

Landing Gear

In the early days of aviation, most airplanes had two wheels in front of the airplane's center of gravity (the point where the plane's weight is evenly balanced). A third, smaller wheel was located in the rear under the tail. Because this arrangement was used successfully for a long time, it is referred to as **conventional landing gear**. Newer aircraft often use **tricycle gear**, which consists of two wheels behind the center of gravity and a third wheel under the nose of the airplane. Aircraft with tricycle gear are easier to control on the ground than those with conventional landing gear. For this reason, tricycle gear aircraft are more popular with most of today's pilots.

All early airplanes were **fixed-gear** aircraft. The wheels remained in place whether the airplane was on the ground or in the air. Today, although many aircraft still have fixed gear, faster airplanes have **retractable gear**—the wheels are pulled up into the fuselage or wings of the airplane. Fixed gear causes a great deal of drag, which slows the airplane down and increases fuel consumption (amount of fuel used). Retracting the wheels into the wings or fuselage reduces drag.

Landing gear may consist of equipment other than wheels. For example, **seaplanes**, special aircraft that take off and land on water, have **pontoons** (floats) instead of wheels. **Flying boats** have a boat-shaped hull on which they land. Seaplanes with retractable landing gear for use on land are called **amphibians**. There are also planes that are equipped with skis for landing on snow. Landing on either water or snow requires different piloting techniques from those used to land on pavement.

Power and Propulsion

In order for an airplane to achieve flight, its wings must be pushed or pulled through the air fast enough to create lift. This function of propulsion is performed by the engine. There are three main types of airplane engines: **reciprocating** engines, **jet** engines, and **rocket** engines.

Reciprocating Engines

Reciprocating engines, or piston engines, used in airplanes are very similar to those used in automobiles. In a reciprocating engine, the expanding force of a burning fuel (gasoline) pushes pistons, which in turn rotate a crankshaft. In an airplane, the crankshaft turns the propeller. (You can learn more about how reciprocating engines work by consulting the article Internal-Combustion Engines.)

Reciprocating engines need cooling systems so they will not overheat. The first airplanes had liquid-cooled engines like those of many automobiles. Today, most reciprocating airplane engines are air cooled.

An air-cooled engine is lighter than a liquid-cooled engine because it does not have to carry hoses, radiators, cooling fluid, and circulation pumps. Air-cooled engines must be constructed so that the greatest possible area is exposed to the onrushing air. Air is forced into openings in the **cowling** (engine cover) behind the propeller and then flows over the engine to cool it. Because of their lightness, air-cooled engines replaced liquid-cooled engines for most uses by the 1930's. But liquid-cooled engines continued to be used very successfully for certain types of airplanes because they last longer than air-cooled engines and can produce more power. For example, some of the fastest piston-driven aircraft used during World War II (1939–45), such as the Spitfire and P-51 Mustang, had liquid-cooled engines. The *Voyager*, which in 1986 flew around the world without landing or refueling, used one air-cooled and one liquid-cooled engine.

Propellers.

All reciprocating engines turn propellers. Some early airplanes, like the Wright *Flyer*, were pushed into the air by propellers at the rear, while most modern airplanes are pulled into the air by propellers at the front.

The propeller consists of a control **hub** at the center with two or more blades attached. The entire assembly is rotated by the engine, and the blades convert engine power into thrust. The propeller is a **rotating airfoil**. As the blade rotates through the air, lower pressure is created on its curved front surface, pulling the propeller and plane forward.

The angle at which the propeller blade strikes the air determines how much pulling or pushing power it produces. A flatter angle results in high pulling power but low forward speed. Early airplane propellers had fairly flat blade angles that could not be changed. This flatter blade angle was satisfactory as long as airplanes flew slowly, but it was not practical for high-speed aircraft. The problem was solved by **variable-pitch** propellers, invented in 1923. The blades of a variable-pitch propeller can be adjusted so that they have a flat angle for takeoff, when the most power is needed, and steep angles for normal flight, when speed is important. A more recent development is the **constant-speed** propeller, which automatically (without pilot input) adjusts the angle of the propeller blade to maintain a constant forward speed.

Jet Engines

Jet engines have fewer moving parts than reciprocating engines, but they burn a great deal more fuel. A jet engine burns its fuel in an enclosed space called a combustion chamber. The burning of fuel produces hot gases that rush out of the rear opening of the engine at high speed. This powerful jet exhaust pushes the engine (and the plane to which it is attached) forward.

Before leaving the engine, the gases race past a fanlike device called a **turbine**, making it turn. The turbine is mounted on a drive shaft. As the drive shaft turns, it turns another set of fans, called the **compressor**, at the front end of the engine. The spinning compressor packs enormous amounts of air into the combustion chamber, providing the oxygen needed for continuous burning of the fuel. This basic type of jet engine is called the **turbojet**. It powers some of the fastest high-altitude aircraft, such as military fighters and bombers.

The **turboprop** engine is very similar to the turbojet, but it uses the power of the jet exhaust to turn a propeller. Turboprops are used on planes that must use fuel more efficiently, but planes using them do not fly as fast.

Turbofans are jet engines with a second turbine that drives a fan near the front of the engine. This fan, which acts something like a propeller, forces air out through special openings at very high speed. The air passes around the outside of the engine and provides extra thrust without burning extra fuel. The rest of the air enters the engine. Turbofan engines are widely used in modern airliners because they burn less fuel and are usually quieter than turbojet engines used in earlier airliners.

More about how jet engines work can be found in the article Jet Propulsion.

Rocket Engines

Rocket engines are used very rarely in aircraft today. Rockets require much more fuel than jet engines, so they would require much larger fuel tanks. Also, refueling a rocket is more complicated than putting jet fuel or aviation gas on an airplane. Unlike jet engines, rockets are closed at the forward end. As a solid or liquid fuel burns in the combustion chamber, hot gases rush rearward through a nozzle. Because every physical action results in an opposite reaction, the engine, and the aircraft attached to it, is pushed forward. Rocket engines have been used primarily on experimental types of aircraft such as the Bell X-1, which, in 1947, was the first plane to break the sound barrier. (Rocket engines are described in the article Rockets.)

New Designs

Today, a great deal of research and development is being devoted to engines and propulsion. Because reciprocating engines are less expensive to operate than jet engines, and because jet engines often make a great deal of noise, many researchers are experimenting with high-performance propeller-driven engines. In the late 1980's, the National Aeronautics and Space Administration (NASA) and several private companies were experimenting with curved propeller blades, which will be used on airliners of the future. The Beech Starship, which was developed by a private company, uses a rear-mounted **pusher prop**, which is almost as fast as a jet engine and more efficient than a propeller that pulls an airplane through the air.

There have been new developments in power for very light aircraft. Dr. Paul MacCready, an American inventor, built the *Gossamer Condor* in 1977 and the *Gossamer Albatross* in 1979. These were human-powered airplanes in which the pilot pedaled a bicycle-like mechanism that turns the propeller. A later MacCready design known as the *Solar Challenger* flew across the English Channel in 1981 entirely under solar power.

Instruments

Aviation pioneers flew using very simple methods, such as looking for landmarks and other visual references. They also sensed the forces on the airplane through their bodies, so they said they "flew by the seat of their pants." But instruments have become more and more important in aviation. Generally, the larger the airplane, the greater the number of instruments. Even a relatively simple training airplane like a Cessna 152 contains enough instruments to confuse the nonflyer. But a highly complex airplane such as the Concorde, a supersonic airliner, contains many more instruments. As a result, the crew of the Concorde and some other large airliners includes a special crew member, the flight engineer, whose job is to monitor these instruments and make the necessary adjustments to the engines and other systems. The pilot and co-pilot fly the airplane and also give their attention to flight instruments and navigation instruments.

☑ Engine Instruments

Each airplane, no matter how large or how small, has a number of instruments for each engine. A **tachometer** tells how many revolutions per minute the engine makes. The temperature and the pressure of the air entering the engine, the fuel pressure, the oil pressure, and the engine temperature are usually measured as well. Jet planes use gauges that measure the temperature of the exhaust gases as they exit the tail pipe. Although all aircraft also have fuel gauges, most pilots measure the amount of fuel at the beginning of the flight and mathematically compute their fuel consumption throughout the trip. They use the fuel gauge only as a backup to their own computations.

☑ Flight Instruments

If a pilot is flying low and slow, he or she does not need many flight instruments. However, all pilots need to know four basic types of information. They must know the **heading** (the direction in which the airplane is flying), its altitude, its airspeed, and its **attitude** (pitch and bank in relation to the horizon).

The most basic of all flight instruments is the compass, which indicates the heading of the airplane. The magnetic compass can give a true heading in straight and level flight but has a tendency to be inaccurate when the airplane is turning. For this reason, many larger aircraft are equipped with instruments called **gyrocompasses**, which are not affected by the turns. (Gyrocompasses are described in the article Gyroscope .)

Altimeters measure altitude. There are two types of altimeters. One measures the pressure of the outside air, which decreases at a fairly regular rate as the aircraft gains altitude. A pilot, however, must be careful with this type of altimeter because it is affected by changes in temperature and barometric pressure, which in turn are affected by the weather. The **radio altimeter** uses a radio beam to measure the distance to the ground.

The **airspeed indicator** measures the speed with which the airplane moves through the air. The air enters the instrument through a special tube called a **Pilot-static tube**, which is mounted on the outside of the airplane. The faster the plane moves, the more air rushes into the tube, moving a **diaphragm**—a flexible surface inside the instrument—that turns an indicator needle.

An airplane's **airspeed** (speed through the air) is seldom the same as its **ground speed** (speed in relation to the ground). For example, if a plane flies into the wind, this head wind reduces the plane's ground speed but does not affect its airspeed. If the plane is flying at the same airspeed but in the same direction as the wind is blowing, this tail wind increases the speed with which the plane moves over the ground. Ground speed may be calculated by measuring how long it takes to fly a known distance between two points. It also may be measured electronically with DME (Distance Measuring Equipment).

The attitude of the airplane in relation to the ground must be known when flying in clouds or fog. Three instruments can be used to determine the plane's attitude. The **rate-of-climb indicator** tells how many feet per minute the plane is climbing or descending. The **turn-and-bank indicator** shows how many degrees the plane is banked to the left or right. The artificial horizon shows the pitch of the nose above or below the horizon. All commercial aircraft have these instruments.

Navigation Instruments

Navigation is the science of getting to a destination in an airplane without getting lost. The oldest method of navigating an airplane is called **pilotage**.The pilot navigated by watching for landmarks on the ground and comparing them with a map. Pilotage works well at relatively low speeds and altitudes, when landmarks can be seen easily. However, when flying a plane higher, faster, or in clouds or fog, a pilot must be able to navigate without seeing the ground.

If a pilot knows the direction in which the aircraft is headed, its altitude and airspeed, the direction and speed of the wind, and the outside air temperature, he or she can compute, with the aid of a watch, the airplane's position on a flight map without seeing the ground. This is an excellent method of navigation called **dead reckoning**. However, the use of reliable electronic instruments has largely replaced dead reckoning for commercial flights.

The development of radio and electronic navigation has greatly simplified the task of navigating an aircraft. Many aircraft are equipped with automatic **radio compasses** that indicate the direction from which a radio signal is coming. If lost, the pilot simply tunes the radio compass to the frequency of an airport radio range transmitter. An indicator needle shows the way to the station. This is sometimes known as **homing in** on a radio station. The pilot can also pinpoint the airplane's position by tuning in two or three different stations and plotting the signals on a map. The airplane's position will be the point on the map where the directional lines cross. The locations and frequencies of these old-style radio range stations are still given on flight charts used by all pilots.

Radio ranges, however, are being replaced by more effective devices known as VOR's. VOR stands for Very-high-frequency Omni-directional Range. A VOR radio station sends out 360 course signals spaced one degree apart, radiating like the spokes of a wheel from a radio transmitter. Pilots may select and fly on any of these courses. An indicator in the cockpit tells the pilot the position of the airplane in relationship to the VOR. As previously mentioned, a DME can be used for measuring the exact speed of the airplane. It also measures the exact distance of the airplane from the VOR transmitter.

Military pilots use a radio navigation system known as TACAN (TACtical Airborne Navigation). TACAN works like a combination of VOR and DME and has a longer range.

Several years ago, sailors began using a radio system called loran (*lo*ng-*ra*nge *n*avigation) aboard ships at sea and in the Great Lakes. Soon, private pilots discovered that loran signals can be transmitted long distances and that the system is extremely accurate. They began experimenting with Marine loran radio receivers. Today, loran plays an important role in aerial navigation across the United States for many types of aircraft.

Inertial Navigation.

Today, most commercial aircraft and many military aircraft use inertial navigation. Inertial navigation is accomplished by a computer that uses a very precise program together with a memory, accelerometer (an instrument measuring all directions and rates of movement), and gyroscopes to measure the plane's precise position above the earth's surface in latitude and longitude. The latest developments in precision navigation make use of satellite technology.

Radar.

Commercial aircraft and larger general aviation aircraft use radar to find and avoid storm systems. This is an important function because bad weather is the age-old enemy of the pilot. In fact, approximately 40 percent of all general aviation accidents are caused by bad weather. However, the type of radar used in civilian aircraft cannot help pilots detect other airplanes. Another, more complex type of radar is used for this purpose. It is found only in military aircraft, which must locate enemy planes even when they are too far away to see.

Auto Pilot.

Automatic pilots are standard equipment on most commercial aircraft, and increasing numbers of military and private aircraft have them as well. The simplest auto pilot is based on two gyroscopes, each of which is connected to the aircraft's controls. When an airplane deviates (strays) from straight and level flight, the gyroscopes detect the change. By means of electrical servomotors (much like those used on radio-controlled model airplanes), they move the controls slightly to return the airplane to straight and level flight. More sophisticated automatic pilots are used by aircraft that have computerized navigation systems. In these aircraft, the auto pilot may be set to fly a particular course at a certain airspeed and altitude. The auto pilot automatically updates its position through the navigation computers while monitoring its speed, altitude, and heading.

Until recently, the dozens, or sometimes hundreds, of instruments in an airplane's cockpit had analog displays; that is, they had clock-type faces with dials and hands. In today's most modern aircraft, these analog instruments have been replaced by digital instruments, which display information in the form of numbers. Also, high technology in the form of computerization and CRT's (Cathode-Ray Tubes) is changing the look of the modern aircraft cockpit. Some corporate aircraft such as the Beech Starship and the Gulfstream IV already have what have been nicknamed "glass cockpits." These areas display on video screens all of the important information needed to fly and navigate an airplane. Many military aircraft and commercial airliners are also beginning to use this highly developed technology.

Airplane Design

An airplane can fly at fast or slow speeds over long or short distances. It can carry hundreds of vacationers around the world or a single person from one side of a major city to the other. The designer of an airplane must keep in mind the task the airplane is to accomplish. Will the airplane fly great distances? If so, the designer will have to provide either very efficient power or the capacity to store a great amount of fuel. Should the airplane's structure be relatively light or heavy? That depends on the cargo it will carry. This might be two persons or a whole company of soldiers and equipment. A large airplane will mean more weight and more drag. As a result, larger engines and wings will be necessary to get it airborne. Crop dusters, aerobatic biplanes, personal transportation aircraft, and airliners all have different design requirements. The airplane designer has many choices to make, and modern technology can help with these decisions.

Recently, airplanes have been designed with the aid of computers. CAD-CAM (Computer-Aided Design and Computer-Aided Manufacturing) is becoming part of the industry. The *Voyager* was designed with the aid of a computer. The design required very light weight, large fuel capacity, relatively high horsepower for propulsion, and efficient engines. After determining these requirements, the designers used computers to solve the complex mathematical problems encountered in designing aircraft.

The Future

New technology leads to improved airplanes. Composite materials similar to fiberglass are replacing some metal parts on many airplanes. These materials are stronger and lighter than those they replace. New engine and design technology will let aircraft fly higher and farther than ever before. Scientists are working on a hypersonic plane that will fly in the upper atmosphere at more than five times the speed of sound. It should cross the Pacific Ocean in only 2 hours instead of the 12 to 14 hours required by most commercial planes. Computer automation enables the development of unmanned aerial vehicles. Pilot-free aircraft are already used by the military.

Manufacturing giants pursue different airliner strategies. In 2005, the Airbus A380 first flew, and Boeing took the first orders for its 787 Dreamliner. The huge A380 can carry over 550 passengers. The smaller 787 boasts greater efficiency.

Other developments may bring planes closer to home. Planes called VTOL's (Vertical Take Off and Landing) need little space to take off and land, allowing planes to use small airports closer to city centers.

At air shows around the world, engineers, designers, and developers share ideas on ways to improve airplanes. The future of flight is limited only by our imaginations.

Paul H. Poberezny
President
Experimental Aircraft Association

See also: Aerodynamics; Aviation; Gliders; Gyroscope; Internal-Combustion Engines; Jet Propulsion; Navigation; Radar and Sonar; Rockets.

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