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## **LEARNING TO FLY: IT'S EASY!**

You probably have a driver's license issued by your government. The Transport Canada governs pilot privileges and requires specific flight experience, a knowledge test (formerly known as a written test), and a practical (flight test) to earn a pilot's license (called a certificate). The Transport Canada Civil Aviation (TCCA) regulates civil aviation.

Most people believe airplanes are to be ridden in as a passenger rather than flown as a pilot. In contrast, when you see a nice automobile, you usually project yourself into the driver's seat and imagine yourself driving the automobile. We want you and others to do the same with airplanes. Imagine yourself in the left seat as the pilot. Try it, it's fun: Imagine yourself flying the airplane as the pilot when you see airplanes.

Flying an airplane is more complex than driving a car because you are controlling altitude (up and down) in addition to left-right movement. It is also more exhilarating than driving because you have the freedom of three-dimensional movement, greater speed, and spectacular panoramas. Flying provides lifelong satisfaction and pride.

It's fun to learn to fly and earn a pilot license. Many people might consider learning to fly beyond their capability or budget, but it is not as difficult, time consuming, or expensive as generally believed.



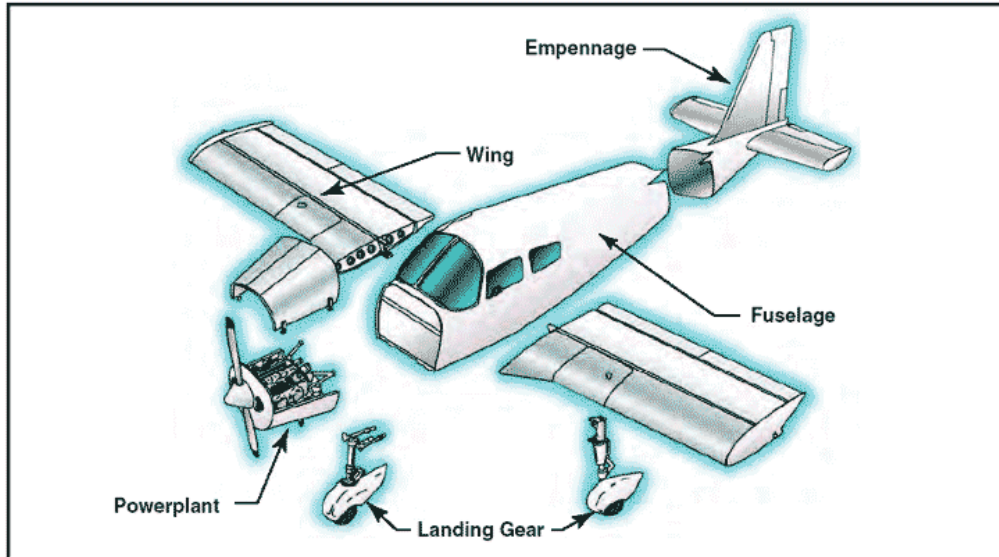
Happy Flying

Aero Academy Flight Center

### **Major components**

Although airplanes are designed for a variety of purposes, most of them have the same major components.

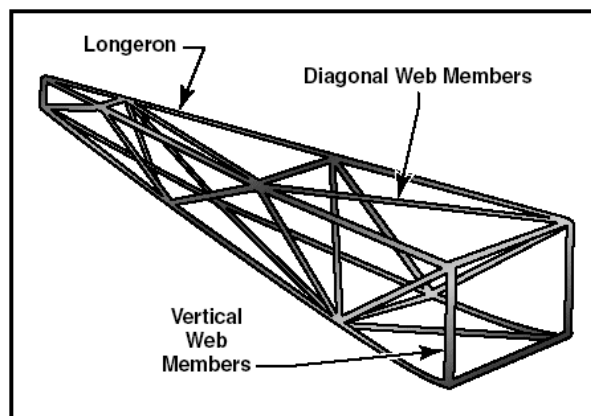
The overall characteristics are largely determined by the original design objectives. Most airplane structures include a fuselage, wings, an empennage, landing gear, and a powerplant.



*Airplane components.*

### Fuselage

The fuselage includes the cabin and/or cockpit, which contains seats for the occupants and the controls for the airplane. In addition, the fuselage may also provide room for cargo and attachment points for the other major airplane components. Some aircraft utilize an open truss structure. The truss-type fuselage is constructed of steel or aluminum tubing. Strength and rigidity is achieved by welding the tubing together into a series of triangular shapes, called trusses.



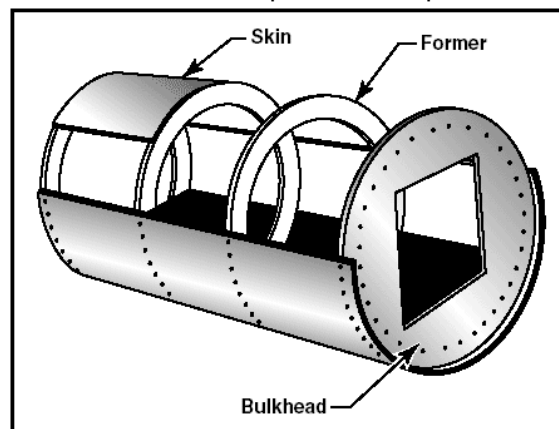
*The Warren truss.*

Construction of the Warren truss features longerons, as well as diagonal and vertical web members. To reduce weight, small airplanes generally utilize aluminum alloy tubing, which may be riveted or bolted into one piece with cross-bracing members.

As technology progressed, aircraft designers began to enclose the truss members to streamline the airplane and improve performance. This was originally accomplished with cloth fabric, which eventually gave way to lightweight metals such as aluminum. In some cases, the outside skin can support all or a major portion of the flight loads. Most modern aircraft use a form of this stressed skin structure known as monocoque or semimonocoque construction.

The monocoque design uses stressed skin to support almost all imposed loads. This structure can be very strong but cannot tolerate dents or deformation of the surface. This characteristic is easily demonstrated by a thin aluminum beverage can. You can exert considerable force to the ends of the can without causing any damage.

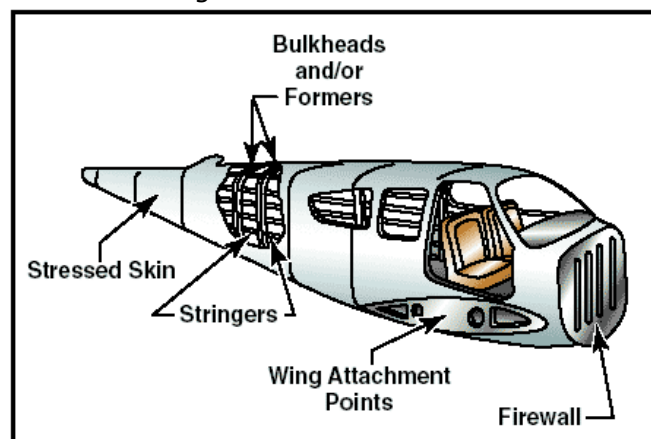
However, if the side of the can is dented only slightly, the can will collapse easily. The true monocoque construction mainly consists of the skin, formers, and bulkheads. The formers and bulkheads provide shape for the fuselage.



*Monocoque fuselage design.*

Since no bracing members are present, the skin must be strong enough to keep the fuselage rigid. Thus, a significant problem involved in monocoque construction is maintaining enough strength while keeping the weight within allowable limits. Due to the limitations of the monocoque design, a semi-monocoque structure is used on many of today's aircraft.

The semi-monocoque system uses a substructure to which the airplane's skin is attached. The substructure, which consists of bulkheads and/or formers of various sizes and stringers, reinforces the stressed skin by taking some of the bending stress from the fuselage.



*Semi-monocoque construction.*

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The main section of the fuselage also includes wing attachment points and a firewall.

On single-engine airplanes, the engine is usually attached to the front of the fuselage. There is a fireproof partition between the rear of the engine and the cockpit or cabin to protect the pilot and passengers from accidental engine fires. This partition is called a firewall and is usually made of heat-resistant material such as stainless steel.

### Wings

The wings are airfoils attached to each side of the fuselage and are the main lifting surfaces that support the airplane in flight. There are numerous wing designs, sizes, and shapes used by the various manufacturers.

Each fulfills a certain need with respect to the expected performance for the particular airplane.

How the wing produces lift is explained in aerodynamics pages.

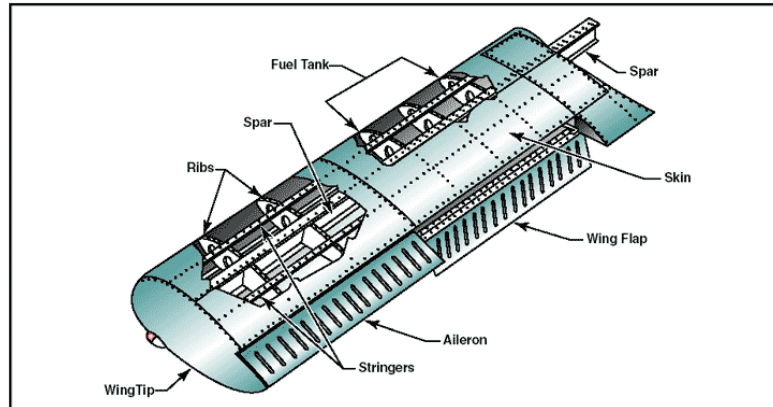
Wings may be attached at the top, middle, or lower portion of the fuselage. These designs are referred to as high-, mid-, and low-wing, respectively. The number of wings can also vary. Airplanes with a single set of wings are referred to as monoplanes, while those with two sets are called biplanes.



*Monoplane and biplane.*

Many high-wing airplanes have external braces, or wing struts, which transmit the flight and landing loads through the struts to the main fuselage structure. Since the wing struts are usually attached approximately halfway out on the wing, this type of wing structure is called semi-cantilever. A few high-wing and most low-wing airplanes have a full cantilever wing designed to carry the loads without external struts.

The principal structural parts of the wing are spars, ribs, and stringers.



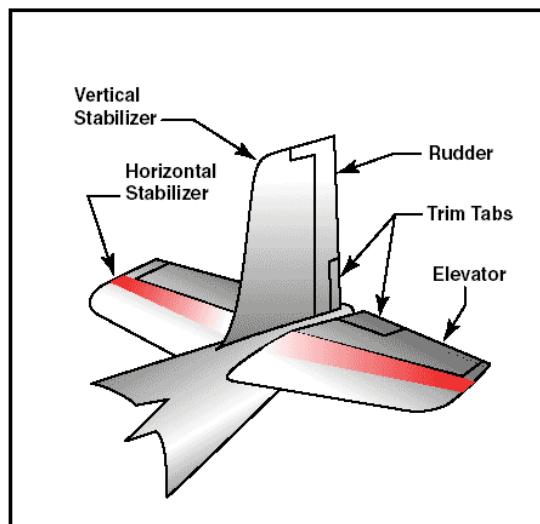
*Wing components.*

These are reinforced by trusses, I-beams, tubing, or other devices, including the skin. The wing ribs determine the shape and thickness of the wing (airfoil). In most modern airplanes, the fuel tanks either are an integral part of the wing's structure, or consist of flexible containers mounted inside of the wing.

Attached to the rear, or trailing, edges of the wings are two types of control surfaces referred to as ailerons and flaps. Ailerons extend from about the midpoint of each wing outward toward the tip and move in opposite directions to create aerodynamic forces that cause the airplane to roll. Flaps extend outward from the fuselage to near the midpoint of each wing. The flaps are normally flush with the wing's surface during cruising flight. When extended, the flaps move simultaneously downward to increase the lifting force of the wing for takeoffs and landings.

Empennage

The correct name for the tail section of an airplane is empennage. The empennage includes the entire tail group, consisting of fixed surfaces such as the vertical stabilizer and the horizontal stabilizer. The movable surfaces include the rudder, the elevator, and one or more trim tabs.

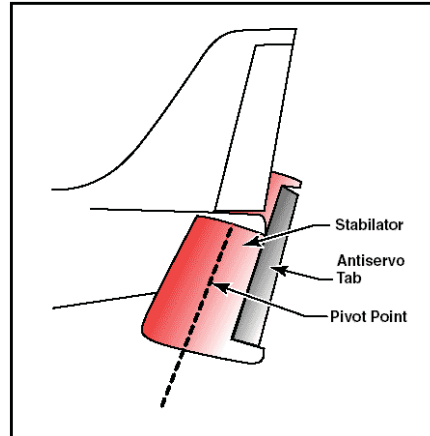


*Empennage components.*

A second type of empennage design does not require an elevator. Instead, it incorporates a one-piece horizontal stabilizer that pivots from a central hinge point.

This type of design is called a stabilator, and is moved using the control wheel, just as you would the elevator.

For example, when you pull back on the control wheel, the stabilator pivots so the trailing edge moves up. This increases the aerodynamic tail load and causes the nose of the airplane to move up. Stabilators have an antiservo tab extending across their trailing edge.



*Stabilator components.*

The antiservo tab moves in the same direction as the trailing edge of the stabilator. The antiservo tab also functions as a trim tab to relieve control pressures and helps maintain the stabilator in the desired position.

The rudder is attached to the back of the vertical stabilizer.

During flight, it is used to move the airplane's nose left and right. The rudder is used in combination with the ailerons for turns during flight. The elevator, which is attached to the back of the horizontal stabilizer, is used to move the nose of the airplane up and down during flight.

Trim tabs are small, movable portions of the trailing edge of the control surface. These movable trim tabs, which are controlled from the cockpit, reduce control pressures. Trim tabs may be installed on the ailerons, the rudder, and/or the elevator.

### Landing gear

The landing gear is the principle support of the airplane when parked, taxiing, taking off, or when landing. The most common type of landing gear consists of wheels, but airplanes can also be equipped with floats for water operations, or skis for landing on snow.



*Landing gear.*

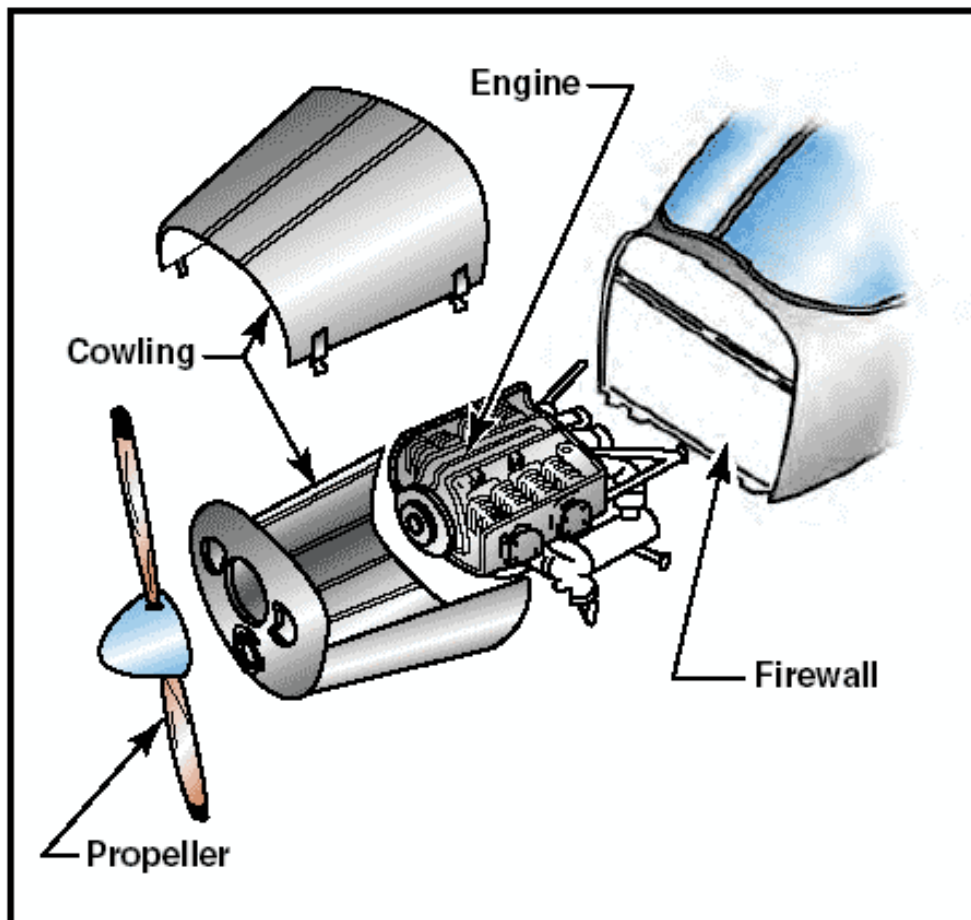
The landing gear consists of three wheels — two main wheels and a third wheel positioned either at the front or rear of the airplane. Landing gear employing a rearmounted wheel is called conventional landing gear.

Airplanes with conventional landing gear are sometimes referred to as tailwheel airplanes. When the third wheel is located on the nose, it is called a nosewheel, and the design is referred to as a tricycle gear. A steerable nosewheel or tailwheel permits the airplane to be controlled throughout all operations while on the ground.

The powerplant

The powerplant usually includes both the engine and the propeller. The primary function of the engine is to provide the power to turn the propeller. It also generates electrical power, provides a vacuum source for some flight instruments, and in most single-engine airplanes, provides a source of heat for the pilot and passengers. The engine is covered by a cowling, or in the case of some airplanes, surrounded by a nacelle.

The purpose of the cowling or nacelle is to streamline the flow of air around the engine and to help cool the engine by ducting air around the cylinders. The propeller, mounted on the front of the engine, translates the rotating force of the engine into a forwardacting force called thrust that helps move the airplane through the air.

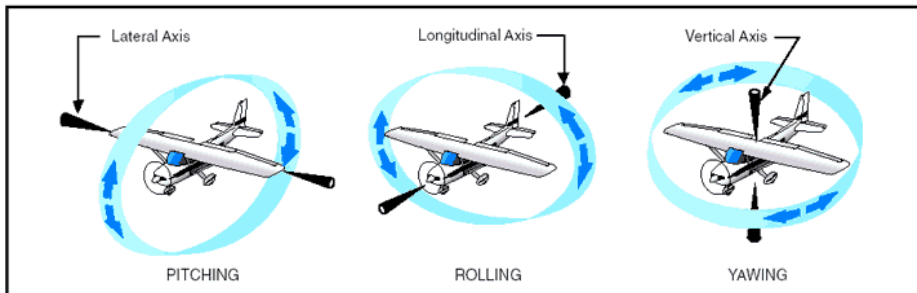


*Engine compartment*

## **Flight controls: How an airplane is controlled.**

### **Axes of an airplane**

Whenever an airplane changes its flight attitude or position in flight, it rotates about one or more of three axes, which are imaginary lines that pass through the airplane's center of gravity. The axes of an airplane can be considered as imaginary axes around which the airplane turns, much like the axle around which a wheel rotates. At the point where all three axes intersect, each is at a 90° angle to the other two. The axis, which extends lengthwise through the fuselage from the nose to the tail, is the longitudinal axis. The axis, which extends crosswise from wingtip to wingtip, is the lateral axis. The axis, which passes vertically through the center of gravity, is the vertical axis.



### *Axes of an airplane.*

The airplane's motion about its longitudinal axis resembles the roll of a ship from side to side. In fact, the names used in describing the motion about an airplane's three axes were originally nautical terms. They have been adapted to aeronautical terminology because of the similarity of motion between an airplane and the seagoing ship.

In light of the adoption of nautical terms, the motion about the airplane's longitudinal axis is called "roll"; motion about its lateral axis is referred to as "pitch." Finally, an airplane moves about its vertical axis in a motion, which is termed "yaw"—that is, a horizontal (left and right) movement of the airplane's nose.

The three motions of the airplane (roll, pitch, and yaw) are controlled by three control surfaces. Roll is controlled by the ailerons; pitch is controlled by the elevators; yaw is controlled by the rudder. The use of these controls is explained further down on this page.

### **Moments and moment arm**

A study of physics shows that a body that is free to rotate will always turn about its center of gravity. In aerodynamic terms, the mathematical measure of an airplane's tendency to rotate about its center of gravity is called a "moment." A moment is said to be equal to the product of the force applied and the distance at which the force is applied. (A moment arm is the distance from a datum [reference point or line] to the applied force.) For airplane weight and balance computations, "moments" are expressed in terms of the distance of the arm times the airplane's weight, or simply, inch pounds.

Airplane designers locate the fore and aft position of the airplane's center of gravity as nearly as possible to the 20 percent point of the mean aerodynamic chord (MAC). If the thrust line is designed to pass horizontally through the center of gravity, it will not cause the airplane to pitch when power is changed, and



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there will be no difference in moment due to thrust for a power-on or power-off condition of flight.

Although designers have some control over the location of the drag forces, they are not always able to make the resultant drag forces pass through the center of gravity of the airplane. However, the one item over which they have the greatest control is the size and location of the tail. The objective is to make the moments (due to thrust, drag, and lift) as small as possible; and, by proper location of the tail, to provide the means of balancing the airplane longitudinally for any condition of flight.

The pilot has no direct control over the location of forces acting on the airplane in flight, except for controlling the center of lift by changing the angle of attack.

Such a change, however, immediately involves changes in other forces.

Therefore, the pilot cannot independently change the location of one force without changing the effect of others. For example, a change in airspeed involves a change in lift, as well as a change in drag and a change in the up or down force on the tail. As forces such as turbulence and gusts act to displace the airplane, the pilot reacts by providing opposing control forces to counteract this displacement.

Some airplanes are subject to changes in the location of the center of gravity with variations of load.

Trimming devices are used to counteract the forces set up by fuel burnoff, and loading or off-loading of passengers or cargo. Elevator trim tabs and adjustable horizontal stabilizers comprise the most common devices provided to the pilot for trimming for load variations. Over the wide ranges of balance during flight in large airplanes, the force which the pilot has to exert on the controls would become excessive and fatiguing if means of trimming were not provided.

Aircraft flight control systems are classified as primary and secondary. The primary control systems consist of those that are required to safely control an airplane during flight. These include the ailerons, elevator (or stabilator), and rudder. Secondary control systems improve the performance characteristics of the airplane, or relieve the pilot of excessive control forces.

Examples of secondary control systems are wing flaps and trim systems.

### **Primary flight controls**

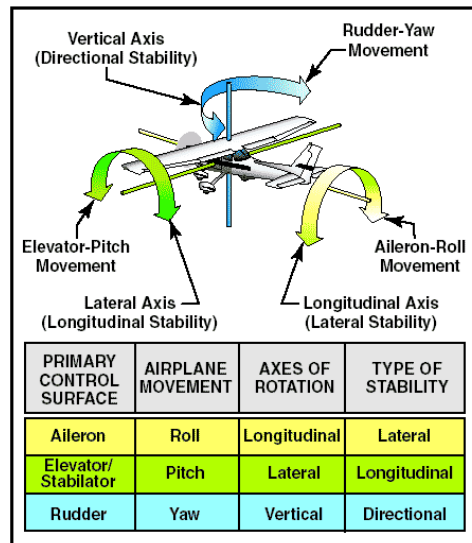
Airplane control systems are carefully designed to provide a natural feel, and at the same time, allow adequate responsiveness to control inputs. At low airspeeds, the controls usually feel soft and sluggish, and the airplane responds slowly to control applications. At high speeds, the controls feel firm and the response is more rapid.

Movement of any of the three primary flight control surfaces changes the airflow and pressure distribution over and around the airfoil. These changes affect the lift and drag produced by the airfoil/control surface combination, and allow a pilot to control the airplane about its three axes of rotation.

Design features limit the amount of deflection of flight control surfaces. For example, control-stop mechanisms may be incorporated into the flight controls, or movement of the control column and/or rudder pedals may be limited. The purpose of these design limits is to prevent the pilot from inadvertently overcontrolling and overstressing the aircraft during normal maneuvers.

A properly designed airplane should be stable and easily controlled during maneuvering. Control surface inputs cause movement about the three axes of rotation.

The types of stability an airplane exhibits also relate to the three axes of rotation.



*Airplane controls, movement, axes of rotation, and type of stability.*

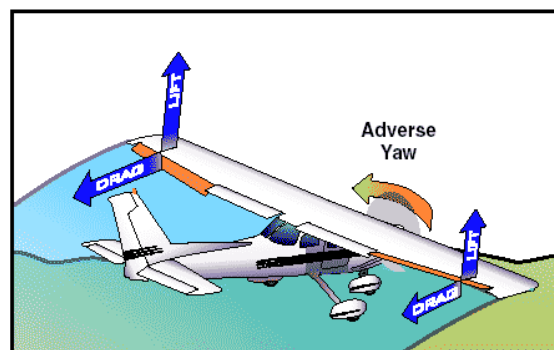
### Ailerons

Ailerons control roll about the longitudinal axis. The ailerons are attached to the outboard trailing edge of each wing and move in the opposite direction from each other. Ailerons are connected by cables, bellcranks, pulleys or push-pull tubes to each other and to the control wheel.

Moving the control wheel to the right causes the right aileron to deflect upward and the left aileron to deflect downward. The upward deflection of the right aileron decreases the camber resulting in decreased lift on the right wing. The corresponding downward deflection of the left aileron increases the camber resulting in increased lift on the left wing. Thus, the increased lift on the left wing and the decreased lift on the right wing causes the airplane to roll to the right.

### Adverse yaw

Since the downward deflected aileron produces more lift, it also produces more drag. This added drag attempts to yaw the airplane's nose in the direction of the raised wing. This is called adverse yaw.



*Adverse yaw is caused by higher drag on the outside wing, which is producing more lift.*

The rudder is used to counteract adverse yaw, and the amount of rudder control required is greatest at low airspeeds, high angles of attack, and with large aileron



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deflections. However, with lower airspeeds, the vertical stabilizer/rudder combination becomes less effective, and magnifies the control problems associated with adverse yaw.

All turns are coordinated by use of ailerons, rudder, and elevator. Applying aileron pressure is necessary to place the airplane in the desired angle of bank, while simultaneously applying rudder pressure to counteract the resultant adverse yaw. During a turn, the angle of attack must be increased by applying elevator pressure because more lift is required than when in straight-and level flight. The steeper the turn, the more back elevator pressure is needed.

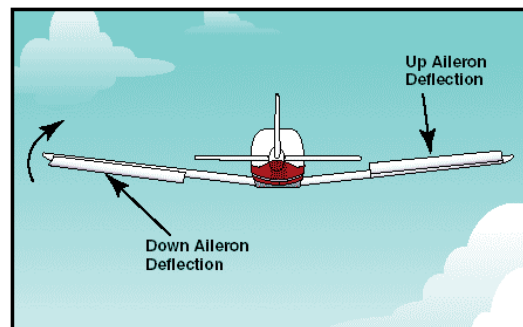
As the desired angle of bank is established, aileron and rudder pressures should be relaxed. This will stop the bank from increasing because the aileron and rudder control surfaces will be neutral in their streamlined position. Elevator pressure should be held constant to maintain a constant altitude.

The rollout from a turn is similar to the roll-in except the flight controls are applied in the opposite direction.

Aileron and rudder are applied in the direction of the rollout or toward the high wing. As the angle of bank decreases, the elevator pressure should be relaxed as necessary to maintain altitude.

#### Differential Ailerons

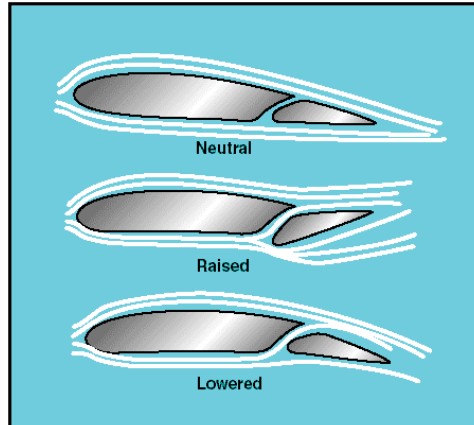
With differential ailerons, one aileron is raised a greater distance than the other aileron is lowered for a given movement of the control wheel. This produces an increase in drag on the descending wing. The greater drag results from deflecting the up aileron on the descending wing to a greater angle than the down aileron on the rising wing. While adverse yaw is reduced, it is not eliminated completely.



*Differential ailerons.*

#### Frise-type ailerons

With a Frise-type aileron, when pressure is applied to the control wheel, the aileron that is being raised pivots on an offset hinge. This projects the leading edge of the aileron into the airflow and creates drag. This helps equalize the drag created by the lowered aileron on the opposite wing and reduces adverse yaw.

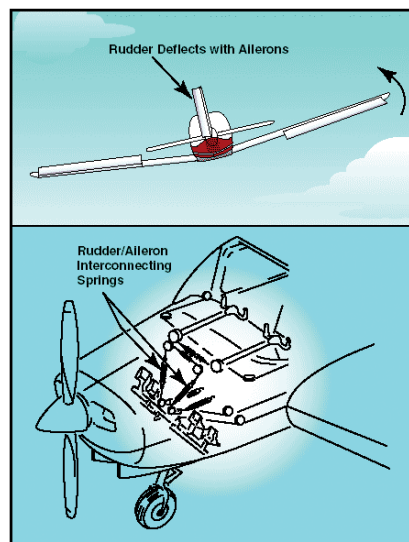


*Frise-type ailerons.*

The Frise-type aileron also forms a slot so that air flows smoothly over the lowered aileron, making it more effective at high angles of attack. Frise-type ailerons also may be designed to function differentially. Like the differential aileron, the Frise-type aileron does not eliminate adverse yaw entirely. Coordinated rudder application is still needed wherever ailerons are applied.

Coupled ailerons and rudder

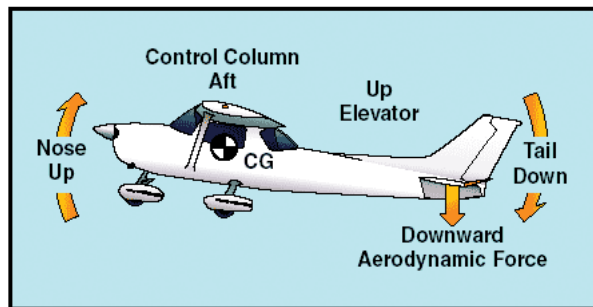
Coupled ailerons and rudder means these controls are linked. This is accomplished with rudder-aileron interconnect springs, which help correct for aileron drag by automatically deflecting the rudder at the same time the ailerons are deflected. For example, when the control yoke is moved to produce a left roll, the interconnect cable and spring pulls forward on the left rudder pedal just enough to prevent the nose of the airplane from yawing to the right. The force applied to the rudder by the springs can be overridden if it becomes necessary to slip the airplane.



*Coupled ailerons and rudder.*

Elevator

The elevator controls pitch about the lateral axis. Like the ailerons on small airplanes, the elevator is connected to the control column in the cockpit by a series of mechanical linkages. Aft movement of the control column deflects the trailing edge of the elevator surface up. This is usually referred to as up elevator.



*The elevator is the primary control for changing the pitch attitude of an airplane.*

The up-elevator position decreases the camber of the elevator and creates a downward aerodynamic force, which is greater than the normal tail-down force that exists in straight-and-level flight. The overall effect causes the tail of the airplane to move down and the nose to pitch up. The pitching moment occurs about the center of gravity (CG). The strength of the pitching moment is determined by the distance between the CG and the horizontal tail surface, as well as by the aerodynamic effectiveness of the horizontal tail surface.

Moving the control column forward has the opposite effect. In this case, elevator camber increases, creating more lift (less tail-down force) on the horizontal stabilizer/elevator. This moves the tail upward and pitches the nose down. Again, the pitching moment occurs about the CG.

As mentioned in the page on stability , power, thrustline, and the position of the horizontal tail surfaces on the empennage are factors in how effective the elevator is in controlling pitch. For example, the horizontal tail surfaces may be attached near the lower part of the vertical stabilizer, at the midpoint, or at the high point, as in the T-tail design.

### T-tail

In a T-tail configuration, the elevator is above most of the effects of downwash from the propeller as well as airflow around the fuselage and/or wings during normal flight conditions. Operation of the elevators in this undisturbed air makes for control movements that are consistent throughout most flight regimes. T-tail designs have become popular on many light airplanes and on large aircraft, especially those with aft-fuselage mounted engines since the T-tail configuration removes the tail from the exhaust blast of the engines. Seaplanes and amphibians often have T-tails in order to keep the horizontal surfaces as far from the water as possible. An additional benefit is reduced vibration and noise inside the aircraft.

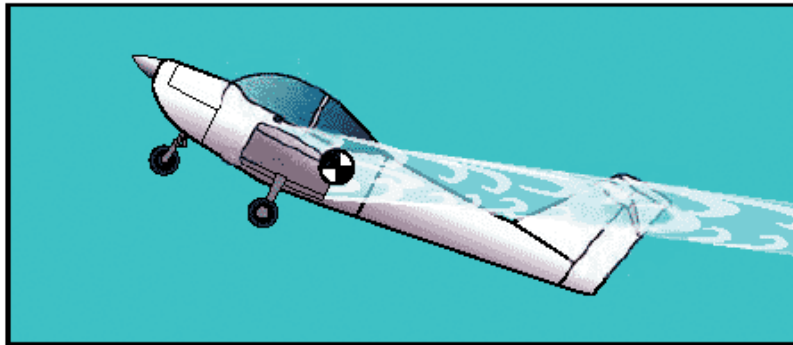
At slow speeds, the elevator on a T-tail aircraft must be moved through a larger number of degrees of travel to raise the nose a given amount as compared to a conventional-tail aircraft. This is because the conventional-tail aircraft has the downwash from the propeller pushing down on the tail to assist in raising the nose. Since controls on aircraft are rigged in such a manner as to require

increasing control forces for increased control travel, the forces required to raise the nose of a T-tail aircraft are greater than for a conventional-tail aircraft. Longitudinal stability of a trimmed aircraft is the same for both types of configuration, but the pilot must be aware that at slow speeds during takeoffs and landings or stalls, the control forces will be greater than for similar size airplanes equipped with conventional tails.

T-tail airplanes also require additional design considerations to counter the problem of flutter. Since the weight of the horizontal surfaces is at the top of the vertical stabilizer, the moment arm created causes high loads on the vertical stabilizer which can result in flutter. Engineers must compensate for this by increasing the design stiffness of the vertical stabilizer, usually resulting in a weight penalty over conventional tail designs.

When flying at a very high angle of attack with a low airspeed and an aft CG, the T-tail airplane may be susceptible to a deep stall. In a deep stall, the airflow over the horizontal tail is blanketed by the disturbed airflow from the wings and fuselage. In these circumstances, elevator or stabilator control could be diminished, making it difficult to recover from the stall.

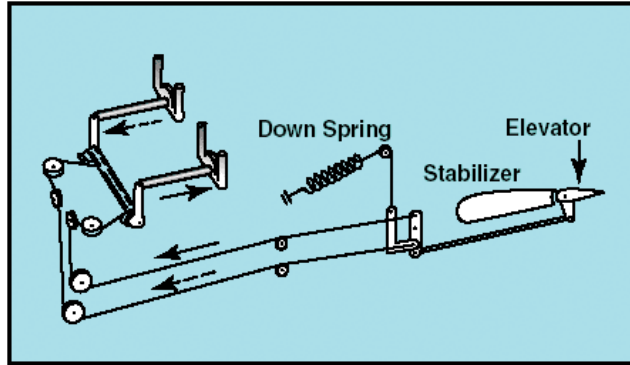
It should be noted that an aft CG could be a contributing factor in these incidents since similar recovery problems are also found with conventional-tail aircraft with an aft CG.



*Airplane with a T-tail design at a high angle of attack and an aft CG.*

Since flight at a high angle of attack with a low airspeed and an aft CG position can be dangerous, many airplanes have systems to compensate for this situation. The systems range from control stops to elevator down springs. An elevator down spring assists in lowering the nose to prevent a stall caused by the aft CG position. The stall occurs because the properly trimmed airplane is flying with the elevator in a trailing edge down position, forcing the tail up and the nose down. In this unstable condition, if the airplane encounters turbulence and slows down further, the trim tab no longer positions the elevator in the nose-down position. The elevator then streamlines, and the nose of the aircraft pitches upward. This aggravates the situation and can possibly result in a stall.

The elevator down spring produces a mechanical load on the elevator, causing it to move toward the nosedown position if not otherwise balanced. The elevator trim tab balances the elevator down spring to position the elevator in a trimmed position. When the trim tab becomes ineffective, the down spring drives the elevator to a nose down position. The nose of the aircraft lowers, speed builds up, and a stall is prevented.



*When the aerodynamic efficiency of the horizontal tail surface is inadequate due to an aft center of gravity condition, an elevator down spring may be used to supply a mechanical load to lower the nose.*

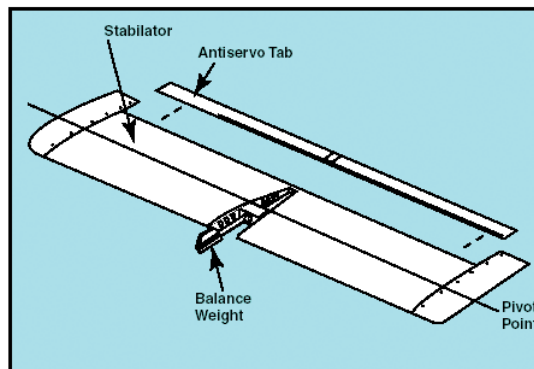
The elevator must also have sufficient authority to hold the nose of the airplane up during the roundout for a landing. In this case, a forward CG may cause a problem. During the landing flare, power normally is reduced, which decreases the airflow over the empennage. This, coupled with the reduced landing speed, makes the elevator less effective.

From this discussion, it should be apparent that pilots must understand and follow proper loading procedures, particularly with regard to the CG position. Click [here](#) for more information on aircraft loading, as well as weight and balance.

### Stabilator

A stabilator is essentially a one-piece horizontal stabilizer with the same type of control system. Because stabilators pivot around a central hinge point, they are extremely sensitive to control inputs and aerodynamic loads.

Antiservo tabs are incorporated on the trailing edge to decrease sensitivity. In addition, a balance weight is usually incorporated ahead of the main spar. The balance weight may project into the empennage or may be incorporated on the forward portion of the stabilator tips.



*The stabilator is a one-piece horizontal tail surface that pivots up and down about a central hinge point.*

When the control column is pulled back, it raises the stabilator's trailing edge, rotating the airplane's nose up. Pushing the control column forward lowers the trailing edge of the stabilator and pitches the nose of the airplane down. Without an antiservo tab, the airplane would be prone to overcontrolling from pilot-induced control inputs.

### Canard



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The term canard refers to a control surface that functions as a horizontal stabilizer but is located in front of the main wings. The term also is used to describe an airplane equipped with a canard. In effect, it is an airfoil similar to the horizontal surface on a conventional aft-tail design. The difference is that the canard actually creates lift and holds the nose up, as opposed to the aft-tail design which exerts downward force on the tail to prevent the nose from rotating downward.

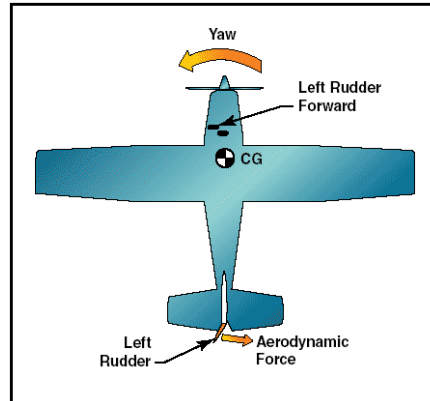
Although the Wright Flyer was configured as a canard with the horizontal surfaces in front of the lifting surface, it was not until recently that the canard configuration began appearing on newer airplanes. Canard designs include two types—one with a horizontal surface of about the same size as a normal aft-tail design, and the other with a surface of the same approximate size and airfoil of the aft-mounted wing known as a tandem wing configuration. Theoretically, the canard is considered more efficient because using the horizontal surface to help lift the weight of the aircraft should result in less drag for a given amount of lift. The canard's main advantage is in the area of stall characteristics. A properly designed canard or tandem wing will run out of authority to raise the nose of the aircraft at a point before the main wing will stall. This makes the aircraft stall-proof and results only in a descent rate that can be halted by adding power. Ailerons on the main wing remain effective throughout the recovery. Other canard configurations are designed so the canard stalls before the main wing, automatically lowering the nose and recovering the aircraft to a safe flying speed. Again, the ailerons remain effective throughout the stall.

The canard design has several limitations. First, it is important that the forward lifting surface of a canard design stalls before the main wing. If the main wing stalls first, the lift remaining from the forward wing or canard would be well ahead of the CG, and the airplane would pitch up uncontrollably. Second, when the forward surface stalls first, or is limited in its ability to increase the angle of attack, the main wing never reaches a point where its maximum lift is created, sacrificing some performance. Third, use of flaps on the main wing causes design problems for the forward wing or canard. As lift on the main wing is increased by extension of flaps, the lift requirement of the canard is also increased. The forward wing or canard must be large enough to accommodate flap use, but not so large that it creates more lift than the main wing. Finally, the relationship of the main wing to the forward surface also makes a difference. When positioned closely in the vertical plane, downwash from the forward wing can have a negative effect on the lift of the main wing. Increasing vertical separation increases efficiency of the design. Efficiency is also increased as the size of the two surfaces grows closer to being equal.

### Rudder

The rudder controls movement of the airplane about its vertical axis. This motion is called yaw. Like the other primary control surfaces, the rudder is a movable surface hinged to a fixed surface, in this case, to the vertical stabilizer, or fin. Moving the left or right rudder pedal controls the rudder.

When the rudder is deflected into the airflow, a horizontal force is exerted in the opposite direction.



*The effect of left rudder pressure.*

By pushing the left pedal, the rudder moves left. This alters the airflow around the vertical stabilizer/rudder, and creates a sideward lift that moves the tail to the right and yaws the nose of the airplane to the left.

Rudder effectiveness increases with speed, so large deflections at low speeds and small deflections at high speeds may be required to provide the desired reaction. In propeller-driven aircraft, any slipstream flowing over the rudder increases its effectiveness.

### V-tail

The V-tail design utilizes two slanted tail surfaces to perform the same functions as the surfaces of a conventional elevator and rudder configuration. The fixed surfaces act as both horizontal and vertical stabilizers.



*V-tail design.*

The movable surfaces, which are usually called ruddervators, are connected through a special linkage that allows the control wheel to move both surfaces simultaneously. On the other hand, displacement of the rudder pedals moves the surfaces differentially, thereby providing directional control.

When both rudder and elevator controls are moved by the pilot, a control mixing mechanism moves each surface the appropriate amount. The control system for the V-tail is more complex than that required for a conventional tail. In addition, the V-tail design is more susceptible to Dutch roll tendencies than a conventional tail and total reduction in drag is only minimal.

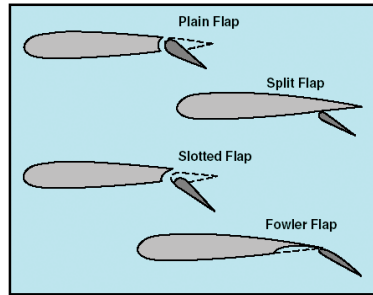
### **Secondary flight controls**

Secondary flight control systems may consist of the flaps, leading edge devices, spoilers, and trim devices.

### Flaps

Flaps are the most common high-lift devices used on practically all airplanes.

These surfaces, which are attached to the trailing edge of the wing, increase both lift and induced drag for any given angle of attack.



*Four common types of flaps.*

The plain flap is the simplest of the four types. It increases the airfoil camber, resulting in a significant increase in the coefficient of lift at a given angle of attack. At the same time, it greatly increases drag and moves the center of pressure aft on the airfoil, resulting in a nose-down pitching moment.

The split flap is deflected from the lower surface of the airfoil and produces a slightly greater increase in lift than does the plain flap. However, more drag is created because of the turbulent air pattern produced behind the airfoil. When fully extended, both plain and split flaps produce high drag with little additional lift.

The most popular flap on airplanes today is the slotted flap. Variations of this design are used for small airplanes as well as for large ones. Slotted flaps increase the lift coefficient significantly more than plain or split flaps. On small airplanes, the hinge is located below the lower surface of the flap, and when the flap is lowered, it forms a duct between the flap well in the wing and the leading edge of the flap.

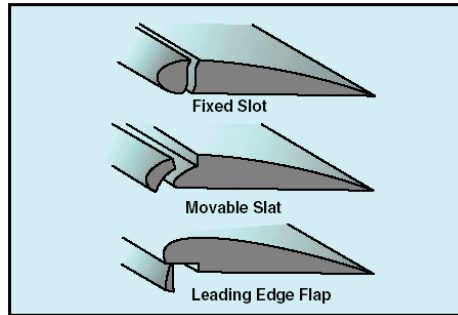
When the slotted flap is lowered, high-energy air from the lower surface is ducted to the flap's upper surface.

The high-energy air from the slot accelerates the upper surface boundary layer and delays airflow separation, providing a higher coefficient of lift. Thus, the slotted flap produces much greater increases in  $CL_{max}$  than the plain or split flap. While there are many types of slotted flaps, large airplanes often have double- and even triple-slotted flaps. These allow the maximum increase in drag without the airflow over the flaps separating and destroying the lift they produce.

Fowler flaps are a type of slotted flap. This flap design not only changes the camber of the wing, it also increases the wing area. Instead of rotating down on a hinge, it slides backwards on tracks. In the first portion of its extension, it increases the drag very little, but increases the lift a great deal as it increases both the area and camber. As the extension continues, the flap deflects downward, and during the last portion of its travel, it increases the drag with little additional increase in lift.

#### Leading edge devices

High-lift devices also can be applied to the leading edge of the airfoil. The most common types are fixed slots, movable slats, and leading edge flaps.



*Leading edge high lift devices.*

Fixed slots direct airflow to the upper wing surface and delay airflow separation at higher angles of attack. The slot does not increase the wing camber, but allows a higher maximum coefficient of lift because the stall is delayed until the wing reaches a greater angle of attack.

Movable slats consist of leading edge segments, which move on tracks. At low angles of attack, each slat is held flush against the wing's leading edge by the high pressure that forms at the wing's leading edge. As the angle of attack increases, the high-pressure area moves aft below the lower surface of the wing, allowing the slats to move forward. Some slats, however, are pilot operated and can be deployed at any angle of attack. Opening a slat allows the air below the wing to flow over the wing's upper surface, delaying airflow separation.

Leading edge flaps, like trailing edge flaps, are used to increase both  $CL_{max}$  and the camber of the wings. This type of leading edge device is frequently used in conjunction with trailing edge flaps and can reduce the nose-down pitching movement produced by the latter.

As is true with trailing edge flaps, a small increment of leading edge flaps increases lift to a much greater extent than drag. As greater amounts of flaps are extended, drag increases at a greater rate than lift.

### Spoilers

On some airplanes, high-drag devices called spoilers are deployed from the wings to spoil the smooth airflow, reducing lift and increasing drag. Spoilers are used for roll control on some aircraft, one of the advantages being the elimination of adverse yaw. To turn right, for example, the spoiler on the right wing is raised, destroying some of the lift and creating more drag on the right. The right wing drops, and the airplane banks and yaws to the right. Deploying spoilers on both wings at the same time allows the aircraft to descend without gaining speed.

Spoilers are also deployed to help shorten ground roll after landing. By destroying lift, they transfer weight to the wheels, improving braking effectiveness.



*Spoilers reduce lift and increase drag during descent and landing.*



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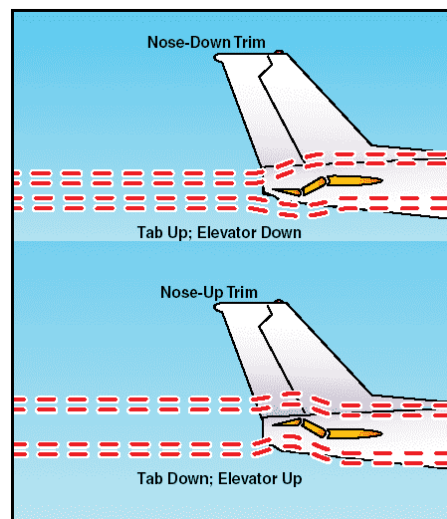
### Trim systems

Although the airplane can be operated throughout a wide range of attitudes, airspeeds, and power settings, it can only be designed to fly hands off within a very limited combination of these variables.

Therefore, trim systems are used to relieve the pilot of the need to maintain constant pressure on the flight controls. Trim systems usually consist of cockpit controls and small hinged devices attached to the trailing edge of one or more of the primary flight control surfaces. They are designed to help minimize a pilot's workload by aerodynamically assisting movement and position of the flight control surface to which they are attached. Common types of trim systems include trim tabs, balance tabs, antiservo tabs, ground adjustable tabs, and an adjustable stabilizer.

### Trim tabs

The most common installation on small airplanes is a single trim tab attached to the trailing edge of the elevator. Most trim tabs are manually operated by a small, vertically mounted control wheel. However, a trim crank may be found in some airplanes. The cockpit control includes a tab position indicator. Placing the trim control in the full nose-down position moves the tab to its full up position. With the tab up and into the airstream, the airflow over the horizontal tail surface tends to force the trailing edge of the elevator down. This causes the tail of the airplane to move up, and results in a nose-down pitch change.



*The movement of the elevator is opposite to the direction of movement of the elevator trim tab.*

If you set the trim tab to the full nose-up position, the tab moves to its full-down position. In this case, the air flowing under the horizontal tail surface hits the tab and tends to force the trailing edge of the elevator up, reducing the elevator's angle of attack. This causes a tail-down movement of the airplane and a nose-up pitch change.

In spite of the opposite direction movement of the trim tab and the elevator, control of trim is natural to a pilot.

If you have to exert constant back pressure on the control column, the need for nose-up trim is indicated.

The normal trim procedure is to continue trimming until the airplane is balanced and the nose-heavy condition is no longer apparent. Pilots normally establish the desired power, pitch attitude, and configuration first, and then trim the airplane

to relieve control pressures that may exist for that flight condition. Any time power, pitch attitude, or configuration is changed, expect that retrimming will be necessary to relieve the control pressures for the new flight condition.

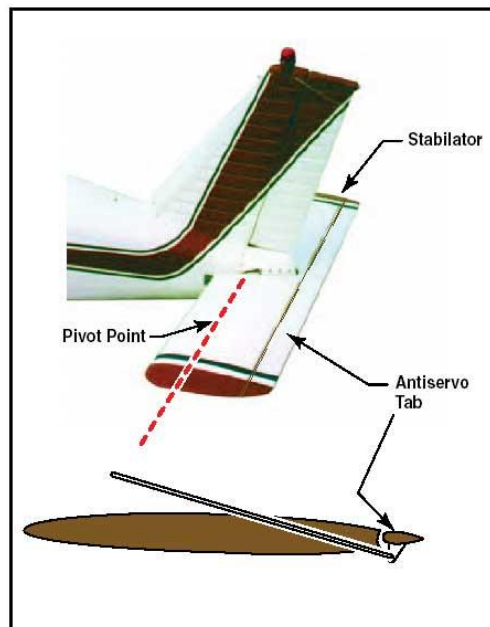
#### Balance tabs

The control forces may be excessively high in some airplanes, and in order to decrease them, the manufacturer may use balance tabs. They look like trim tabs and are hinged in approximately the same places as trim tabs. The essential difference between the two is that the balancing tab is coupled to the control surface rod so that when the primary control surface is moved in any direction, the tab automatically moves in the opposite direction. In this manner, the airflow striking the tab counter-balances some of the air pressure against the primary control surface, and enables the pilot to more easily move and hold the control surface in position.

If the linkage between the tab and the fixed surface is adjustable from the cockpit, the tab acts as a combination trim and balance tab, which can be adjusted to any desired deflection. Any time the control surface is deflected, the tab moves in the opposite direction and eases the load on the pilot.

#### Antiservo tabs

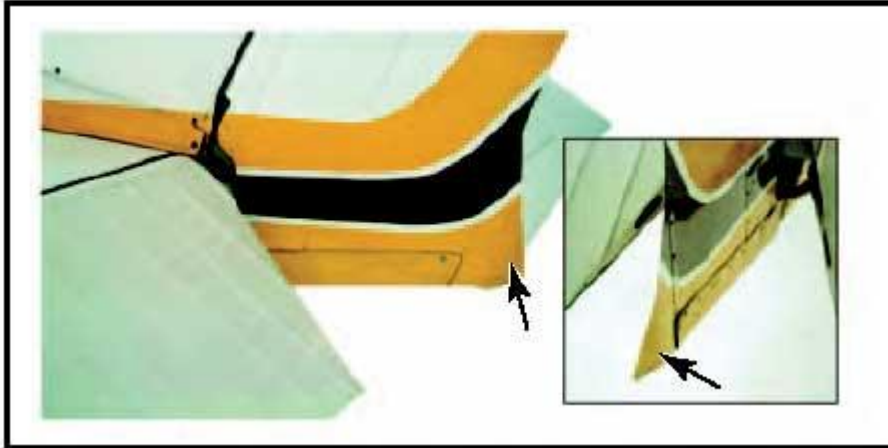
In addition to decreasing the sensitivity of the stabilator, an antiservo tab also functions as a trim device to relieve control pressure and maintain the stabilator in the desired position. The fixed end of the linkage is on the opposite side of the surface from the horn on the tab, and when the trailing edge of the stabilator moves up, the linkage forces the trailing edge of the tab up. When the stabilator moves down, the tab also moves down. This is different than trim tabs on elevators, which move opposite of the control surface.



*An antiservo tab attempts to streamline the control surface and is used to make the stabilator less sensitive by opposing the force exerted by the pilot. This tab works in the same manner as the balance tab except that, instead of moving in the opposite direction, it moves in the same direction as the trailing edge of the stabilator. For example, when the trailing edge of the stabilator moves up, the linkage forces the trailing edge of the tab up. When the stabilator moves down, the tab also moves down.*

### Ground adjustable tabs

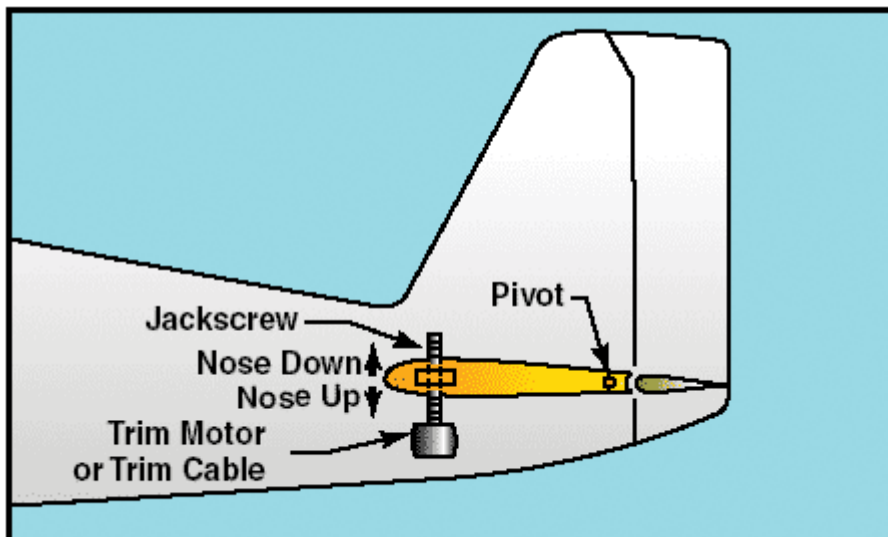
Many small airplanes have a non-moveable metal trim tab on the rudder. This tab is bent in one direction or the other while on the ground to apply a trim force to the rudder. The correct displacement is determined by trial-and-error process. Usually, small adjustments are necessary until you are satisfied that the airplane is no longer skidding left or right during normal cruising flight.



*A ground-adjustable tab is used on the rudder of many small airplanes to correct for a tendency to fly with the fuselage slightly misaligned with the relative wind.*

### Adjustable stabilizer

Rather than using a movable tab on the trailing edge of the elevator, some airplanes have an adjustable stabilizer. With this arrangement, linkages pivot the horizontal stabilizer about its rear spar. This is accomplished by use of a jackscrew mounted on the leading edge of the stabilizer.



*Some airplanes, including most jet transports, use an adjustable stabilizer to provide the required pitch trim forces.*

On small airplanes, the jackscrew is cable-operated with a trim wheel or crank, and on larger airplanes, it is motor driven. The trimming effect and cockpit indications for an adjustable stabilizer are similar to those of a trim tab. Since the primary and secondary flight control systems vary extensively between aircraft, you need to be familiar with the systems in your aircraft. A good source



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of information is the Airplane Flight Manual (AFM) or the Pilot's Operating Handbook (POH).

## The aircraft powerplant

The airplane engine and propeller, often referred to as the aircraft powerplant, work in combination to produce thrust. The powerplant propels the airplane and drives the various systems that support the operation of an airplane.

### Reciprocating engines

Most small airplanes are designed with reciprocating engines. The name is derived from the back-and-forth, or reciprocating, movement of the pistons. It is this motion that produces the mechanical energy needed to accomplish work. Two common means of classifying reciprocating engines are:

1. by cylinder arrangement with respect to the crankshaft—radial, in-line, v-type or opposed, or
2. by the method of cooling—liquid or air-cooled.

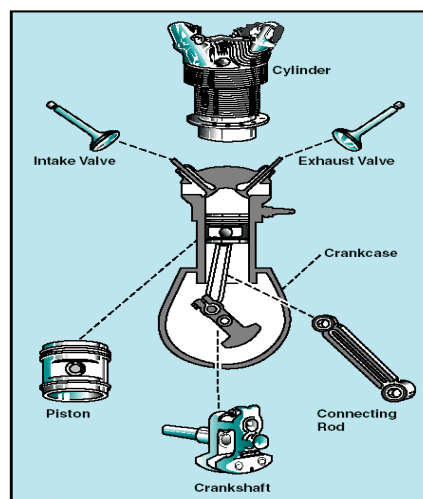
Radial engines were widely used during World War II, and many are still in service today. With these engines, a row or rows of cylinders are arranged in a circular pattern around the crankcase. The main advantage of a radial engine is the favorable power-to-weight ratio.

In-line engines have a comparatively small frontal area, but their power-to-weight ratios are relatively low. In addition, the rearmost cylinders of an air-cooled, in-line engine receive very little cooling air, so these engines are normally limited to four or six cylinders.

V-type engines provide more horsepower than in-line engines and still retain a small frontal area. Further improvements in engine design led to the development of the horizontally-opposed engine.

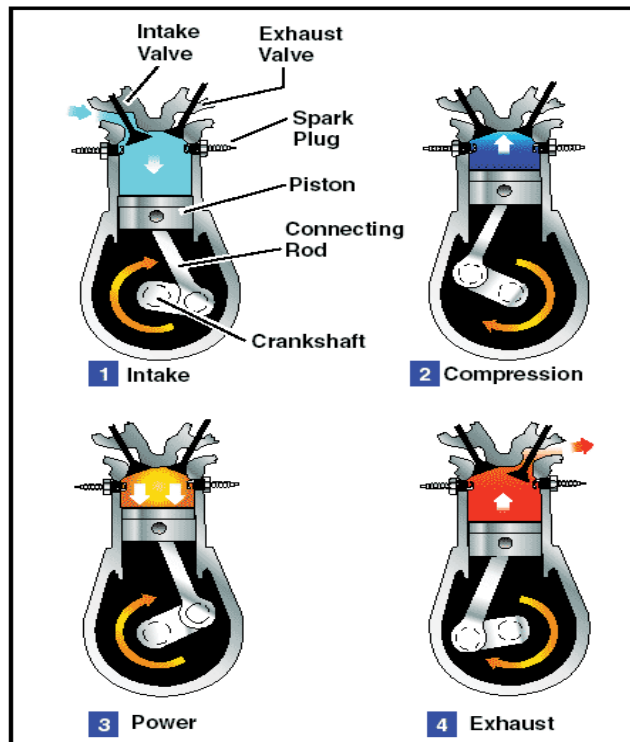
Opposed-type engines are the most popular reciprocating engines used on small airplanes. These engines always have an even number of cylinders, since a cylinder on one side of the crankcase "opposes" a cylinder on the other side. The majority of these engines are air cooled and usually are mounted in a horizontal position when installed on fixed-wing airplanes. Opposed-type engines have high power-to-weight ratios because they have a comparatively small, lightweight crankcase. In addition, the compact cylinder arrangement reduces the engine's frontal area and allows a streamlined installation that minimizes aerodynamic drag.

The main parts of a reciprocating engine include the cylinders, crankcase, and accessory housing. The intake/exhaust valves, spark plugs, and pistons are located in the cylinders. The crankshaft and connecting rods are located in the crankcase. The magnetos are normally located on the engine accessory housing.



*Main components of a reciprocating engine.*

The basic principle for reciprocating engines involves the conversion of chemical energy, in the form of fuel, into mechanical energy. This occurs within the cylinders of the engine through a process known as the four-stroke operating cycle. These strokes are called intake, compression, power, and exhaust.



*The arrows in this illustration indicate the direction of motion of the crankshaft and piston during the four-stroke cycle.*

1. The intake stroke begins as the piston starts its downward travel. When this happens, the intake valve opens and the fuel/air mixture is drawn into the cylinder.
2. The compression stroke begins when the intake valve closes and the piston starts moving back to the top of the cylinder. This phase of the cycle is used to obtain a much greater power output from the fuel/air mixture once it is ignited.
3. The power stroke begins when the fuel/air mixture is ignited. This causes a tremendous pressure increase in the cylinder, and forces the piston downward away from the cylinder head, creating the power that turns the crankshaft.
4. The exhaust stroke is used to purge the cylinder of burned gases. It begins when the exhaust valve opens and the piston starts to move toward the cylinder head once again.

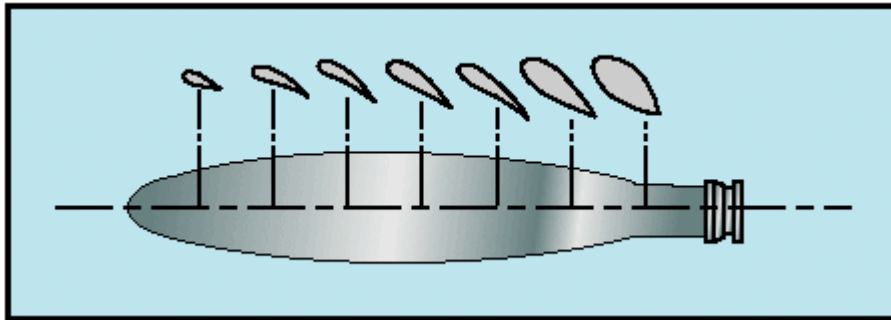
Even when the engine is operated at a fairly low speed, the four-stroke cycle takes place several hundred times each minute. In a four-cylinder engine, each cylinder operates on a different stroke. Continuous rotation of a crankshaft is maintained by the precise timing of the power strokes in each cylinder. Continuous operation of the engine depends on the simultaneous function of auxiliary systems, including the induction, ignition, fuel, oil, cooling, and exhaust systems.

## Propeller

The propeller is a rotating airfoil, subject to induced drag, stalls, and other aerodynamic principles that apply to any airfoil. It provides the necessary thrust to pull, or in some cases push, the airplane through the air.

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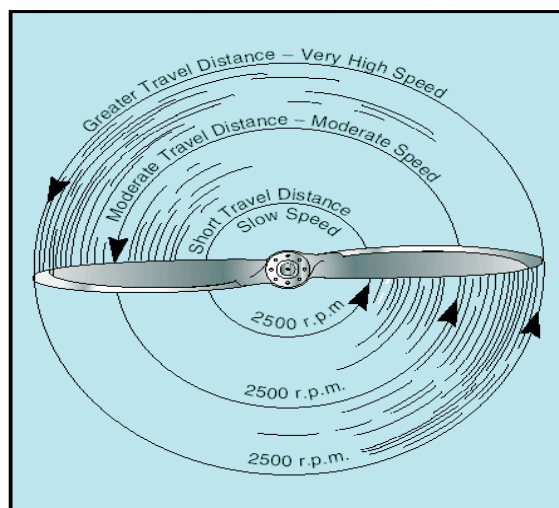
The engine power is used to rotate the propeller, which in turn generates thrust very similar to the manner in which a wing produces lift. The amount of thrust produced depends on the shape of the airfoil, the angle of attack of the propeller blade, and the r.p.m. of the engine. The propeller itself is twisted so the blade angle changes from hub to tip. The greatest angle of incidence, or the highest pitch, is at the hub while the smallest pitch is at the tip.



*Changes in propeller blade angle from hub to tip.*

The reason for the twist is to produce uniform lift from the hub to the tip. As the blade rotates, there is a difference in the actual speed of the various portions of the blade. The tip of the blade travels faster than that part near the hub, because the tip travels a greater distance than the hub in the same length of time.

Changing the angle of incidence (pitch) from the hub to the tip to correspond with the speed produces uniform lift throughout the length of the blade. If the propeller blade was designed with the same angle of incidence throughout its entire length, it would be inefficient, because as airspeed increases in flight, the portion near the hub would have a negative angle of attack while the blade tip would be stalled.



*Relationship of travel distance and speed of various portions of propeller blade.*

Small airplanes are equipped with either one of two types of propellers. One is the fixed-pitch, and the other is the controllable-pitch.



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## **Aviation Weather - Principles**

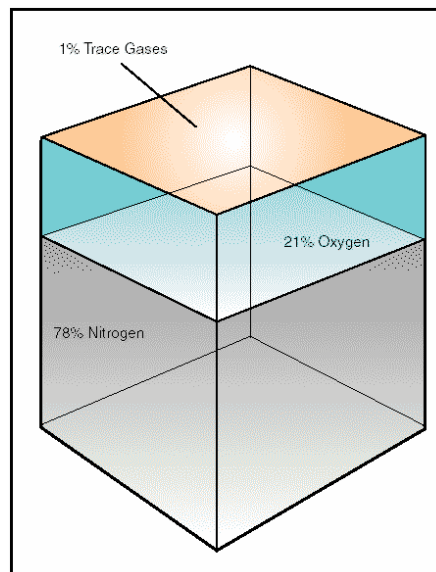
Whether preparing for a local flight or a long cross-country, flight-planning decisions based on aviation weather can dramatically affect the safety of the flight.

A solid understanding of aviation weather theory provides the tools necessary to understand the reports and forecasts obtained from a Flight Service Station aviation weather specialist and other aviation weather services.

The following pages are designed to help pilots acquire the background knowledge of aviation weather principles necessary to develop sound decision making skills relating to weather. It is important to note, however, that there is no substitute for experience.

### **Nature of the atmosphere**

The atmosphere is a mixture of gases that surround the Earth. This blanket of gases provides protection from ultraviolet rays as well as supporting human, animal, and plant life on the planet. Nitrogen accounts for 78 percent of the gases that comprise the atmosphere, while oxygen makes up 21 percent. Argon, carbon dioxide, and traces of other gases make up the remaining 1 percent.

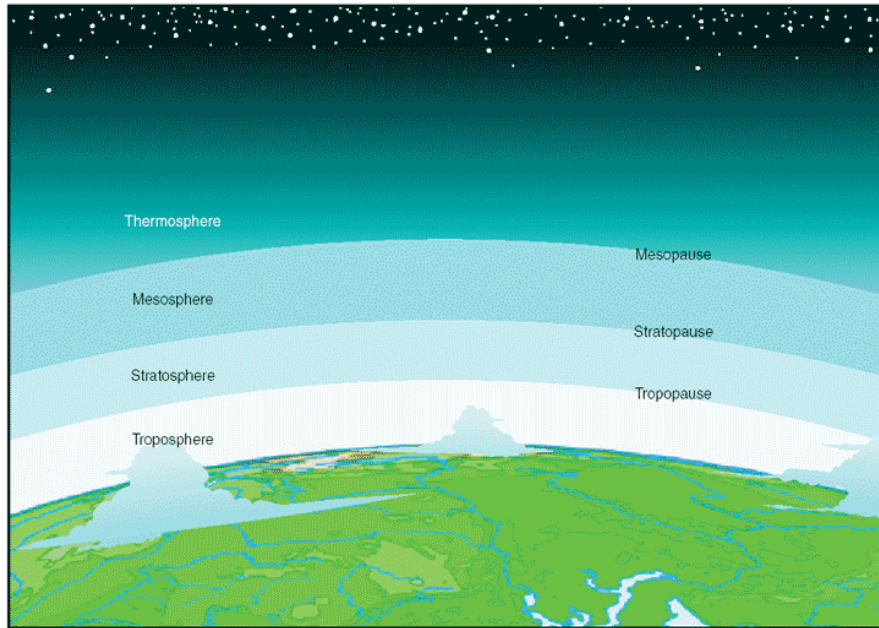


*Composition of the atmosphere.*

Within this envelope of gases, there are several recognizable layers of the atmosphere that are defined not only by altitude, but also by the specific characteristics of that level.



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*Layers of the atmosphere.*

The first layer, known as the troposphere, extends from sea level up to 20,000 feet (6 km) over the northern and southern poles and up to 48,000 feet (14.5 km) over the equatorial regions. The vast majority of weather, clouds, storms, and temperature variances occur within this first layer of the atmosphere. Inside the troposphere, the temperature decreases at a rate of about 2°Celsius every 1,000 feet of altitude gain, and the pressure decreases at a rate of about 1 inch per 1,000 feet of altitude gain. At the top of the troposphere is a boundary known as the tropopause, which traps moisture, and the associated weather, in the troposphere. The altitude of the tropopause varies with latitude and with the season of the year; therefore, it takes on an elliptical shape, as opposed to round.

Location of the tropopause is important because it is commonly associated with the location of the jetstream and possible clear air turbulence.

The atmospheric level above the tropopause is the stratosphere, which extends from the tropopause to a height of about 160,000 feet (50 km). Little weather exists in this layer and the air remains stable. At the top of the stratosphere is another boundary known as the stratopause, which exists at approximately 160,000 feet. Directly above this is the mesosphere, which extends to the mesopause boundary at about 280,000 feet (85 km). The temperature in the mesosphere decreases rapidly with an increase in altitude and can be as cold as -90°C. The last layer of the atmosphere is the thermosphere. It starts above the mesosphere and gradually fades into outer space.

### Oxygen and the human body

As discussed earlier, nitrogen and other trace gases make up 79 percent of the atmosphere, while the remaining 21 percent is life sustaining, atmospheric oxygen. At sea level, atmospheric pressure is great enough to support normal growth, activity, and life. At 18,000 feet, however, the partial pressure of oxygen is significantly reduced to the point that it adversely affects the normal activities and functioning of the human body. In fact, the reactions of the average person



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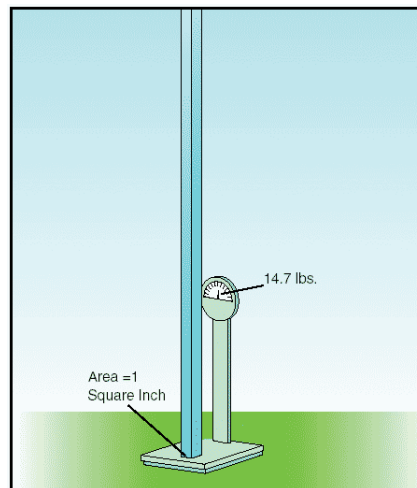
begin to be impaired at an altitude of about 10,000 feet and for some people as low as 5,000 feet.

The physiological reactions to oxygen deprivation are insidious and affect people in different ways. These symptoms range from mild disorientation to total incapacitation, depending on body tolerance and altitude.

By using supplemental oxygen or cabin pressurization systems, pilots can fly at higher altitudes and overcome the ill effects of oxygen deprivation.

### Significance of atmospheric pressure

At sea level, the atmosphere exerts pressure on the Earth at a force of 14.7 pounds per square inch. This means a column of air 1-inch square, extending from the surface up to the upper atmospheric limit, weighs about 14.7 pounds.



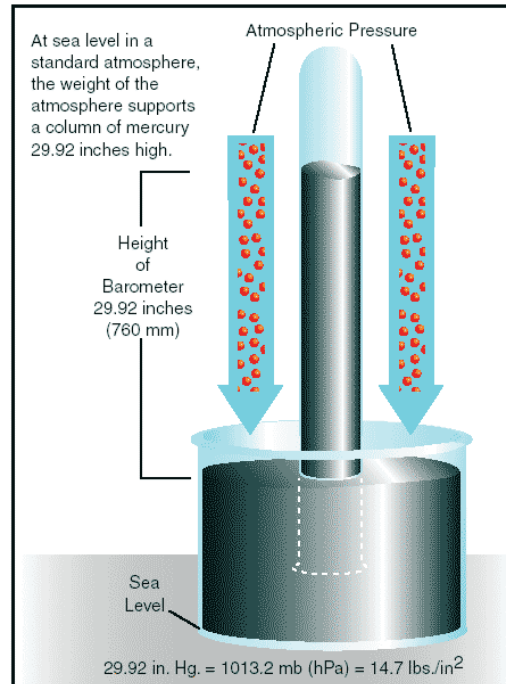
*One square inch of atmosphere weighs approximately 14.7 pounds.*

A person standing at sea level also experiences the pressure of the atmosphere; however, the pressure is not a downward force, but rather a force of pressure over the entire surface of the skin.

The actual pressure at a given place and time will differ with altitude, temperature, and density of the air. These conditions also affect aircraft performance, especially with regard to takeoff, rate of climb, and landings.

### Measurement of atmospheric pressure

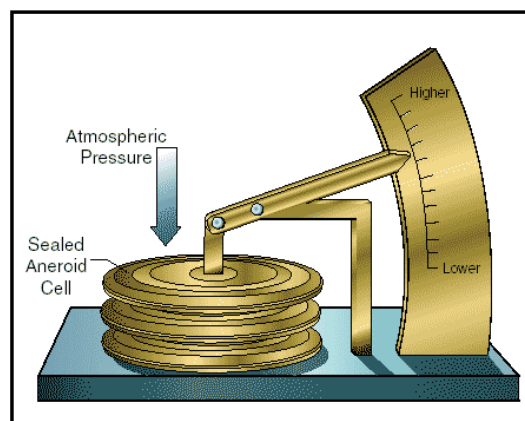
Atmospheric pressure is typically measured in inches of mercury (in. Hg.) by a mercurial barometer.



*Figure 4: Mercurial barometer.*

The barometer measures the height of a column of mercury inside a glass tube. A section of the mercury is exposed to the pressure of the atmosphere, which exerts a force on the mercury. An increase in pressure forces the mercury to rise inside the tube; as pressure drops, mercury drains out of the tube, decreasing the height of the column. This type of barometer is typically used in a lab or weather observation station, is not easily transported, and is a bit difficult to read.

An aneroid barometer is an alternative to a mercurial barometer; it is easier to read and transport.



*Aneroid barometer.*

The aneroid barometer contains a closed vessel, called an aneroid cell, that contracts or expands with changes in pressure. The aneroid cell attaches to a pressure indicator with a mechanical linkage to provide pressure readings. The pressure sensing part of an aircraft altimeter is essentially an aneroid barometer.

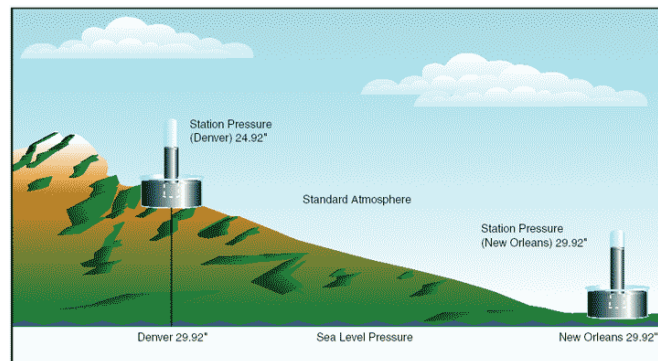


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It is important to note that due to the linkage mechanism of an aneroid barometer, it is not as accurate as a mercurial barometer.

To provide a common reference for temperature and pressure the International Standard Atmosphere (ISA) has been established. These standard conditions are the basis for certain flight instruments and most airplane performance data. Standard sea level pressure is defined as 29.92 in. Hg. at 59°F (15°C). Atmospheric pressure is also reported in millibars, with 1 inch of mercury equaling approximately 34 millibars and standard sea level equaling 1013.2 millibars. Typical millibar pressure readings range from 950.0 to 1040.0 millibars. Constant pressure charts and hurricane pressure reports are written using millibars.

Since weather stations are located around the globe, all local barometric pressure readings are converted to a sea level pressure to provide a standard for records and reports. To achieve this, each station converts its barometric pressure by adding approximately 1 inch of mercury for every 1,000 feet of elevation gain. For example, a station at 5,000 feet above sea level, with a reading of 24.92 inches of mercury, reports a sea level pressure reading of 29.92 inches.



*Station pressure is converted to, and reported in, sea level pressure.*

Using common sea level pressure readings helps ensure aircraft altimeters are set correctly, based on the current pressure readings.

By tracking barometric pressure trends across a large area, weather forecasters can more accurately predict movement of pressure systems and the associated aviation weather. For example, tracking a pattern of rising pressure at a single weather station generally indicates the approach of fair weather. Conversely, decreasing or rapidly falling pressure usually indicates approaching bad weather and possibly, severe storms.

#### Effect of altitude on atmospheric pressure

As altitude increases, pressure diminishes, as the weight of the air column decreases. On average, with every 1,000 feet of altitude increase, the atmospheric pressure decreases 1 inch of mercury. This decrease in pressure (increase in density altitude) has a pronounced effect on aircraft performance.

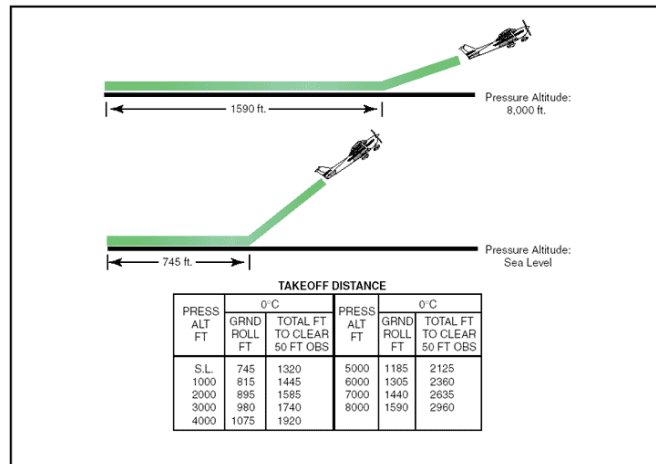
#### Effect of altitude on flight



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Altitude affects every aspect of flight from aircraft performance to human performance. At higher altitudes, with a decreased atmospheric pressure, takeoff and landing distances are increased, as are climb rates.

When an aircraft takes off, lift must be developed by the flow of air around the wings. If the air is thin, more speed is required to obtain enough lift for takeoff; therefore, the ground run is longer. An aircraft that requires a 1,000-foot ground run at sea level will require almost double that at an airport 5,000 feet above sea level.



*Takeoff distance increases with increased altitude.*

It is also true that at higher altitudes, due to the decreased density of the air, aircraft engines and propellers are less efficient. This leads to reduced rates of climb and a greater ground run for obstacle clearance.

Effect of differences in air density

Differences in air density caused by changes in temperature result in changes in pressure. This, in turn, creates motion in the atmosphere, both vertically and horizontally, in the form of currents and wind. Motion in the atmosphere, combined with moisture, produces clouds and precipitation otherwise known as weather.

Wind

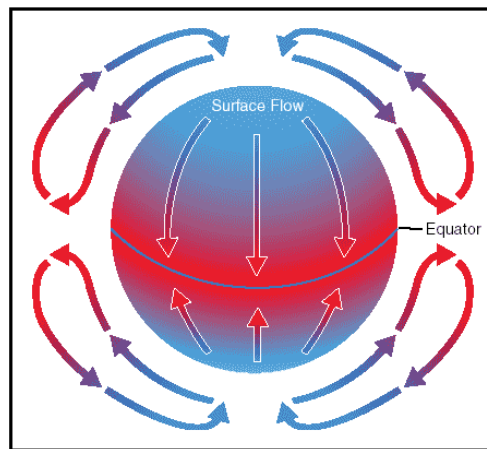
Pressure and temperature changes produce two kinds of motion in the atmosphere—vertical movement of ascending and descending currents, and horizontal movement in the form of wind. Both types of motion in the atmosphere are important as they affect the takeoff, landing, and cruise flight operations. More important, however, is that these motions in the atmosphere, otherwise called atmospheric circulation, cause weather changes.

**The cause of atmospheric circulation**

Atmospheric circulation is the movement of air around the surface of the Earth. It is caused by uneven heating of the Earth’s surface and upsets the equilibrium of the atmosphere, creating changes in air movement and atmospheric pressure. Because the Earth has a curved surface that rotates on a tilted axis while orbiting

the sun, the equatorial regions of the Earth receive a greater amount of heat from the sun than the polar regions. The amount of sun that heats the Earth depends upon the time of day, time of year, and the latitude of the specific region. All of these factors affect the length of time and the angle at which sunlight strikes the surface.

In general circulation theory, areas of low pressure exist over the equatorial regions, and areas of high pressure exist over the polar regions due to a difference in temperature. Solar heating causes air to become less dense and rise in equatorial areas. The resulting low pressure allows the high-pressure air at the poles to flow along the planet's surface toward the equator. As the warm air flows toward the poles, it cools, becoming more dense, and sinks back toward the surface.



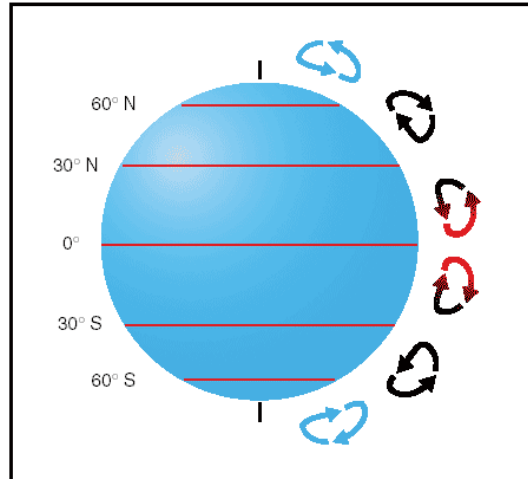
*Circulation pattern in a static environment.*

This pattern of air circulation is correct in theory; however, the circulation of air is modified by several forces, most importantly the rotation of the Earth.

The force created by the rotation of the Earth is known as Coriolis force. This force is not perceptible to us as we walk around because we move so slowly and travel relatively short distances compared to the size and rotation rate of the Earth. However, it does significantly affect bodies that move over great distances, such as an air mass or body of water. The Coriolis force deflects air to the right in the Northern Hemisphere, causing it to follow a curved path instead of a straight line. The amount of deflection differs depending on the latitude.

It is greatest at the poles, and diminishes to zero at the equator. The magnitude of Coriolis force also differs with the speed of the moving body—the faster the speed, the greater the deviation. In the Northern Hemisphere, the rotation of the Earth deflects moving air to the right and changes the general circulation pattern of the air.

The speed of the Earth's rotation causes the general flow to break up into three distinct cells in each hemisphere.



*Three-cell circulation pattern due to the rotation of the Earth.*

In the Northern Hemisphere, the warm air at the equator rises upward from the surface, travels northward, and is deflected eastward by the rotation of the Earth. By the time it has traveled one-third of the distance from the equator to the North Pole, it is no longer moving northward, but eastward.

This air cools and sinks in a belt-like area at about 30° latitude, creating an area of high pressure as it sinks toward the surface. Then it flows southward along the surface back toward the equator. Coriolis force bends the flow to the right, thus creating the northeasterly trade winds that prevail from 30° latitude to the equator. Similar forces create circulation cells that encircle the Earth between 30° and 60° latitude, and between 60° and the poles. This circulation pattern results in the prevailing westerly winds in the conterminous United States.

Circulation patterns are further complicated by seasonal changes, differences between the surfaces of continents and oceans, and other factors.

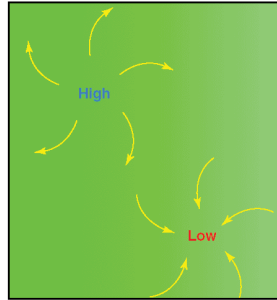
Frictional forces caused by the topography of the Earth's surface modify the movement of the air in the atmosphere. Within 2,000 feet of the ground, the friction between the surface and the atmosphere slows the moving air. The wind is diverted from its path because the frictional force reduces the Coriolis force.

This is why the wind direction at the surface varies somewhat from the wind direction just a few thousand feet above the Earth.

### Wind patterns

Air flows from areas of high pressure into those of low pressure because air always seeks out lower pressure.

In the Northern Hemisphere, this flow of air from areas of high to low pressure is deflected to the right; producing a clockwise circulation around an area of high pressure. This is also known as anti-cyclonic circulation. The opposite is true of low-pressure areas; the air flows toward a low and is deflected to create a counter-clockwise or cyclonic circulation.



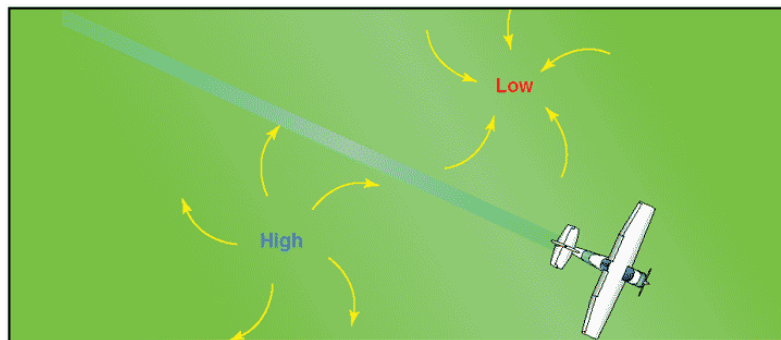
*Circulation pattern about areas of high and low pressure.*

High-pressure systems are generally areas of dry, stable, descending air. Good aviation weather is typically associated with high-pressure systems for this reason.

Conversely, air flows into a low-pressure area to replace rising air. This air tends to be unstable, and usually brings increasing cloudiness and precipitation.

Thus, bad aviation weather is commonly associated with areas of low pressure.

A good understanding of high- and low-pressure wind patterns can be of great help when planning a flight, because a pilot can take advantage of beneficial tailwinds.



*Favorable winds near a high-pressure system.*

When planning a flight from west to east, favorable winds would be encountered along the northern side of a high-pressure system or the southern side of a low-pressure system. On the return flight, the most favorable winds would be along the southern side of the same high-pressure system or the northern side of a low-pressure system. An added advantage is a better understanding of what type of aviation weather to expect in a given area along a route of flight based on the prevailing areas of highs and lows.

The theory of circulation and wind patterns is accurate for large-scale atmospheric circulation; however, it does not take into account changes to the circulation on a local scale. Local conditions, geological features, and other anomalies can change the wind direction and speed close to the Earth's surface.



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## **Human Factor**

It is important to point out the fact that being familiar with the decision-making process does not ensure the good judgment to be a safe pilot. The ability to make effective decisions as pilot in command depends on a number of factors. Some circumstances, such as the time available to make a decision may be beyond a pilot's control. However, one can learn to recognize those factors that can be managed, and learn skills to improve decision-making ability and judgment.

### Pilot self-assessment

The pilot in command of an airplane is directly responsible for, and is the final authority as to, the operation of that airplane. To effectively exercise that responsibility and make effective decisions regarding the outcome of a flight, a pilot should be aware of personal limitations. Performance during a flight is affected by many factors, such as health, recency of experience, knowledge, skill level, and attitude.

Exercising good judgment begins prior to taking the controls of an airplane. Often, pilots thoroughly check their airplane to determine airworthiness, yet do not evaluate their own fitness for flight. Just as a checklist is used when preflighting an airplane, a personal checklist based on such factors as experience, currency, and comfort level can help determine if a pilot is prepared for a particular flight. Specifying when refresher training should be accomplished and designating weather minimums that may be higher than those listed in Title 14 of the Code of Federal Regulations (14 CFR) part 91 are elements that may be included on a personal checklist.

In addition to a review of personal limitations, use the I'M SAFE Checklist to further evaluate fitness for flight.



**I'M SAFE CHECKLIST**

**I**llness—Do I have any symptoms?

**M**edication—Have I been taking prescription or over-the-counter drugs?

**S**tress—Am I under psychological pressure from the job? Worried about financial matters, health problems, or family discord?

**A**lcohol—Have I been drinking within 8 hours?  
Within 24 hours?

**F**atigue—Am I tired and not adequately rested?

**E**ating—Am I adequately nourished?

*Prior to flight, pilot fitness should be assessed the same as the airplane's airworthiness is evaluated.*



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### Recognizing hazardous attitudes

Being fit to fly depends on more than just a pilot's physical condition and recency of experience. For example, attitude will affect the quality of decisions.

Attitude can be defined as a personal motivational predisposition to respond to persons, situations, or events in a given manner. Studies have identified five hazardous attitudes that can interfere with the ability to make sound decisions and exercise authority properly.

THE FIVE HAZARDOUS ATTITUDES	
<b>1. Anti-Authority:</b> "Don't tell me."	This attitude is found in people who do not like anyone telling them what to do. In a sense, they are saying, "No one can tell me what to do." They may be resentful of having someone tell them what to do, or may regard rules, regulations, and procedures as silly or unnecessary. However, it is always your prerogative to question authority if you feel it is in error.
<b>2. Impulsivity:</b> "Do it quickly."	This is the attitude of people who frequently feel the need to do something, anything, immediately. They do not stop to think about what they are about to do; they do not select the best alternative, and they do the first thing that comes to mind.
<b>3. Invulnerability:</b> "It won't happen to me."	Many people feel that accidents happen to others, but never to them. They know accidents can happen, and they know that anyone can be affected. They never really feel or believe that they will be personally involved. Pilots who think this way are more likely to take chances and increase risk.
<b>4. Macho:</b> "I can do it."	Pilots who are always trying to prove that they are better than anyone else are thinking, "I can do it –I'll show them." Pilots with this type of attitude will try to prove themselves by taking risks in order to impress others. While this pattern is thought to be a male characteristic, women are equally susceptible.
<b>5. Resignation:</b> "What's the use?"	Pilots who think, "What's the use?" do not see themselves as being able to make a great deal of difference in what happens to them. When things go well, the pilot is apt to think that it is good luck. When things go badly, the pilot may feel that someone is out to get me, or attribute it to bad luck. The pilot will leave the action to others, for better or worse. Sometimes, such pilots will even go along with unreasonable requests just to be a "nice guy."

*The pilot should examine decisions carefully to ensure that the choices have not been influenced by a hazardous attitude.*

Hazardous attitudes can lead to poor decision making and actions that involve unnecessary risk. The pilot must examine decisions carefully to ensure that the choices have not been influenced by hazardous attitudes and be familiar with positive alternatives to counteract the hazardous attitudes. These substitute attitudes are referred to as antidotes. During a flight operation, it is important to be able to recognize a hazardous attitude, correctly label the thought, and then recall its antidote.



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HAZARDOUS ATTITUDES	ANTIDOTES
<b>Anti-Authority</b> — Although he knows that flying so low to the ground is prohibited by the regulations, he feels that the regulations are too restrictive in some circumstances.	<b>Follow the rules. They are usually right.</b>
<b>Impulsivity</b> — As he is buzzing the park, the airplane does not climb as well as Steve had anticipated and without thinking, Steve pulls back hard on the yoke. The airspeed drops and the airplane is close to a stalling attitude as the wing brushes a power line.	<b>Not so fast. Think first.</b>
<b>Invulnerability</b> — Steve is not worried about an accident since he has flown this low many times before and he has not had any problems.	<b>It could happen to me.</b>
<b>Macho</b> — Steve often brags to his friends about his skills as a pilot and how close to the ground he flies. During a local pleasure flight in his single-engine airplane, he decides to buzz some friends barbecuing at a nearby park.	<b>Taking chances is foolish.</b>
<b>Resignation</b> — Although Steve manages to recover, the wing sustains minor damage. Steve thinks to himself, "It's dangerous for the power company to put those lines so close to a park. If somebody finds out about this I'm going to be in trouble, but it seems like no matter what I do, somebody's always going to criticize."	<b>I'm not helpless. I can make a difference.</b>

*The pilot must be able to identify hazardous attitudes and apply the appropriate antidote when needed.*

### Stress management

Everyone is stressed to some degree almost all the time. A certain amount of stress is good since it keeps a person alert and prevents complacency. However, effects of stress are cumulative and, if not coped with adequately, they eventually add up to an intolerable burden. Performance generally increases with the onset of stress, peaks, and then begins to fall off rapidly as stress levels exceed a person's ability to cope.

The ability to make effective decisions during flight can be impaired by stress. Factors, referred to as stressors, can increase a pilot's risk of error in the cockpit.

STRESSORS	
<p><b>Physical Stress</b>—Conditions associated with the environment, such as temperature and humidity extremes, noise, vibration, and lack of oxygen.</p> <p><b>Physiological Stress</b>—Physical conditions, such as fatigue, lack of physical fitness, sleep loss, missed meals (leading to low blood sugar levels), and illness.</p> <p><b>Psychological Stress</b>—Social or emotional factors, such as a death in the family, a divorce, a sick child, or a demotion at work. This type of stress may also be related to mental workload, such as analyzing a problem, navigating an aircraft, or making decisions.</p>	

*The three types of stressors that can affect a pilot's performance.*