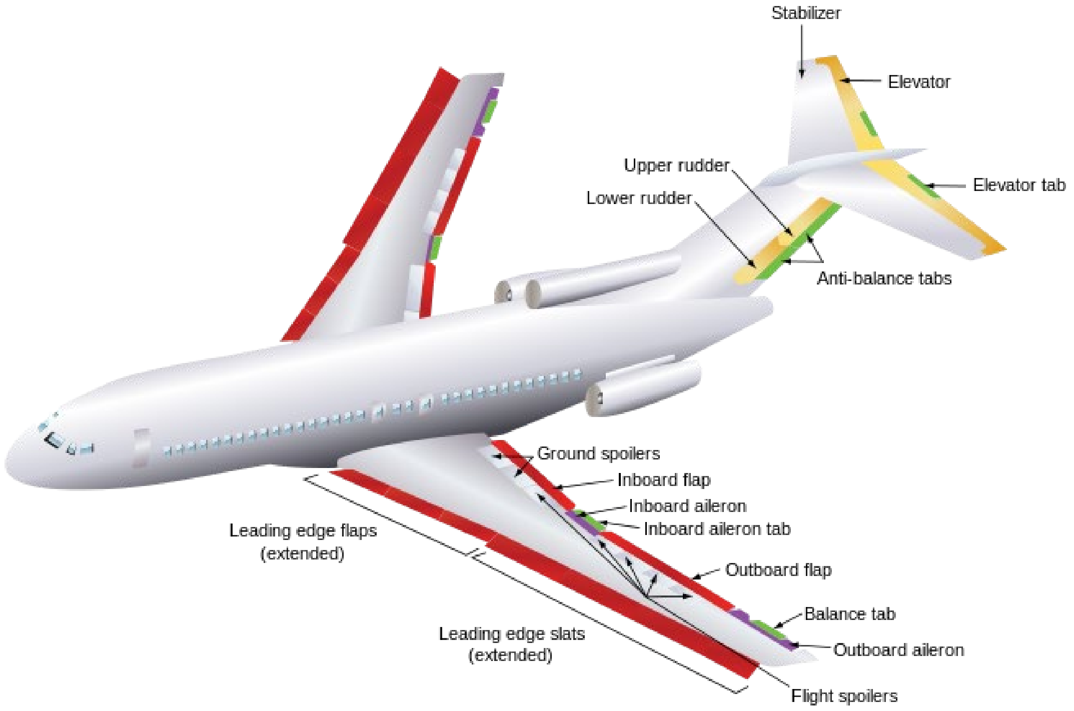
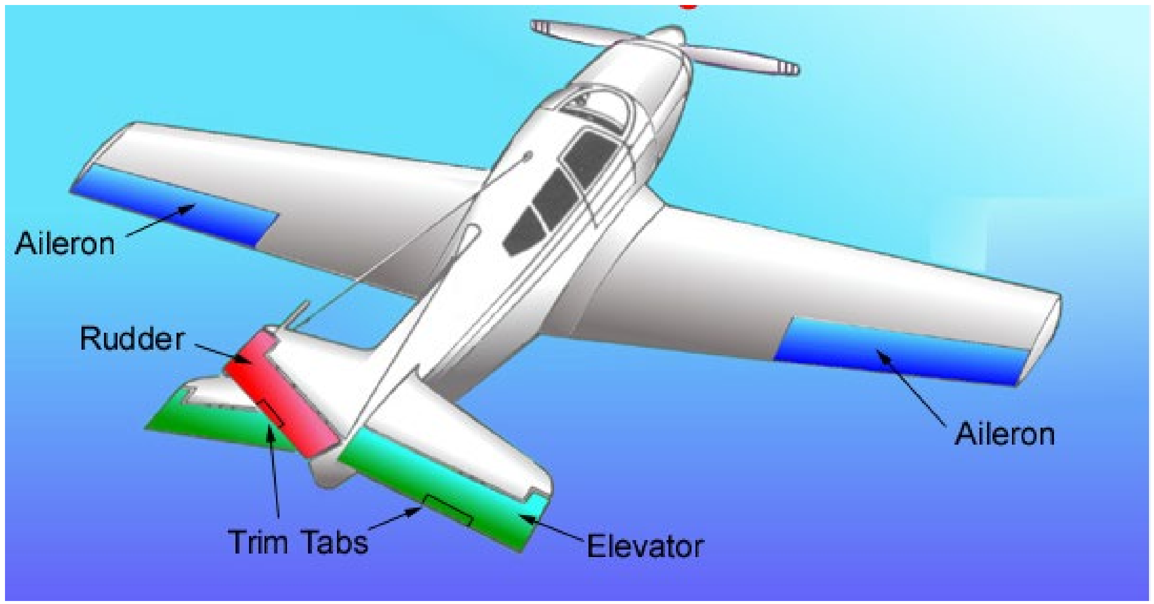
Airplane Flight Controls

Lesson Objective

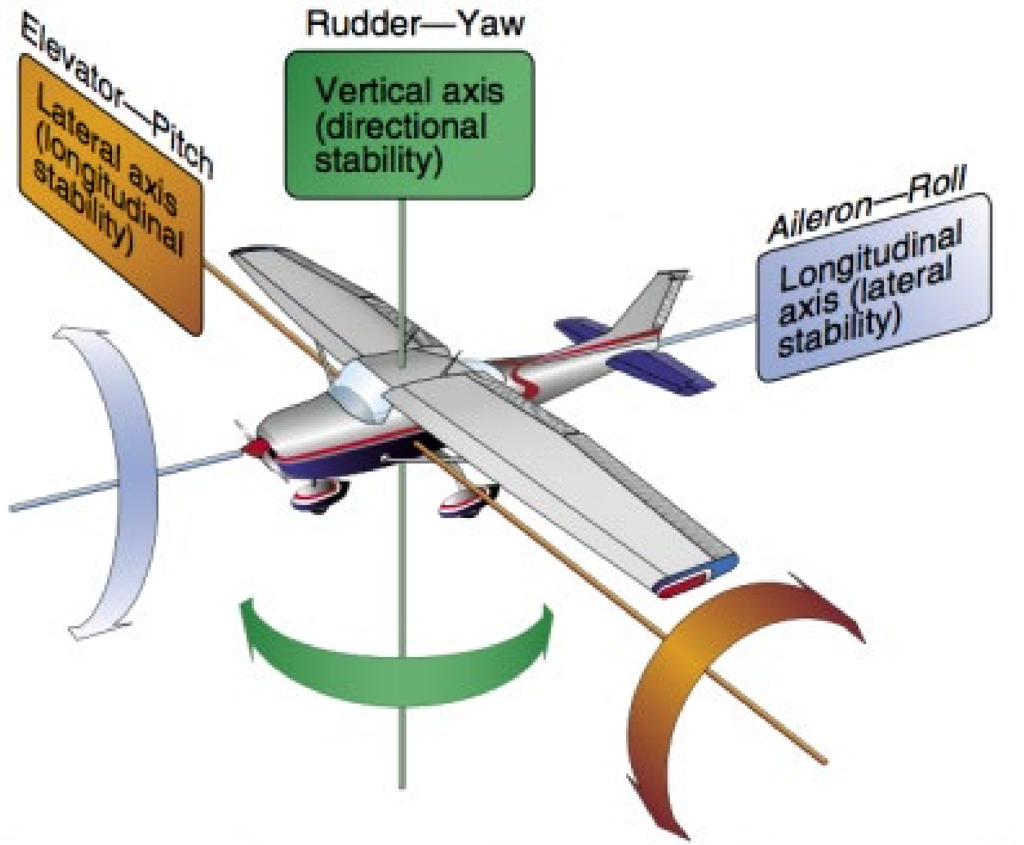
To develop understanding of how we can make the plane go in the direction we planned on

First Some Diagrams





And Another



Primary Control Surface	Airplane Movement	Axes of Rotation	Type of Stability
Aileron	Roll	Longitudinal	Lateral
Elevator/ Stabilator	Pitch	Lateral	Longitudinal
Rudder	Yaw	Vertical	Directional

Effectiveness

Control surface effectiveness increases with speed; therefore, 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.

On the Ground

Throttle for speed

Taxi at ‘wake speed’

Yoke or stick => Nothing except to counter act the wind

Left rudder pedal => Plane moves left

Right rudder pedal => Plane moves right

In the Air

Move the stick right or the yoke clockwise => Plane rolls clockwise

Move the stick left or the yoke counterclockwise => Plane rolls counterclockwise

Move the stick or yoke forward => Plane pitches down

Nose down => Airspeed needle down

Move the stick or yoke toward you => Plane pitches up

Left rudder pedal => Plane's nose moves left

Right rudder pedal => Plane's nose moves right

Pitch for Airspeed

Plane pitches down => Goes faster

Plane pitches up => Goes slower

Think about driving on level road then up or down a hill

…without changing the gas pedal

In the plane you ‘control the hill’

If the airspeed is 90 knots and we desire 75 knots what do you do?

If the airspeed is 60 knots and we desire 75 knots what do you do?

The Recipe for Turns

When flying, you must **combine** the ailerons and rudder pedals to have a coordinated turn.

Roll right + right yaw => Plane banks to the right

Roll left + left yaw => Plane banks to the left

Slip

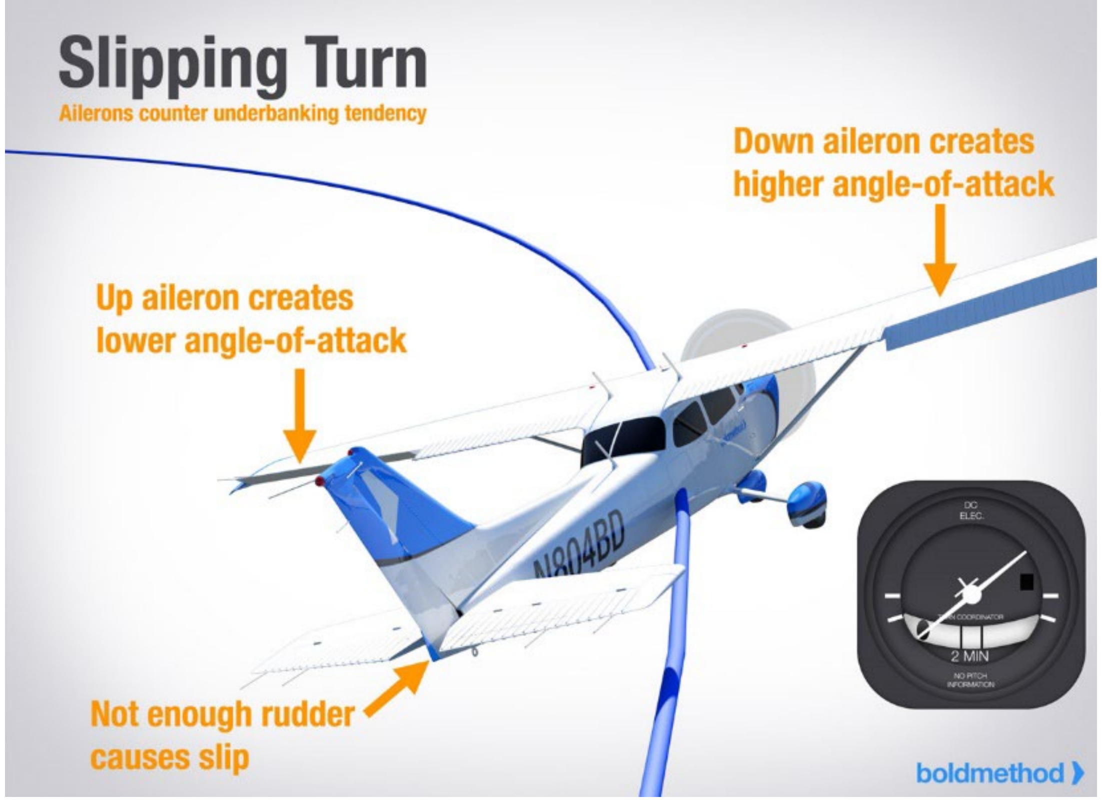
A slip does not have enough rudder, or more likely rudder opposite to the direction of the bank.

A slip is a turn that is stopped by use of the rudder.

Not enough rudder

Centrifugal force < Horizontal lift

Imagine the ball is where the tail is



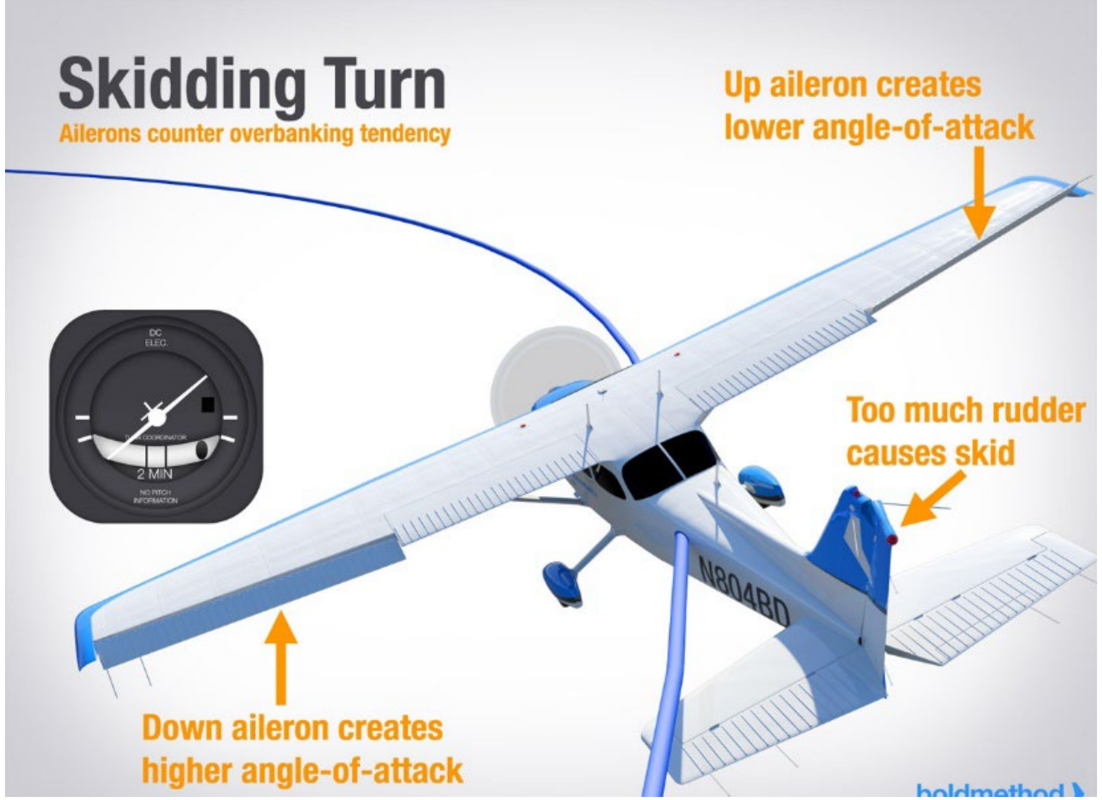
Skid

A skid has too much rudder used in the direction of bank.

Too much rudder

Centrifugal force > Horizontal lift

Imagine the ball is where the tail is



Flaps

Increase lift to assist in flying slower

Increase drag to help reduce airspeed

Increase decent angle without increasing the airspeed

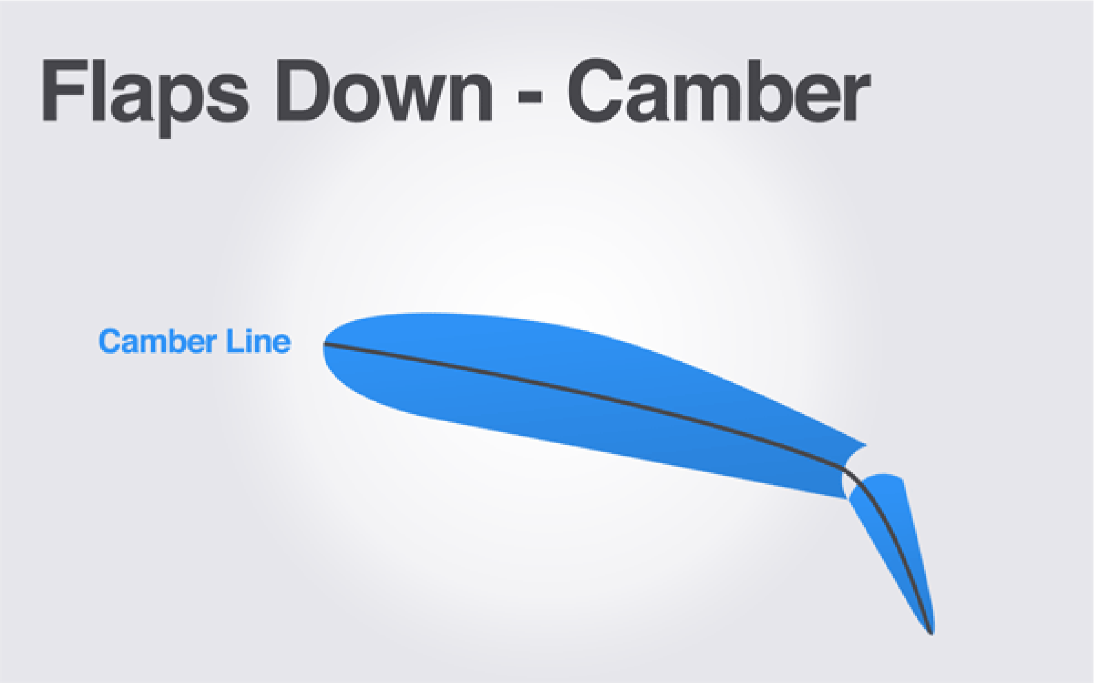
Flaps change:

Chord line

Angle of attack

Camber/Mean camber

Lift and Drag



Trim Systems

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

Trim systems are used to relieve the pilot of the need to maintain constant pressure on the flight controls, and usually consist of flight deck controls and small hinged devices attached to the trailing edge of one or more of the primary flight control surfaces.

Use of Trim

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

Trim systems are used to relieve the pilot of the need to maintain constant pressure on the flight controls, and usually consist of flight deck controls and small hinged devices attached to the trailing edge of one or more of the primary flight control surfaces.

Use of Trim

The normal trim procedure is to continue trimming until the aircraft is balanced and the nose-heavy condition is no longer apparent.

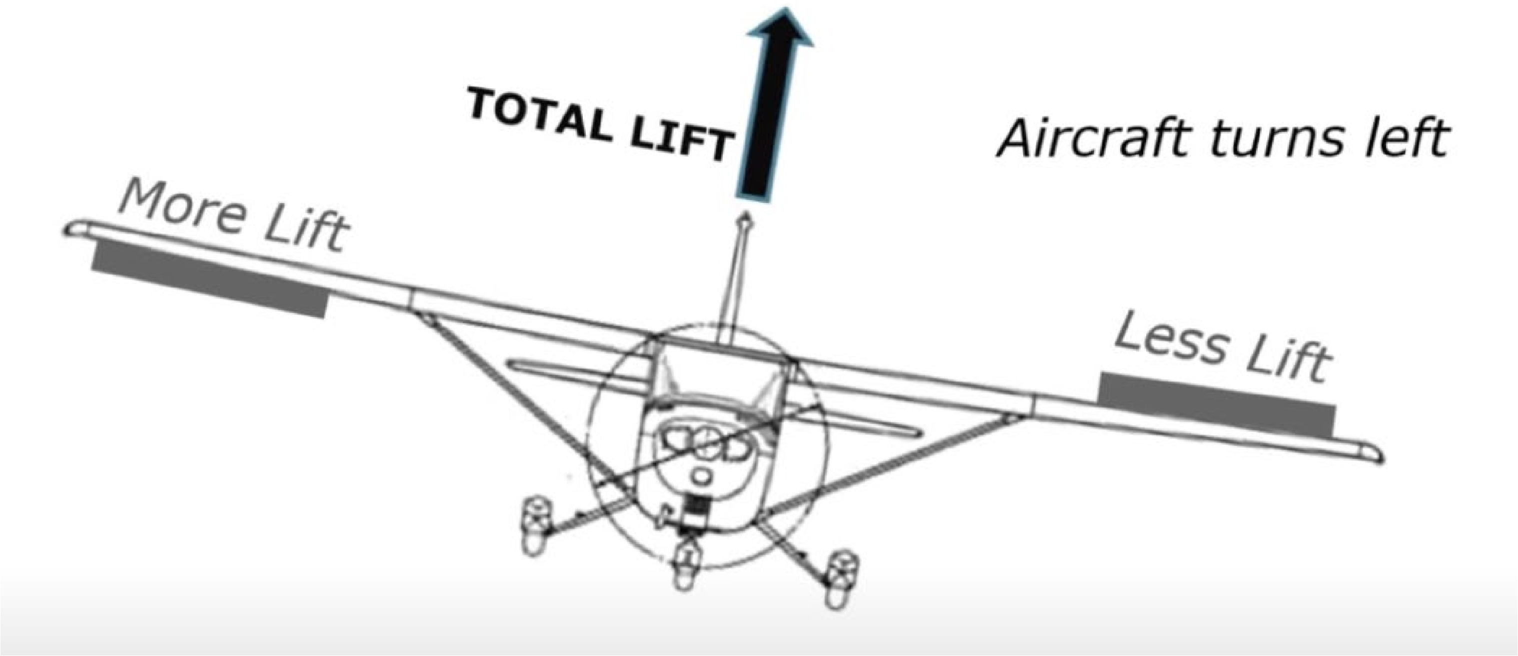
Pilots normally establish the desired power, pitch attitude, and configuration first, and then trim the aircraft to relieve control pressures that may exist for that flight condition.

Use of Trim

As power, pitch attitude, or configuration changes, retrimming is necessary to relieve the control pressures for the new flight condition.

Pitch Power Trim (Rudder)

Now the Deep Dive



Adverse Yaw Summary

Adverse yaw during a turn entry is caused by:

• decreased induced drag on the lowered wing

• increased induced drag on the raised wing

See separate lesson for more details

Rudder

Use the rudder to counteract adverse yaw, applying rudder input in the same direction as the turn to align the aircraft's nose with its flight path and maintain a coordinated turn; essentially, the rudder is the primary control used to combat the yawing effect created by aileron deflection during a turn.

Types of Flaps

<u>Fixed Slots</u>

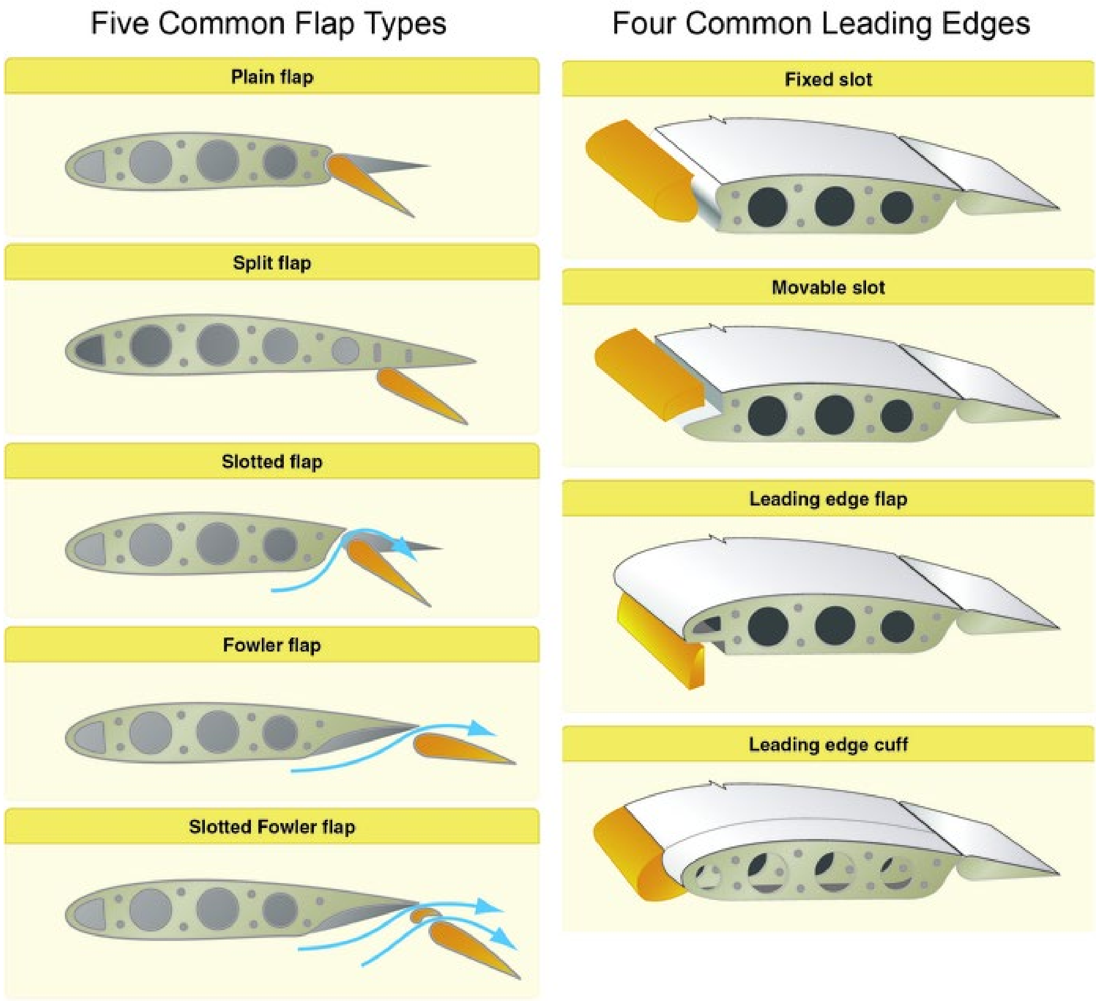
Direct airflow up

Delay airflow separation at high AOA

<u>Leading edge flaps/cuffs</u>

Maximize lift & camber

Lowers stall speeds



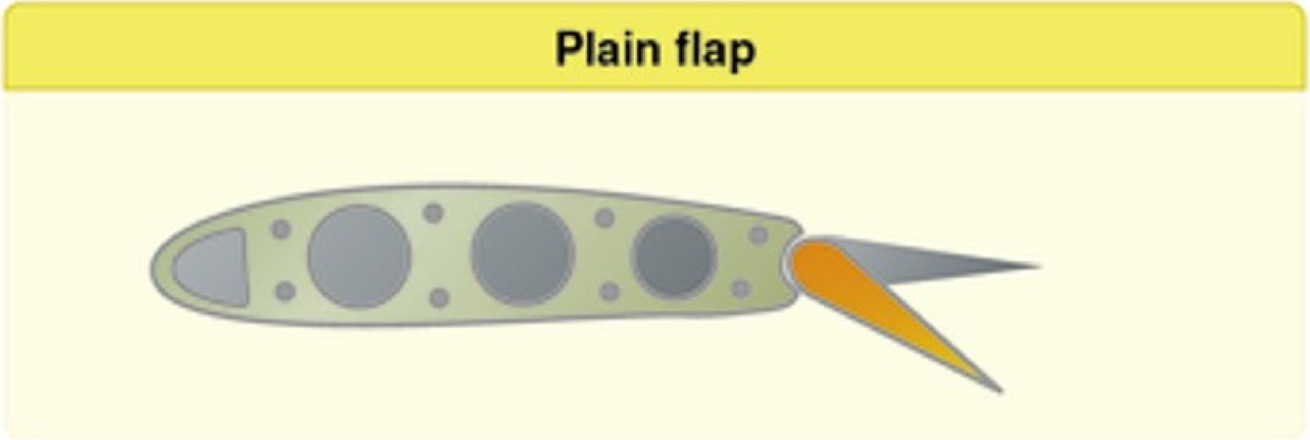
Plain Flap

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 (CL) at a given AOA.

At the same time, it greatly increases drag and moves the center of pressure (CP) aft on the airfoil, resulting in a nose-down pitching moment.

More lift, more drag.



Plain Flap

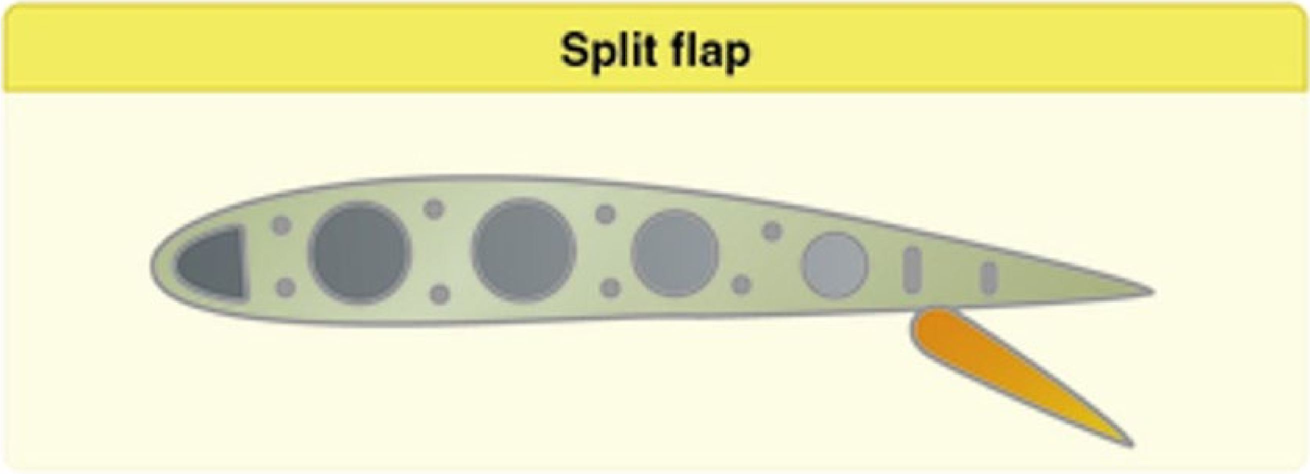
Split Flap

The split flap is deflected from the lower surface of the airfoil and produces a slightly greater increase in lift than the plain flap.

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 split flap produces the least change in the pitching moments of a wing when it is lowered.



Split Flap


Split flaps
Folds out below the wing; creates more drag than lift

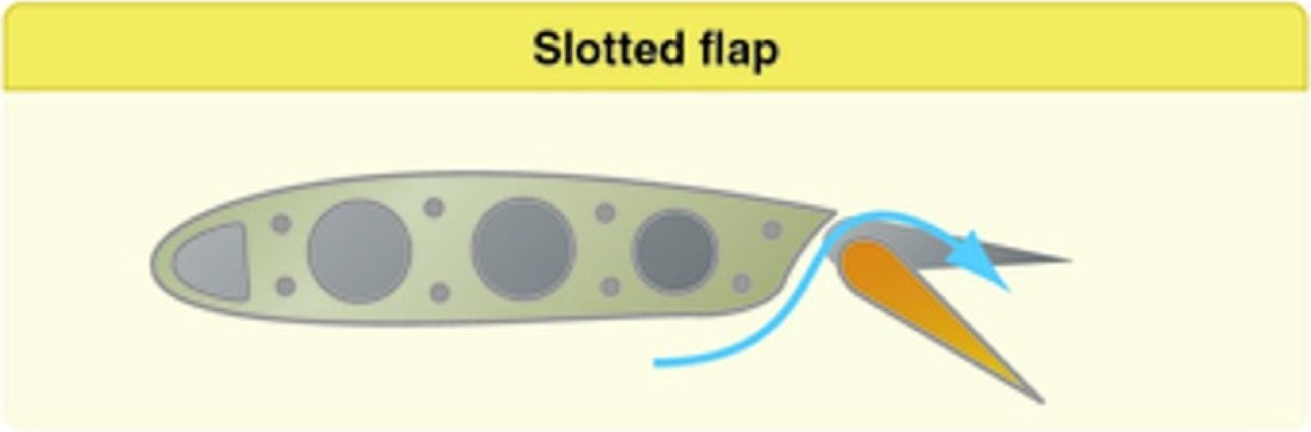
Slotted Flap

Variations of this design are used for small aircraft, as well as for large ones.

Slotted flaps increase the lift coefficient significantly more than plain or split flaps.

On small aircraft, the hinge is located below the lower surface of the flap, and when the flap is lowered, a duct forms 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.



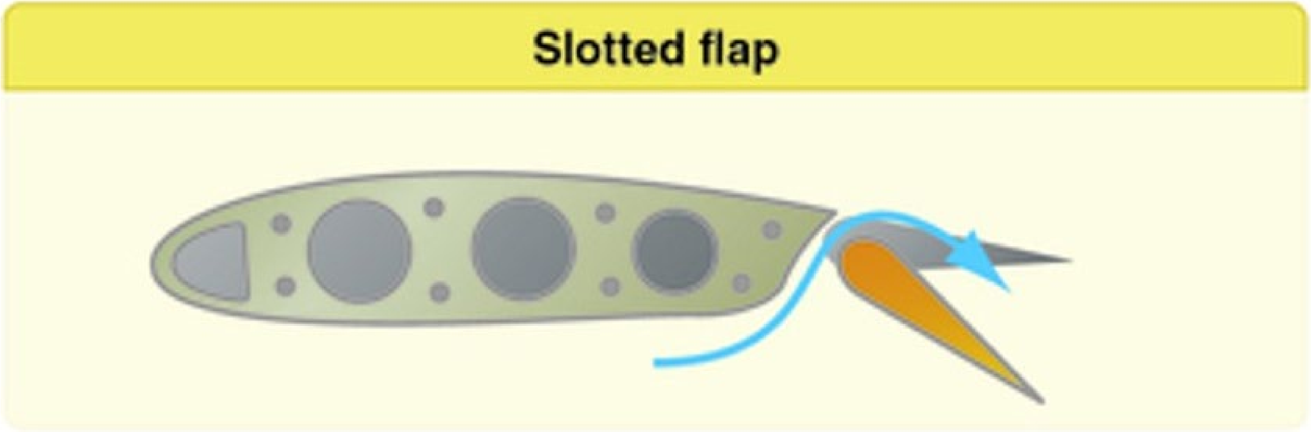
Slotted Flap

Thus, the slotted flap produces much greater increases in maximum coefficient of lift (CL-MAX) than the plain or split flap.

While there are many types of slotted flaps, large aircraft 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.

Cessna 172, 182 use these.



Slotted Flap

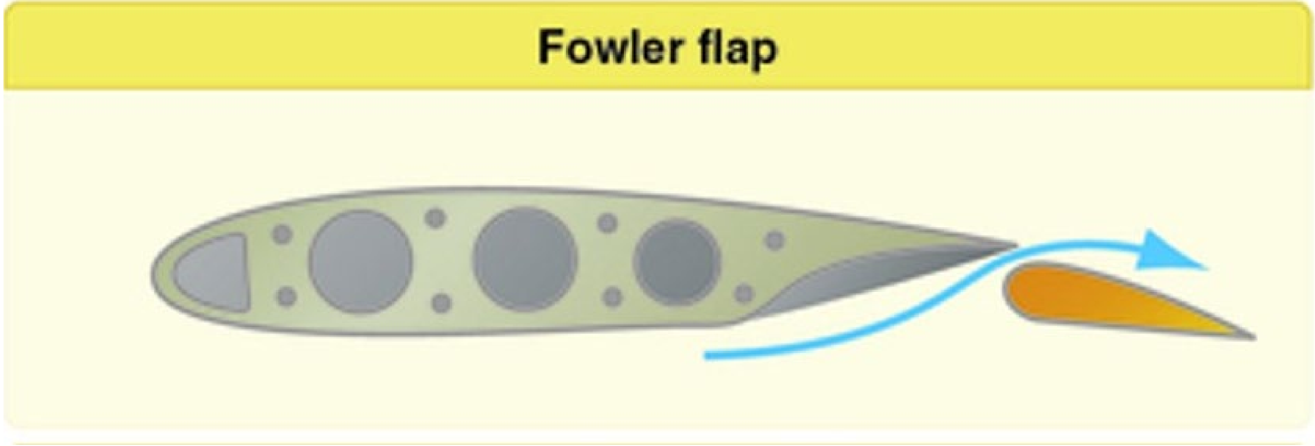
Fowler Flap

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.

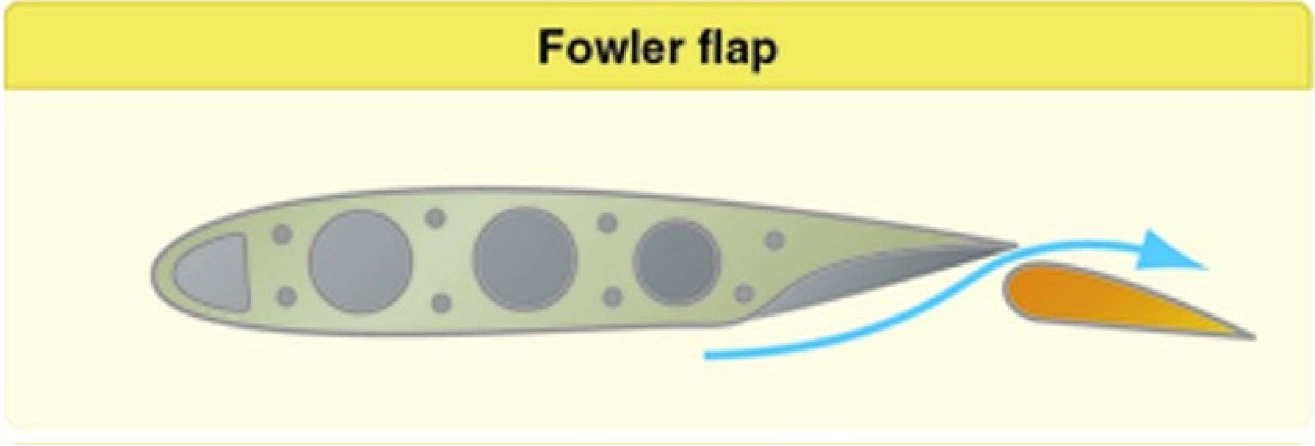


Fowler Flap

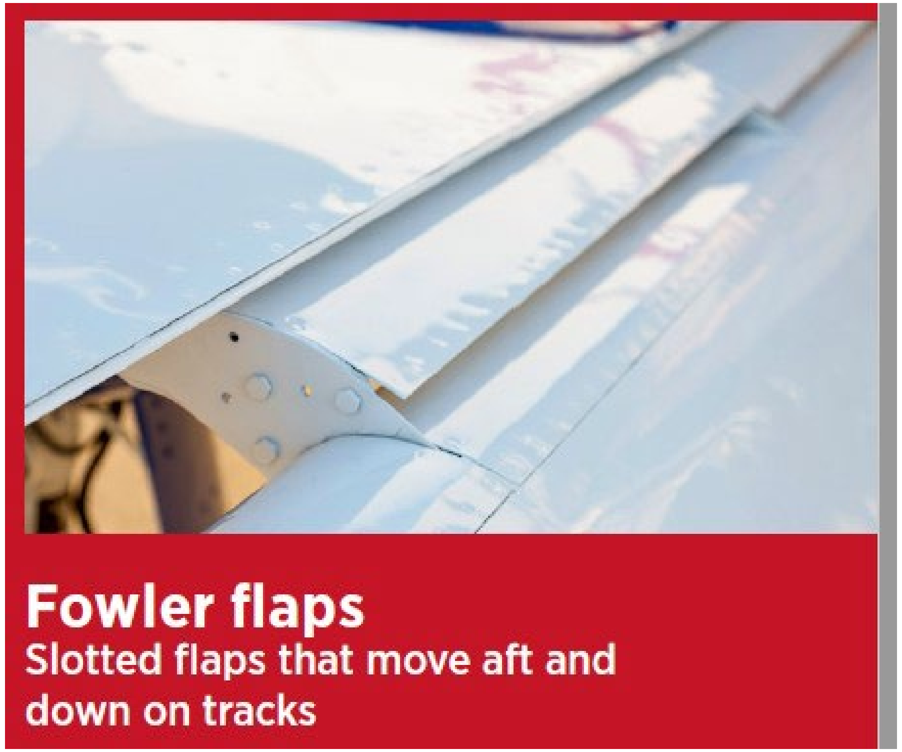
As the extension continues, the flap deflects downward.

During the last portion of its travel, the flap increases the drag with little additional increase in lift.

The Fowler flap also creates the greatest change in pitching moment.



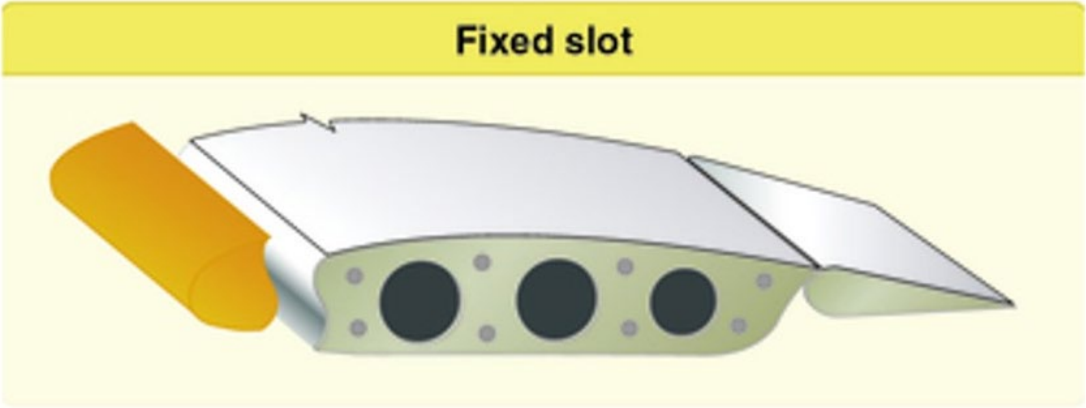
Fowler Flap



Fixed Slot

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 CL because the stall is delayed until the wing reaches a greater AOA.



Moveable Slot

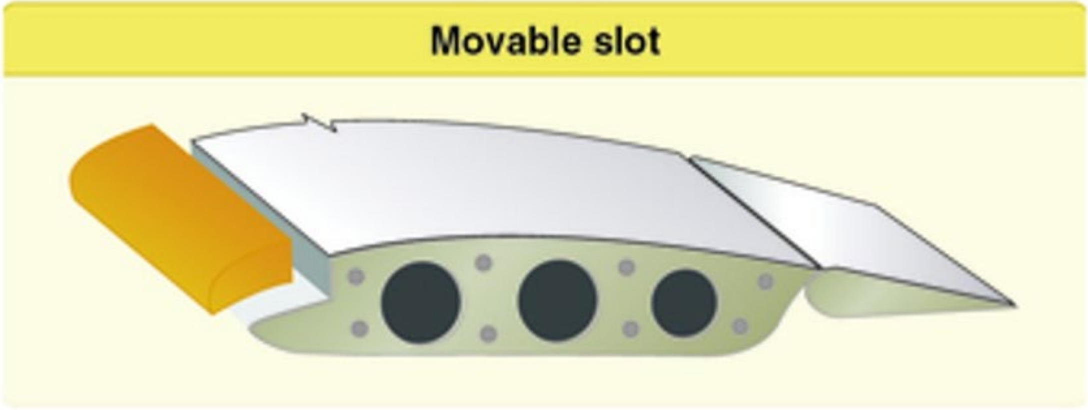
Movable slots consist of leading edge segments that move on tracks.

At low angles of attack, each slot is held flush against the wing's leading edge by the high pressure that forms at the wing's leading edge.

As the AOA increases, the high-pressure area moves aft below the lower surface of the wing, allowing the slots to move forward.

Some slots, however, are pilot operated and can be deployed at any AOA.

Opening a slot allows the air below the wing to flow over the wing's upper surface, delaying airflow separation.



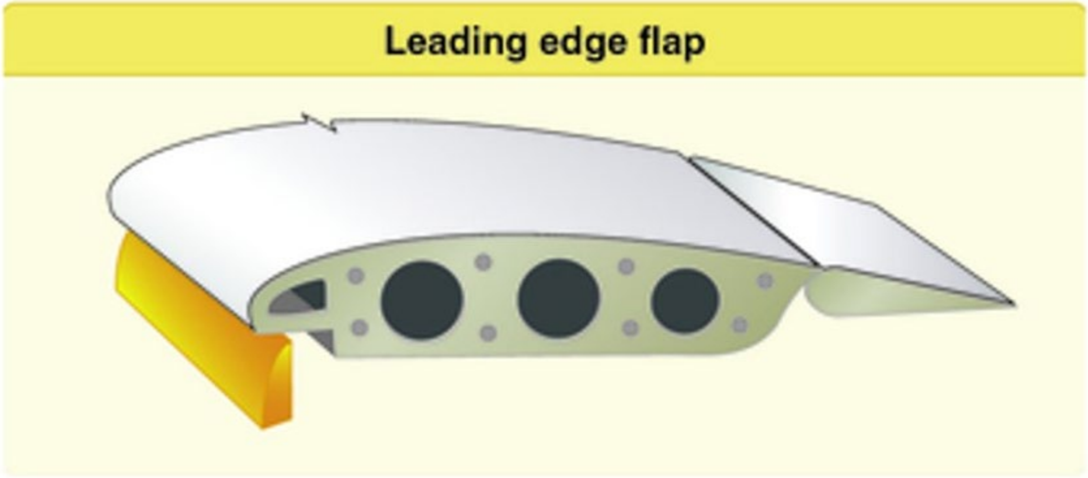
Leading Edge Flap

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 trailing edge flaps.

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

As flaps are extended, drag increases at a greater rate than lift.



Leading Edge Cuff

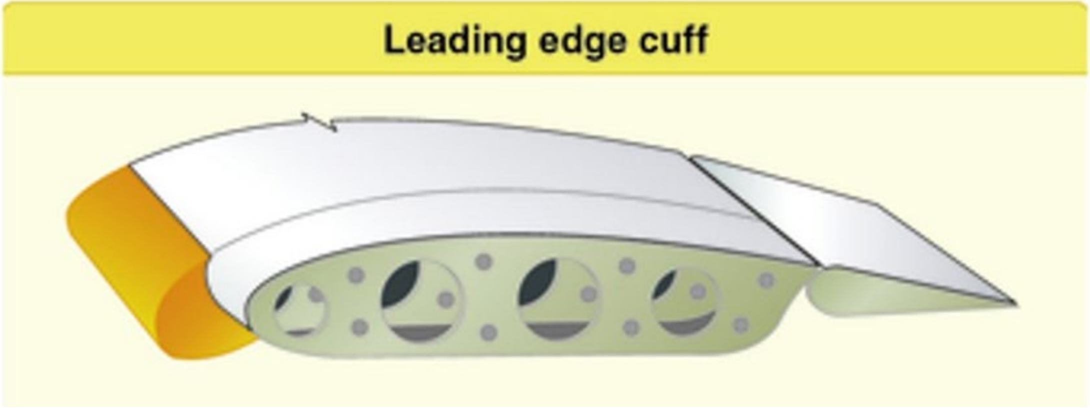
Leading edge cuffs, like leading edge flaps and trailing edge flaps are used to increase both CL-MAX and the camber of the wings.

Unlike leading edge flaps and trailing edge flaps, leading edge cuffs are fixed aerodynamic devices.

In most cases, leading edge cuffs extend the leading edge down and forward.

This causes the airflow to attach better to the upper surface of the wing at higher angles of attack, thus lowering an aircraft's stall speed.

The fixed nature of leading edge cuffs extracts a penalty in maximum cruise airspeed, but recent advances in design and technology have reduced this penalty.



Spoilers

High drag devices called spoilers are deployed from the wings to **spoil the smooth airflow, reducing lift and increasing drag**.

On gliders, spoilers are most often used to control rate of descent for accurate landings.

On other aircraft, spoilers are often used for roll control, an advantage of which is the elimination of adverse yaw.

Spoilers

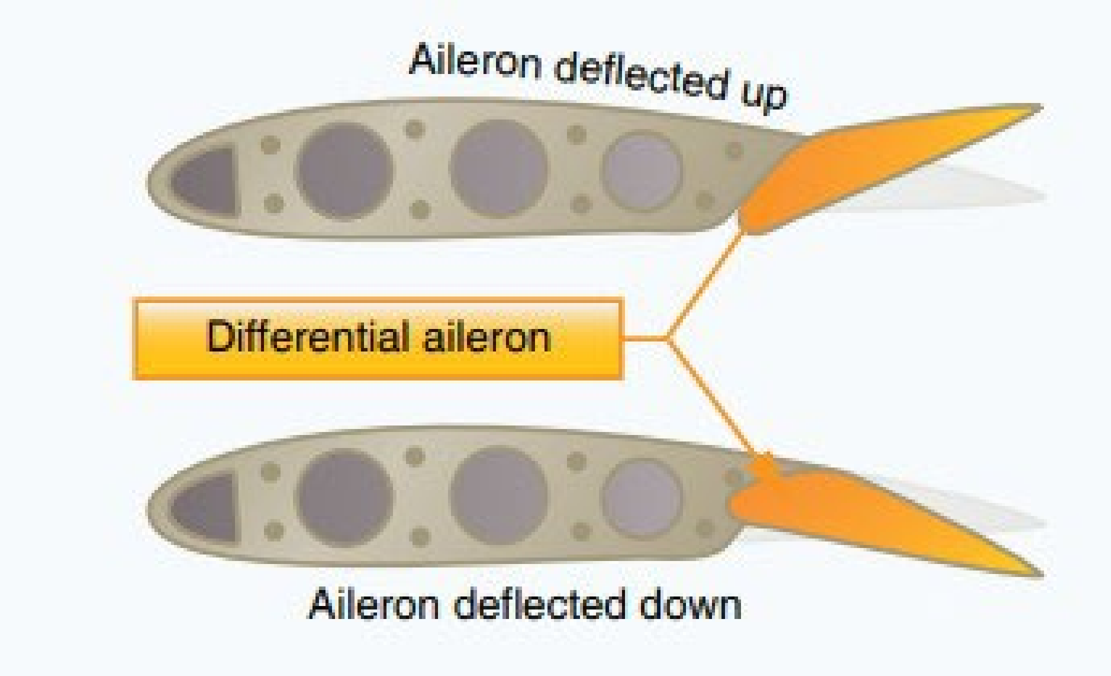
To turn right, for example, the spoiler on the right wing is raised, destroying some of the lift and creating more drag on the right.

The right wing drops, and the aircraft 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 reduce ground roll after landing. By destroying lift, they transfer weight to the wheels, improving braking effectiveness.

Differential Ailerons



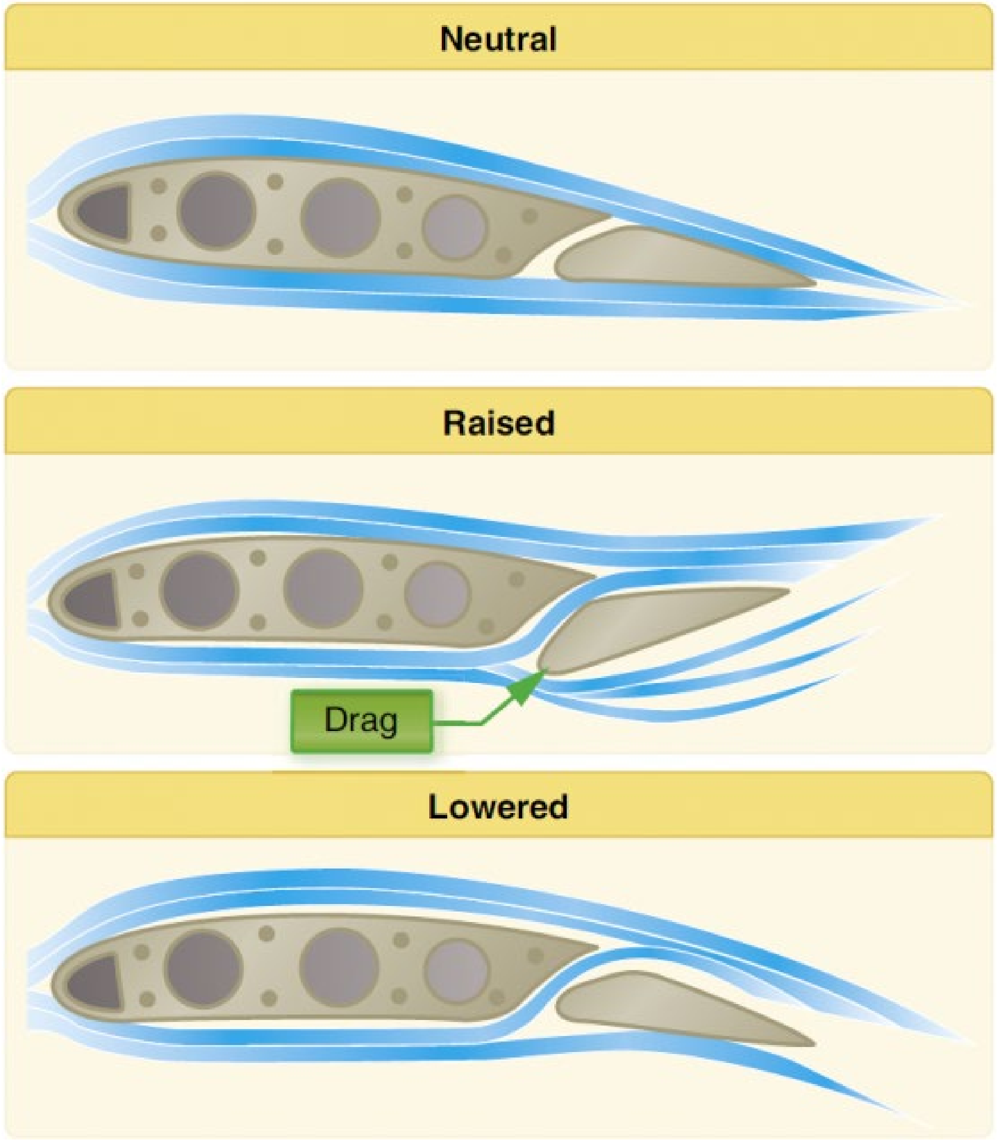
With differential ailerons, one aileron is raised a greater distance than the other aileron is lowered for a given movement of the control yoke or stick.

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.

Cessna 150, 152, 172, 182 use these.



Frise-Type Ailerons

With a frise-type aileron, when pressure is applied to the control yoke or stick, 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.

It helps equalize the drag created by the lowered aileron on the opposite wing and reduces adverse yaw.

Elevators and affect CG

Elevator movement causes a pitching moment 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.

Trim Tabs

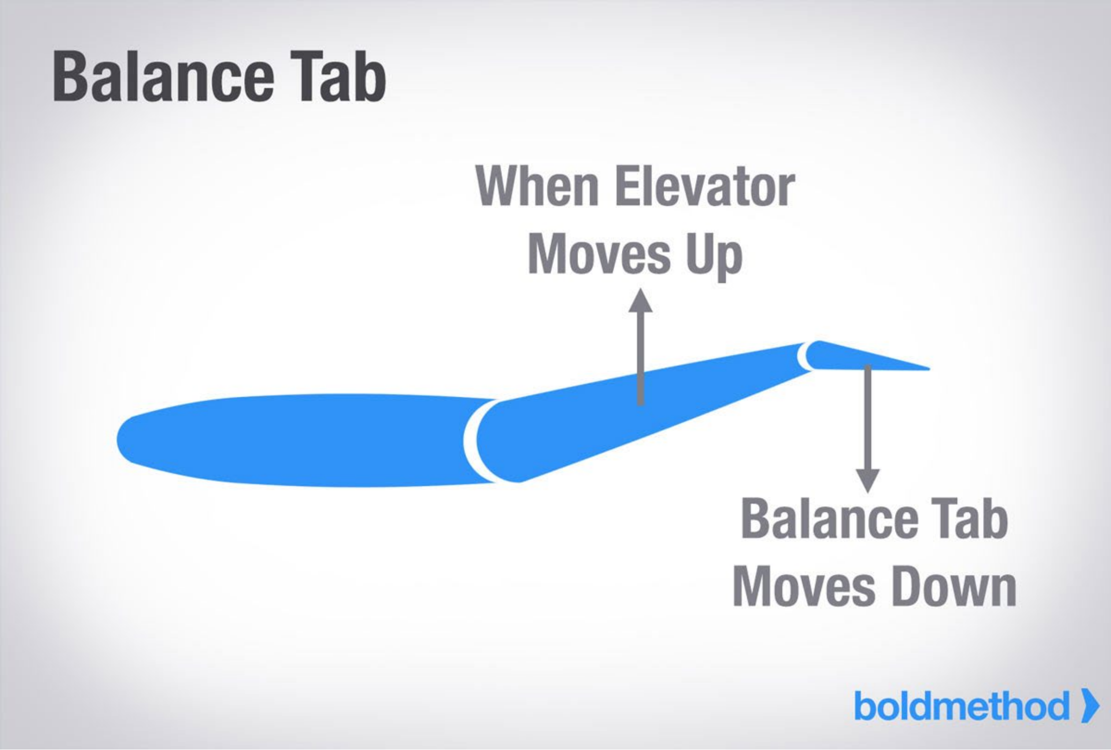
The most common installation on small aircraft is a single trim tab attached to the <u>trailing edge of the elevator</u>.

Placing the trim control in the full nose-down position moves the trim tab to its full up position.

With the trim 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 aircraft to move up and the nose to move down.

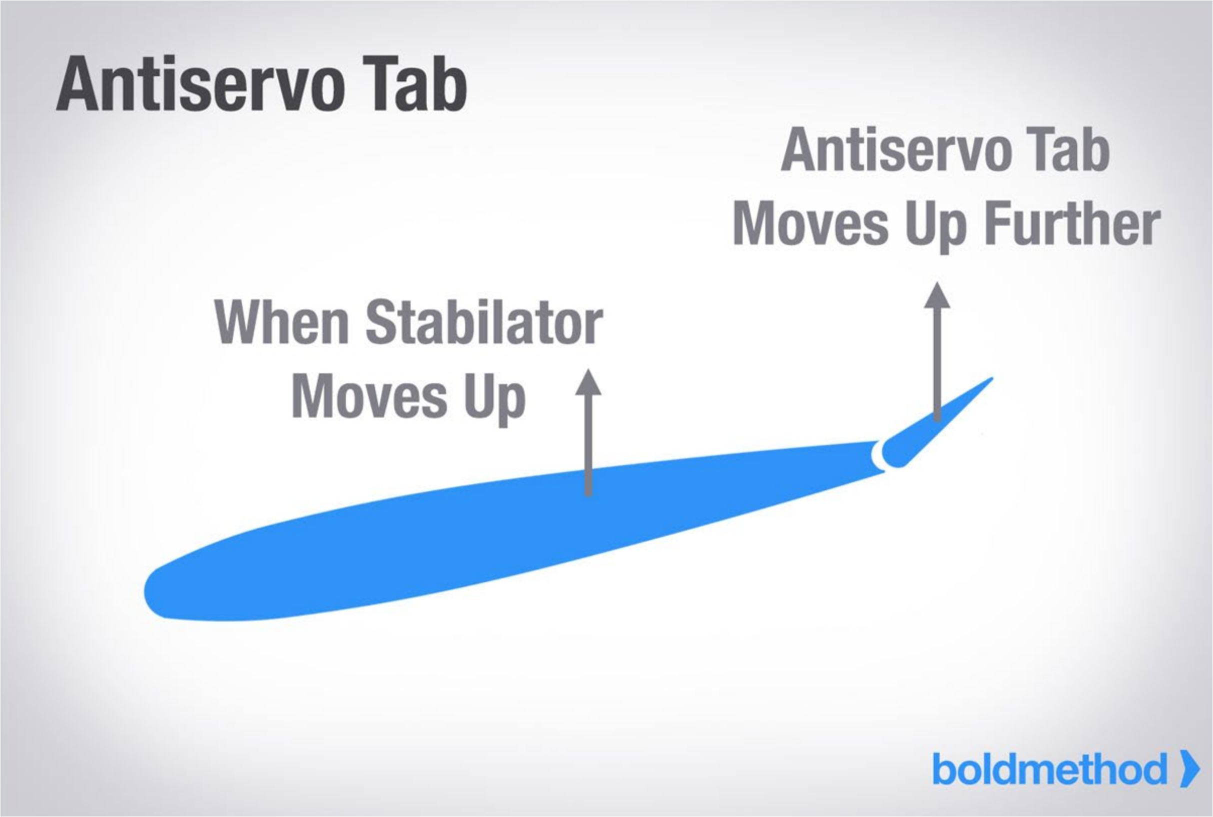
Balance Tab



Some aircraft have very heavy control loads, especially at high speeds. That's where balance tabs come in handy. Balance tabs look like trim tabs, but they have one major difference: balance tabs are attached to the control surface linkage, so when the control surface is moved in one direction, the balance tab moves in the opposite direction.

By moving the balance tab in the opposite direction, the control load on your yoke is significantly reduced, making your airplane easier to fly.

Antiservo Tab



Antiservo tabs are similar to balance tabs, but they move in the opposite direction. For example, when your elevator or stabilator moves up, the antiservo tab moves in the same direction.

In small aircraft, it increases the control feel, and helps prevent you from over-controlling your aircraft's pitch. One of the most popular examples of the antiservo tab is on the Piper Cherokee. Without it, the plane would be much easier to pitch up and down, but it would also be easy to over-control, and possibly overstress the airframe.

Ground Adjustable Tabs

Many small aircraft have a nonmovable 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.

Usually, small adjustments are necessary until the aircraft no longer skids left or right during normal cruising flight.

Any questions I can answer or follow up later on?