stability of the aircraft. On the wing where the aileron is moved up, the spoilers also raise thus amplifying the reduction of lift on that wing. (***Figure 1-9***)

On the wing with downward aileron deflection, the spoilers remain stowed. As the speed of the aircraft increases, the ailerons become more effective and the spoiler interconnect disengages. Note that spoilers are also used in as drag inducing devices.

OPERATION AND EFFECT OF PITCH CONTROL DEVICES

ELEVATORS
The elevator is the primary flight control surface that moves the aircraft around the horizontal or lateral axis. This causes the nose of the aircraft to pitch up or down. The elevator is hinged to the trailing edge of the horizontal stabilizer and typically spans most or all of its width. It is controlled in the cockpit by pushing or pulling the control yoke forward or aft.

Light aircraft use a system of control cables and pulleys or push pull tubes to transfer cockpit inputs to the movement of the elevator. High performance and large aircraft typically employ more complex systems. Hydraulic power is commonly used to move the elevator on these aircraft. On aircraft equipped with fly by wire controls, a combination of electrical and hydraulic power is used.

STABILATORS
A movable horizontal tail section, called a stabilator, is a control surface that combines the action of both the horizontal stabilizer and the elevator. (***Figure 1-10***) Basically, a stabilator is a horizontal stabilizer that can also be rotated about the horizontal axis to affect the pitch of the aircraft.

VARIABLE INCIDENCE STABILIZERS
A variable incidence stabilizer refers to any horizontal stabilizer in which the angle of incidence of the horizontal stabilizer is adjustable. Thus, a stabilator is a variable incidence horizontal stabilizer. Various mechanisms and operating rigging are available. Most large aircraft use a motorized jackscrew to alter the position of the stabilizer often energized by the trim tab switch on the control yoke. The reason for a stabilator or any horizontal stabilizer variable incidence device is to minimize drag when trimming the aircraft in flight. Deflection of the elevator via the use of a trim tab causes drag and requires a relatively large elevator on large aircraft to achieve all desired trim settings. By varying the angle of the horizontal stabilizer to adjust pitch, less drag is created and elevator size and deflection may be reduced. (***Figure 1-11***)

CANARDS
A canard utilizes the concept of two lifting surfaces. It functions as a horizontal stabilizer located in front of the main wings. In effect, the canard is an airfoil similar to the horizontal surface on a conventional aft tail design. The difference is that the canard actually creates lift and

Figure 1-9. Spoilers deployed upon landing a transport category aircraft.

Figure 1-10. A stabilizer and index marks on a transport category aircraft.

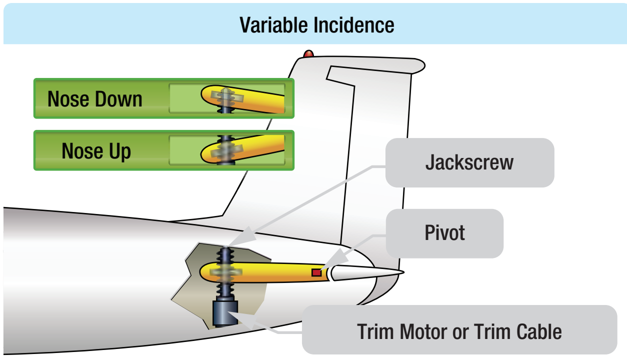

Figure 1-11. Some airplanes, including most jet transports, use an variable stabilizer to provide the required pitch trim forces.

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. (***Figure 1-12***)

The canard design dates back to the pioneer days of aviation, most notably used on the Wright Flyer. Recently, the canard configuration has regained popularity and is appearing on newer aircraft. 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 shape 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.

OPERATION AND EFFECT OF YAW CONTROL DEVICES

RUDDERS

The rudder is the primary control surface that causes an aircraft to yaw or move about the vertical axis. This provides directional control and thus points the nose of the aircraft in the direction desired. Most aircraft have a single rudder hinged to the trailing edge of the vertical stabilizer. It is controlled by a pair of foot operated rudder pedals in the cockpit. When the right pedal is pushed forward, it deflects the rudder to the right which moves the nose of the aircraft to the right. The left pedal is rigged to simultaneously move aft. When the left pedal is pushed forward, the nose of the aircraft moves to the left.

Figure 1-12. The Piaggio P180 includes a variable-sweep canard design, which provides longitudinal stability about the lateral axis.

As with the other primary flight controls, the transfer of the movement of the cockpit controls to the rudder varies with the complexity of the aircraft. Many aircraft incorporate the directional movement of the nose or tail wheel into the rudder control system for ground operation. This allows the operator to steer the aircraft with the rudder pedals during taxi when the airspeed is not high enough for the control surfaces to be effective. Some large aircraft have a split rudder arrangement. This is actually two rudders, one above the other. At low speeds, both rudders deflect in the same direction when the pedals are pushed. At higher speeds, one of the rudders becomes inoperative as the deflection of a single rudder is aerodynamically sufficient to maneuver the aircraft.

RUDDER LIMITERS

In flight, most large aircraft oscillate slightly from side to side. Yaw dampener units automatically detect this movement and send signals to the hydraulic power control unit (PCU) that moves the rudder so that it can correct for these yaw oscillations. Similarly, rudders are known to deflect without being commanded to do so by the flight crew. Again, the yaw dampener is designed to correct the fluctuations by signaling the PCU. However, too large of an involuntary deflection to a rudder can cause a loss of control of the aircraft.

A rudder limiter is fitted to many aircraft to prevent any more than a few degrees of involuntary motion of the rudder. Essentially, it limits the movement unless it is commanded from the flight deck.

SECONDARY OR AUXILIARY CONTROL SURFACES

There are several secondary or auxiliary flight control surfaces. Their names, locations, and functions of those for most large aircraft are listed in ***Figure 1-13***.

OPERATION AND EFFECT OF TABS

TRIM TABS

The force of the air against a control surface during the high speed of flight can make it difficult to move and hold that control surface in the deflected position. A control surface might also be too sensitive for similar reasons. Several different tabs are used to aid with these types of problems. The table in ***Figure 1-14*** summarizes the various tabs and their uses. While in flight, it is desirable for the pilot to be able to take his or her hands and feet off of the controls and have the aircraft maintain its flight condition.

Trims tabs are designed to allow this. Most trim tabs are small movable surfaces located on the trailing edge of a primary flight control surface. A small movement of the tab in the direction opposite of the direction the flight control surface is deflected, causing air to strike the tab, in turn producing a force that aids in maintaining the flight control surface in the desired position. Through linkage set from the cockpit, the tab can be positioned so that it is actually holding the control surface in position rather than the pilot. Therefore, elevator tabs are used to maintain the speed of the aircraft since they assist in maintaining the selected pitch. Rudder tabs can be set to hold yaw in check and maintain heading. Aileron tabs can help keep the wings level.

Occasionally, a simple light aircraft may have a stationary metal plate attached to the trailing edge of a primary flight control, usually the rudder. This is also a trim tab as shown in ***Figure 1-15***. It can be bent slightly on the ground to trim the aircraft in flight to a hands off condition when flying straight and level. The correct amount of bend can be determined only by flying the aircraft after an adjustment. Note that a small amount of bending is usually sufficient.

BALANCE TABS

The aerodynamic phenomenon of moving a trim tab in one direction to cause the control surface to experience a force moving in the opposite direction is exactly what occurs with the use of balance tabs. (***Figure 1-16***) Often,

Secondary/Auxiliary Flight Control Surfaces		
Name	**Location**	**Function**
Flaps	Inboard trailing edge of wings	Extends the camber of the wing for greater lift and slower flight. Allows control at low speeds for short field takeoffs and landings.
Trim Tabs	Trailing edge of primary flight control surfaces	Eliminates the force needed to move a primary control surface (zero Newtons; hands free).
Balance Tabs	Trailing edge of primary flight control surfaces	Reduces the force needed to move a primary control surface.
Anti-balance Tabs	Trailing edge of primary flight control surfaces	Increases feel and effectiveness of primary control surface.
Servo Tabs	Trailing edge of primary flight control surfaces	Assists or provides the force for moving a primary flight control.
Spoilers	Upper and/or trailing edge of wing	Decreases (spoils) lift. Can augment aileron function.
Slats	Mid to outboard leading edge of wing	Extends the camber of the wing for greater lift and slower flight. Allows control at low speeds for short field takeoffs and landings.
Slots	Outer leading edge of wing forward of ailerons	Directs air over upper surface of wing during high angle of attack. Lowers stall speed and provides control during slow flight.
Leading Edge Flap	Inboard leading edge of wing	Extends the camber of the wing for greater lift and slower flight. Allows control at low speeds for short field takeoffs and landings.

NOTE: An aircraft may possess none, one, or a combination of the above control surfaces.

Figure 1-13. Secondary or auxiliary control surfaces and respective locations for larger aircraft.

Flight Control Tabs			
Type	**Direction of Motion (in relation to control surface)**	**Activation**	**Effect**
Trim	Opposite	Set by pilot from cockpit. Uses independent linkage.	Statically balances the aircraft in flight. Allows "hands off" maintenance of flight condition.
Balance	Opposite	Moves when pilot moves control surface. Coupled to control surface linkage.	Aids pilot in overcoming the force needed to move the control surface.
Servo	Opposite	Directly linked to flight control input device. Can be primary or back-up means of control.	Aerodynamically positions control surfaces that require too much force to move manually.
Anti-balance or Anti-servo	Same	Directly linked to flight control input device.	Increases force needed by pilot to change flight control position. De-sensitizes flight controls.
Spring	Opposite	Located in line of direct linkage to servo tab. Spring assists when control forces become too high in high-speed flight.	Enables moving control surface when forces are high. Inactive during slow flight.

Figure 1-14. Various tabs and their uses.

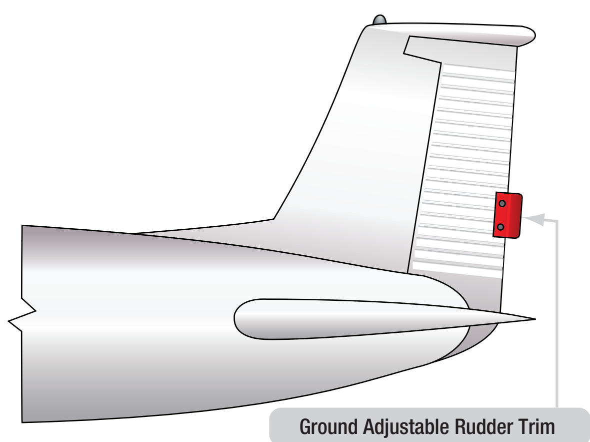

Figure 1-15. Example of a trim tab.

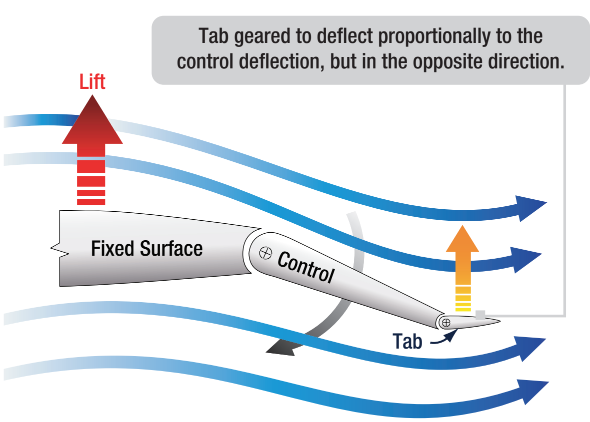

Figure 1-16. Balance tabs assist with forces needed to position control surfaces.

it is difficult to move a primary control surface due to its surface area and the speed of the air rushing over it. Deflecting a balance tab hinged at the trailing edge of the control surface in the opposite direction of the desired control surface movement causes a force to position the surface in the proper direction with reduced force to do so. Balance tabs are usually linked directly to the control surface linkage so that they move automatically when there is an input for control surface movement. They also can double as trim tabs, if adjustable on the flight deck.

SERVO TABS

A servo tab is similar to a balance tab in location and effect, but it is designed to operate the primary flight control surface, not just reduce the force needed to do so. It is usually used as a means to back up the primary control of the flight control surfaces. (***Figure 1-17***)

On heavy aircraft, large control surfaces require too much force to be moved manually and are usually deflected out of the neutral position by hydraulic actuators. These power control units are signaled via a system of hydraulic valves connected to the yoke and rudder pedals. On fly by wire aircraft, the hydraulic actuators that move the flight control surfaces are signaled by electric input. In the case of hydraulic system failure(s), manual linkage to a servo tab can be used to deflect it. This, in turn, provides an aerodynamic force that moves the primary control surface.

ANTI-SERVO/ANTI-BALANCE TABS

Anti-servo tabs, as the name suggests, are like servo tabs but move in the same direction as the primary control surface. On some aircraft, especially those with a movable horizontal stabilizer, the input to the control surface can be too sensitive. An Anti-servo tab tied through the control linkage creates an aerodynamic force that increases the effort needed to move the control surface. This makes flying the aircraft more stable for the pilot. ***Figure 1-18*** shows an Anti-servo tab in the near neutral position. Deflected in the same direction as the desired stabilator movement, it increases the required control surface input. Anti servo tabs are also known as anti-balance tabs.

SPRING TABS

A control surface may require excessive force to move only in the final stages of travel. When this is the case, a spring tab can be used. This is essentially a servo tab that does not activate until an effort is made to move the control surface beyond a certain point. When reached, a spring in line of the control linkage aids in moving the control surface through the remainder of its travel. (***Figure 1-19***)

AERODYNAMIC BALANCE PANELS

Figure 1-20 shows another way of assisting the movement of an aileron on a large aircraft. It is called an aileron balance panel. Not visible when approaching the aircraft, it is positioned in the linkage that hinges the aileron to the wing. Balance panels have been constructed typically of aluminum skin covered frame assemblies or aluminum honeycomb structures. The trailing edge of the wing just forward of the leading edge of the aileron is sealed to allow controlled airflow in and out of the hinge area where the balance panel is located.

MASS BALANCE

Flutter is an undesirable oscillation of an aircraft control surface which can have catastrophic effect on controllability of the aircraft. The center of lift on a control surface should be aft of the control surface center of gravity to prevent control surface flutter. Often, the addition of weight to the forward surface of an aileron, for example, is sufficient to move the CG of the airfoil forward and prevent flutter. Some aircraft designs, however, place the weight on a lever arm that extends forward of the control surface. This is known as a mass balance. Mass balances help prevent flutter and also reduce the required control stick pressure used to move a control surface. (***Figure 1-21***)

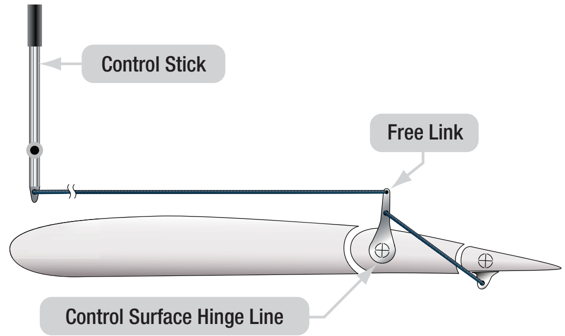

Figure 1-17. Servo tabs can be used to position flight control surfaces in case of hydraulic failure.

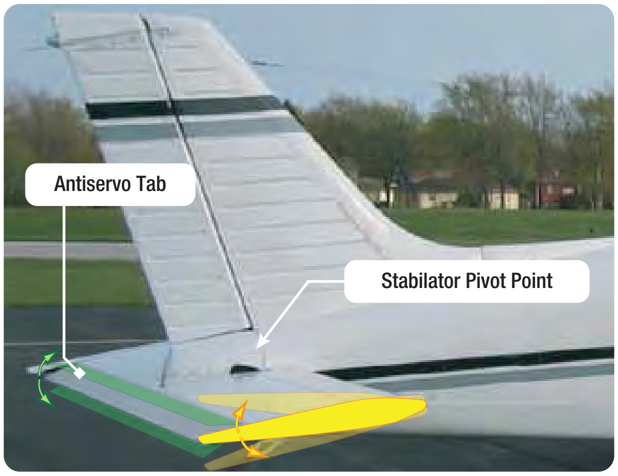

Figure 1-18. An Anti-servo tab moves in the same direction as the control tab. Shown here on a stabilator, it desensitizes the pitch control.

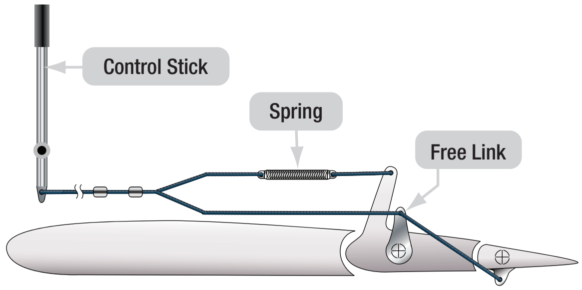

Figure 1-19. Many tab linkages have a spring tab that kicks in as the forces needed to deflect a control increase with speed and the angle of desired deflection.

CONTROL SURFACE BIAS

When a control surface is in the neutral position, is faired with the wing rudder or horizontal stabilizer and no effect on the aircrafts aerodynamic surfaces. Some aircraft are designed with control surface bias.

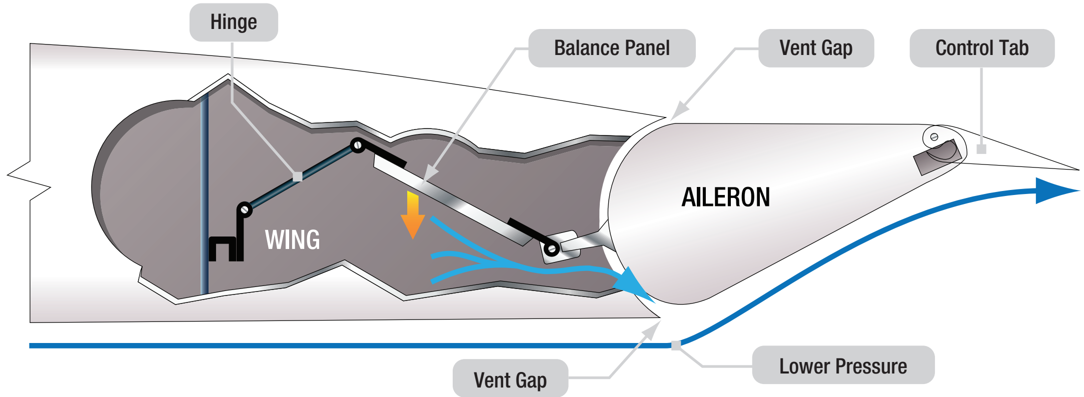

Figure 1-20. An aileron balance panel and linkage uses varying air pressure to assist in control surface positioning.

Figure 1-21. An aileron mass balance.

This means that a control surface is not naturally in the neutral position. It is designed to impart a force on the airfoil at all times. The force is generally used to counter balance a design imbalance and alter the aircraft's aerodynamics for easy hands off flight. This means that when the aircraft is flying straight and level, the control surface bias has effect but all trim position gauges on the flight deck indicate zero trim.

HIGH LIFT DEVICES

Aircraft wings contain devices that are designed to increase the lift produced by the wing with the devices deployed during certain phases of flight.

FLAPS

Flaps are one such high lift device found on most aircraft. They are usually inboard on the wings' trailing edges adjacent to the fuselage. Leading edge flaps are also common. They extend forward and down from the inboard wing leading edge. The flaps are lowered to increase the camber of the wings and provide greater lift and control at slow speeds. They enable landing at slower speeds and shorten the amount of runway required for takeoff and landing. The amount that the flaps extend and the angle they form with the wing can be selected from the cockpit. Typically, flaps can extend up to 45–50°. ***Figure 1-22*** shows various aircraft with flaps in the extended position.

Figure 1-22. An aileron balance panel and linkage uses varying air pressure to assist in control surface positioning.