MODULE 13

FOR B2 CERTIFICATION

AIRCRAFT AERODYNAMICS STRUCTURES AND SYSTEMS

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REVISION LOG

VERSION	EFFECTIVE DATE	DESCRIPTION OF CHANGE
001	2016 01	Module Creation and Release
002	2017 02	Format Update
003	2017 08	Module 03 Revisions. Typo corrections in Sub-Modules 03, 04 and 08.
004	2020 02	Enhanced or modified content within the following Sub-Modules: Sub-Module 03: Added Autopilot Modes of Operation. Sub-Module 04: Reorganized based on Part-66 2018 changes; added content: ADS-B and Datalink; Corrected Figures 4-78 and 4-79. Sub-Module 07: Added Fly-By-Wire Failsafe and Fly-By-Wire operation.

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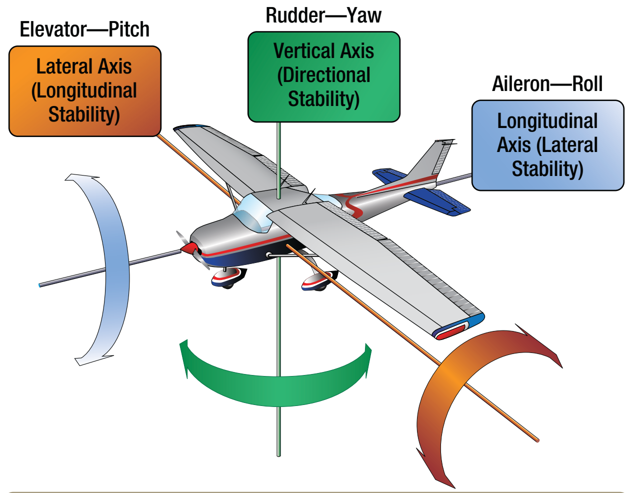
13.1 - AEROPLANE AERODYNAMICS AND FLIGHT CONTROLS

The directional control of a fixed-wing aircraft takes place around the lateral, longitudinal, and vertical axes by means of flight control surfaces designed to create movement about these axes. These control devices are hinged or movable surfaces through which the attitude of an aircraft is controlled during takeoff, flight, and landing. They are usually divided into two major groups: 1) primary or main flight control surfaces and 2) secondary or auxiliary control surfaces.

PRIMARY FLIGHT CONTROL SURFACES

The primary flight control surfaces on a fixed-wing aircraft include: ailerons, elevators, and the rudder. The ailerons are attached to the trailing edge of both wings and when moved, rotate the aircraft around the longitudinal axis. The elevator is attached to the trailing edge of the horizontal stabilizer. When it is moved, it alters aircraft pitch, which is the attitude about the horizontal or lateral axis. The rudder is hinged to the trailing edge of the vertical stabilizer. When the rudder changes position, the aircraft rotates about the vertical axis (yaw). ***Figure 1-1*** shows the primary flight controls of a light aircraft and the movement they create relative to the three axes of flight.



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

Figure 1-1. Flight control surfaces move the aircraft around the three axes of flight.

Primary control surfaces are usually similar in construction to one another and vary only in size, shape, and methods of attachment. On aluminum light aircraft, their structure is often similar to an all-metal wing. This is appropriate because the primary control surfaces are simply smaller aerodynamic devices. They are typically made from an aluminum alloy structure built around a single spar member or torque tube to which ribs are fitted and a skin is attached. The lightweight ribs are, in many cases, stamped out from flat aluminum sheet stock. Holes in the ribs lighten the assembly. An aluminum skin is attached with rivets. ***Figure 1-2*** illustrates this type of structure, which can be found on the primary control surfaces of light aircraft as well as on medium and heavy aircraft.

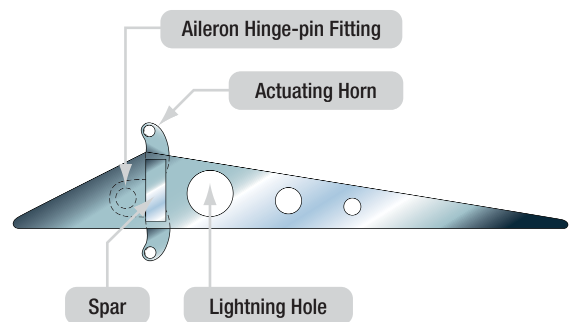


Figure 1-2. Typical structure of an aluminum flight control surface.

Primary control surfaces constructed from composite materials are also commonly used. These are found on many heavy and high-performance aircraft, as well as gliders, home-built, and light-sport aircraft. The weight and strength advantages over traditional construction can be significant. A wide variety of materials and construction techniques are employed. ***Figure 1-3*** shows examples of aircraft that use composite technology on primary flight control surfaces. Note that the control surfaces of fabric-covered aircraft often have fabric covered surfaces just as aluminum-skinned (light) aircraft typically have all-aluminum control surfaces.

OPERATION AND EFFECT OF ROLL CONTROL DEVICES

AILERONS

Ailerons are the primary flight control surfaces that move the aircraft about the longitudinal axis. In other words, movement of the ailerons in flight causes the aircraft to roll. Ailerons are usually located on the outboard trailing edge of each of the wings. They are built into the wing and are calculated as part of the wing's surface area. ***Figure 1-4*** shows aileron locations on various wing tip designs.

Ailerons are controlled by a side-to-side motion of the control stick in the cockpit or a rotation of the control yoke. When the aileron on one wing deflects down, the aileron on the opposite wing deflects upward. This amplifies the movement of the aircraft around the longitudinal axis. On the wing on which the aileron trailing edge moves downward, camber is increased and lift is increased. Conversely, on the other wing, the raised aileron decreases lift. (***Figure 1-5***)

Figure 1-3. Composite control surfaces and some of the many aircraft that utilize them.

The result is a sensitive response to the control input to roll the aircraft. The pilot's request for aileron movement and roll are transmitted from the cockpit to the actual control surface in a variety of ways depending on the aircraft. A system of control cables and pulleys, push-pull tubes, hydraulics, electric, or a combination of these can be employed. (***Figure 1-6***)

Simple, light aircraft usually do not have hydraulic or electric fly-by-wire aileron control. These are found on heavy and high-performance aircraft. Large aircraft and some high performance aircraft may also have a second set of ailerons located inboard on the trailing edge of the wings. These are part of a complex system of primary and secondary control surfaces used to provide lateral control and stability in flight. At low speeds, the ailerons may be augmented by the use of flaps and spoilers. At high speeds, only inboard aileron deflection is required to roll the aircraft while the other control surfaces are locked out or remain stationary.

Figure 1-7 illustrates the location of the typical flight control surfaces found on a transport category aircraft.

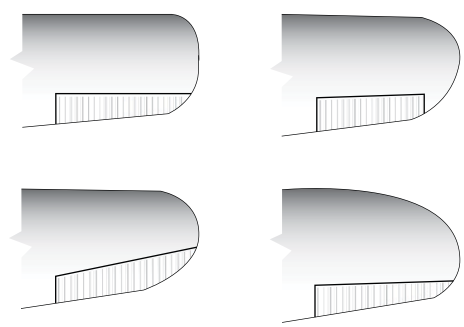


Figure 1-4. Aileron location on various wings.

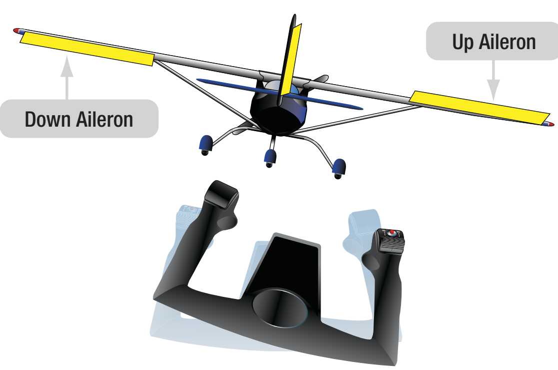


Figure 1-5. Differential aileron control movement. When one aileron is moved down, the aileron on the opposite wing is deflected upward.

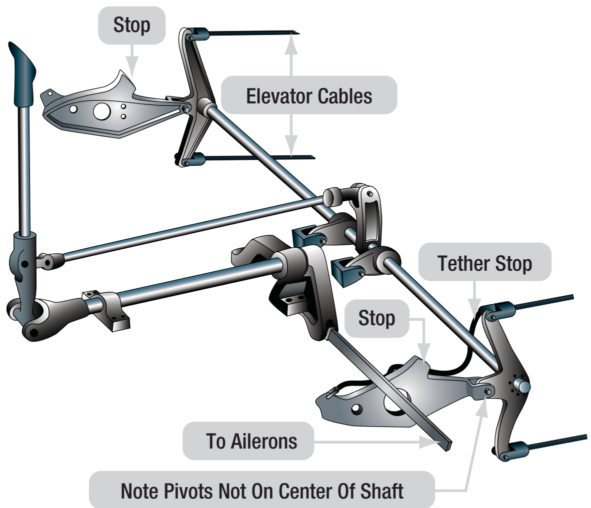


Figure 1-6. Transferring control surface inputs from the cockpit.

SPOILERS

A spoiler is a device found on the upper surface of many heavy and high-performance aircraft. It is stowed flush to the wing's upper surface. When deployed, it raises up into the airstream and disrupts the laminar airflow of the wing, thus reducing lift. Spoilers are made with similar construction materials and techniques as the other flight control surfaces on the aircraft. At low speeds, spoilers are rigged to operate when the ailerons operate to assist with the lateral movement and 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 1-8***) 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.

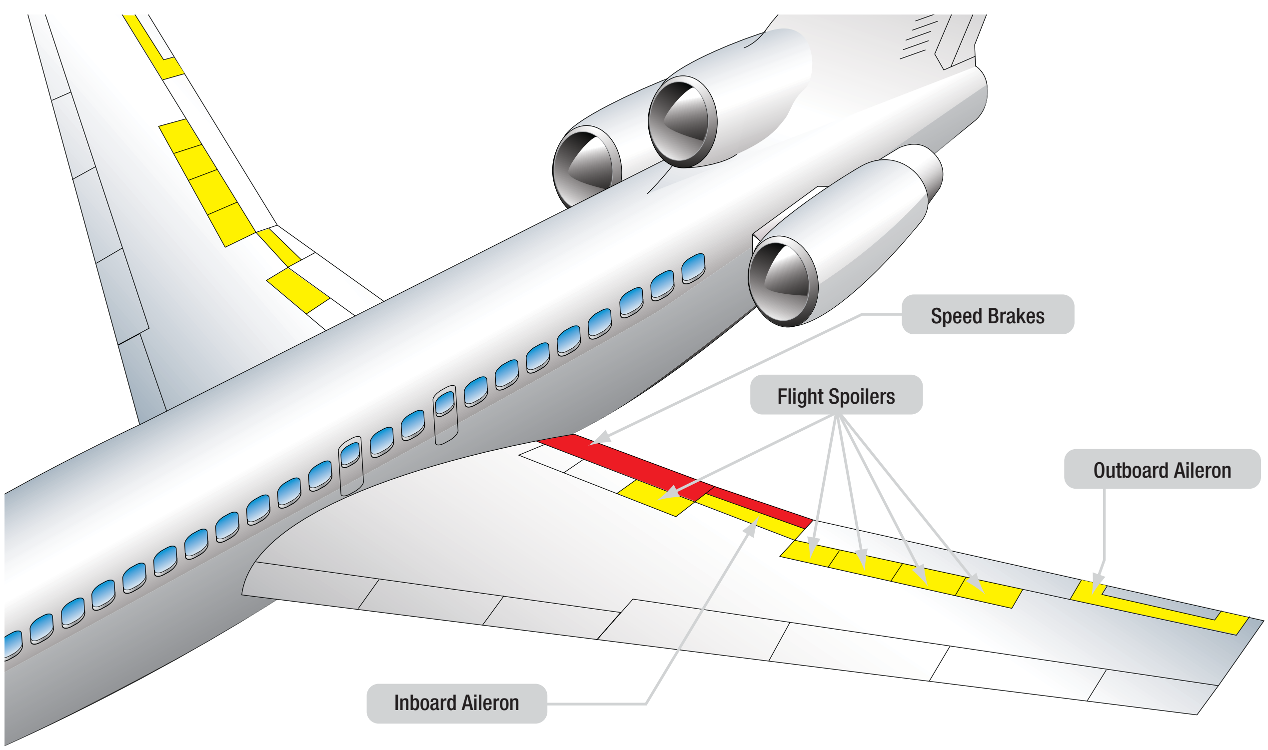


Figure 1-7. Typical flight control surfaces on a transport category aircraft.

Figure 1-8. Spoilers deployed upon landing a transport category aircraft.

Figure 1-9. A stabilizer and index marks on a transport category aircraft.

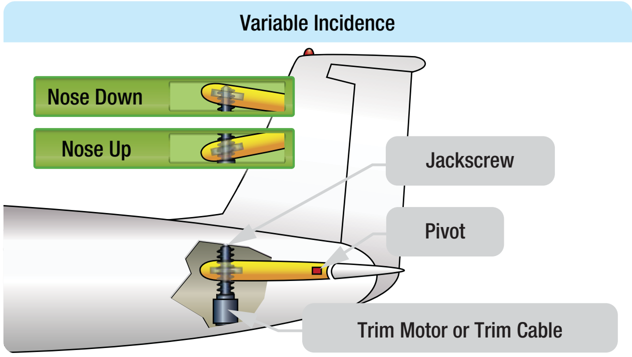


Figure 1-10. Some airplanes, including most jet transports, use an variable stabilizer to provide the required pitch trim forces.

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 1-9***) 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 1-10***)

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 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 1-11***)

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

Figure 1-11. The Piaggio P180 includes a variable-sweep canard design, which provides longitudinal stability about the lateral axis.

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.

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 1-12***.

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 1-13*** 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 1-14***. 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.

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	Reduces the force needed to move a primary control surface.
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 1-12. 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 1-13. Various tabs and their uses.

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 1-15***) Often, it is difficult to move a primary control surface due to its surface area and the speed of the air rushing over it.