Private Pilot (ASEL) Ground School Course

Lesson 04 | Aircraft Flight Controls and Systems

Lesson Overview

Lesson Objectives:

- Develop knowledge and understanding of Flight Controls, Electrical, and Hydraulic
- Gain knowledge, understanding and operations skill of most aircraft systems.

Lesson Completion Standards:

- Student demonstrates satisfactory knowledge of primary and secondary flight controls, and most aircraft systems by answering questions and actively participating in classroom discussions.

Flight Controls

Aircraft Flight Controls and Systems

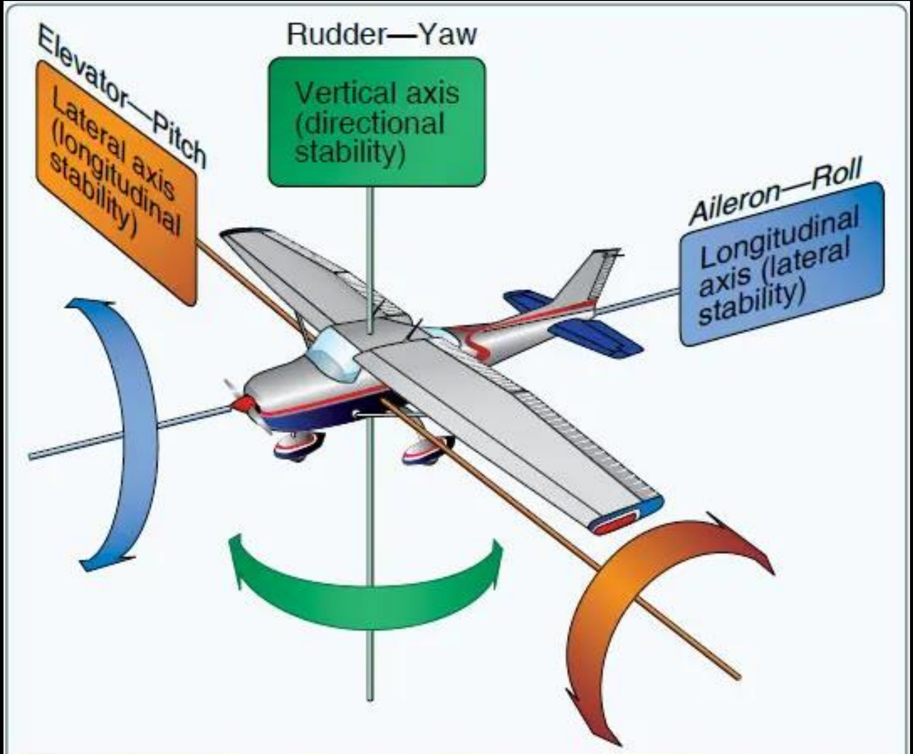
Flight Controls

- Aircraft flight control systems consist of primary and secondary systems.
- The ailerons, elevator (or stabilator), and rudder constitute the primary control system.
  - Required to control an aircraft safely during flight.
- Wing flaps, leading edge devices, spoilers, and trim systems constitute the secondary control system
  - They improve the performance characteristics of the airplane or relieve the pilot of excessive control forces.

Primary Flight Controls

- These three surfaces control the airplane around each of the three axis of flight. Designed to have an “normal” feel.
- At low airspeeds, the controls usually feel soft and sluggish, and the aircraft responds slowly to control applications. At higher airspeeds, the controls become increasingly firm and aircraft response is more rapid.
- Three (3) primary flight controls
  - Elevator
  - Aileron
  - Rudder

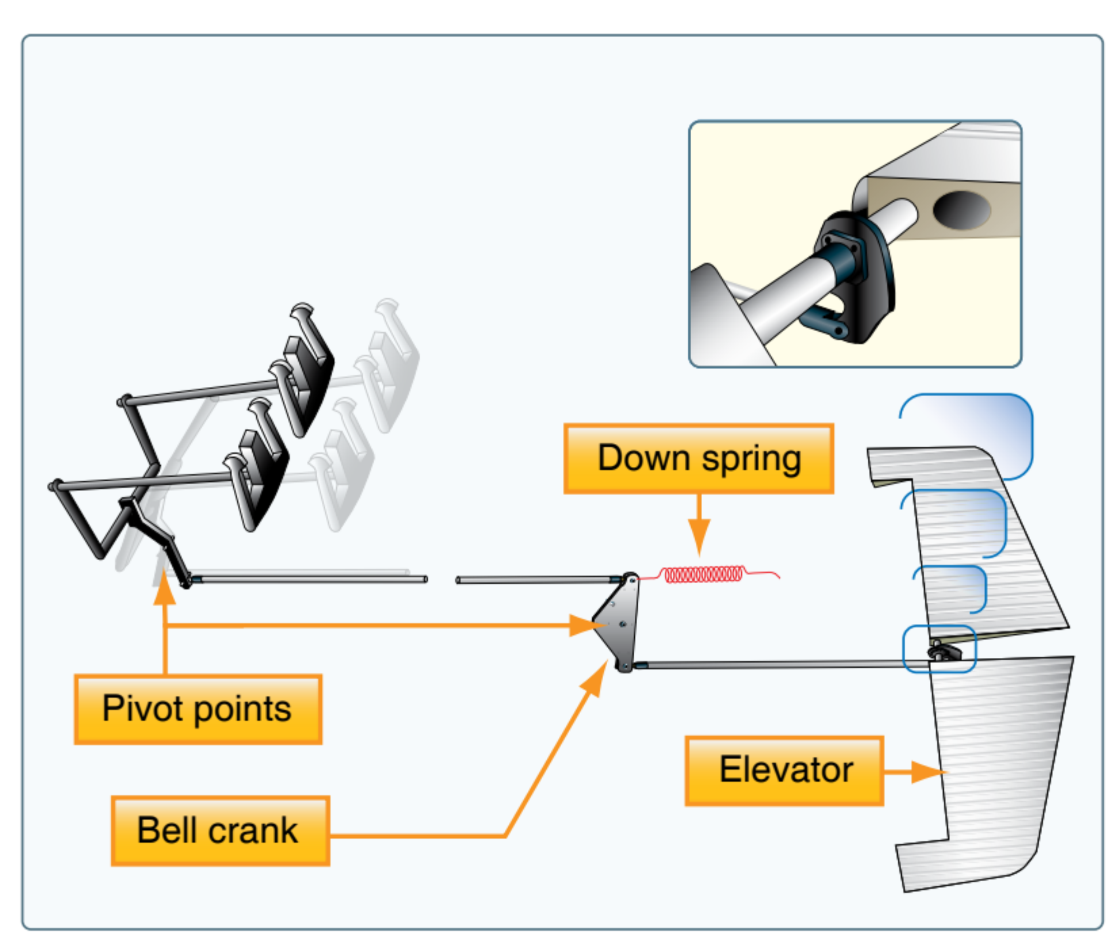
Primary Flight Controls



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

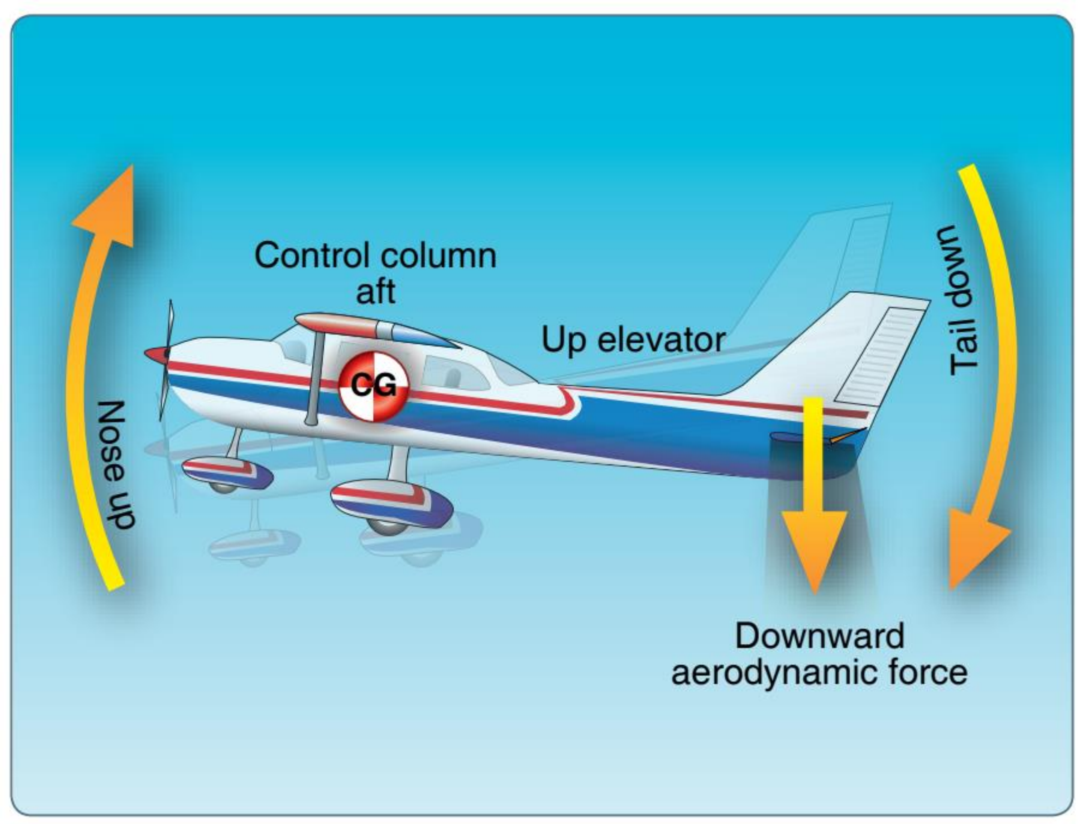
Primary Flight Controls - Elevator

- The elevator controls pitch about the lateral axis.
- Most light airplanes use mechanical control cables and linkages to move the surface.
- Aft movement of the control column deflects the trailing edge of the elevator surface up. This is usually referred to as the up-elevator position



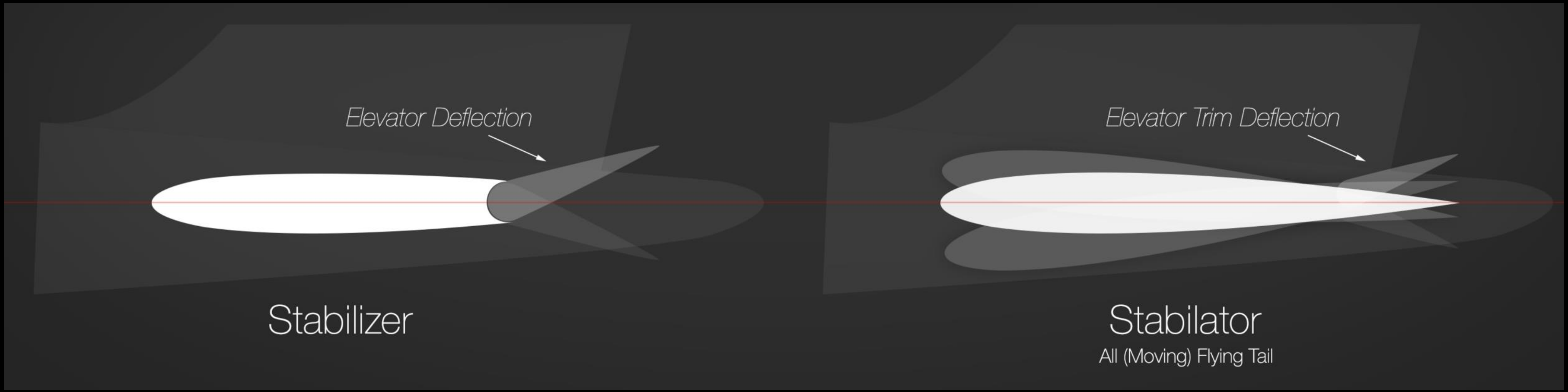
Primary Flight Controls - Elevator

- 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 aircraft to move down and the nose to pitch up.



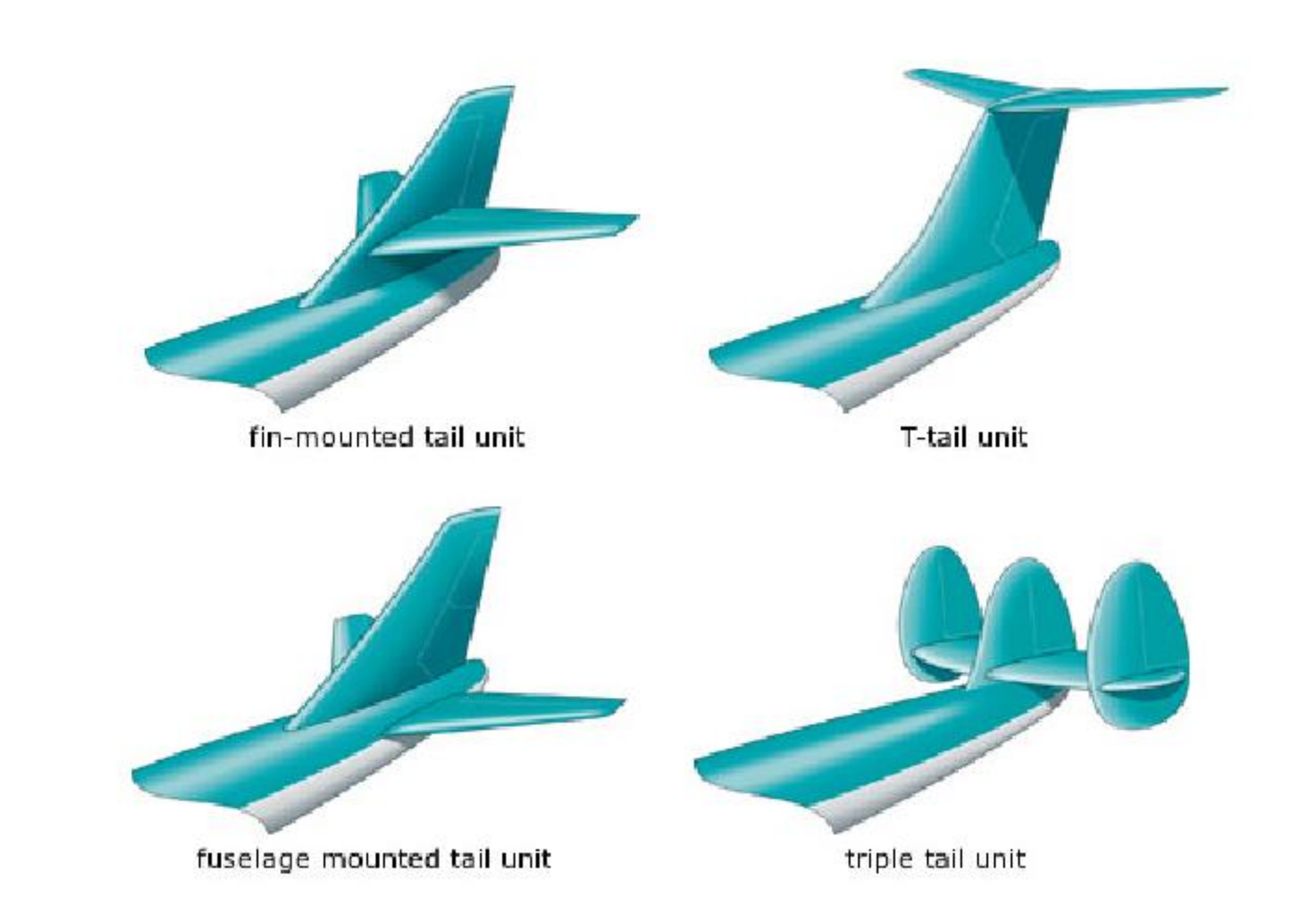
Primary Flight Controls - Elevator

- Some airplanes have a fixed horizontal stabilizer and moveable elevator.
- Some airplanes have a completely moveable stabilator that acts as both horizontal stabilizer and elevator.



Primary Flight Controls - Elevator

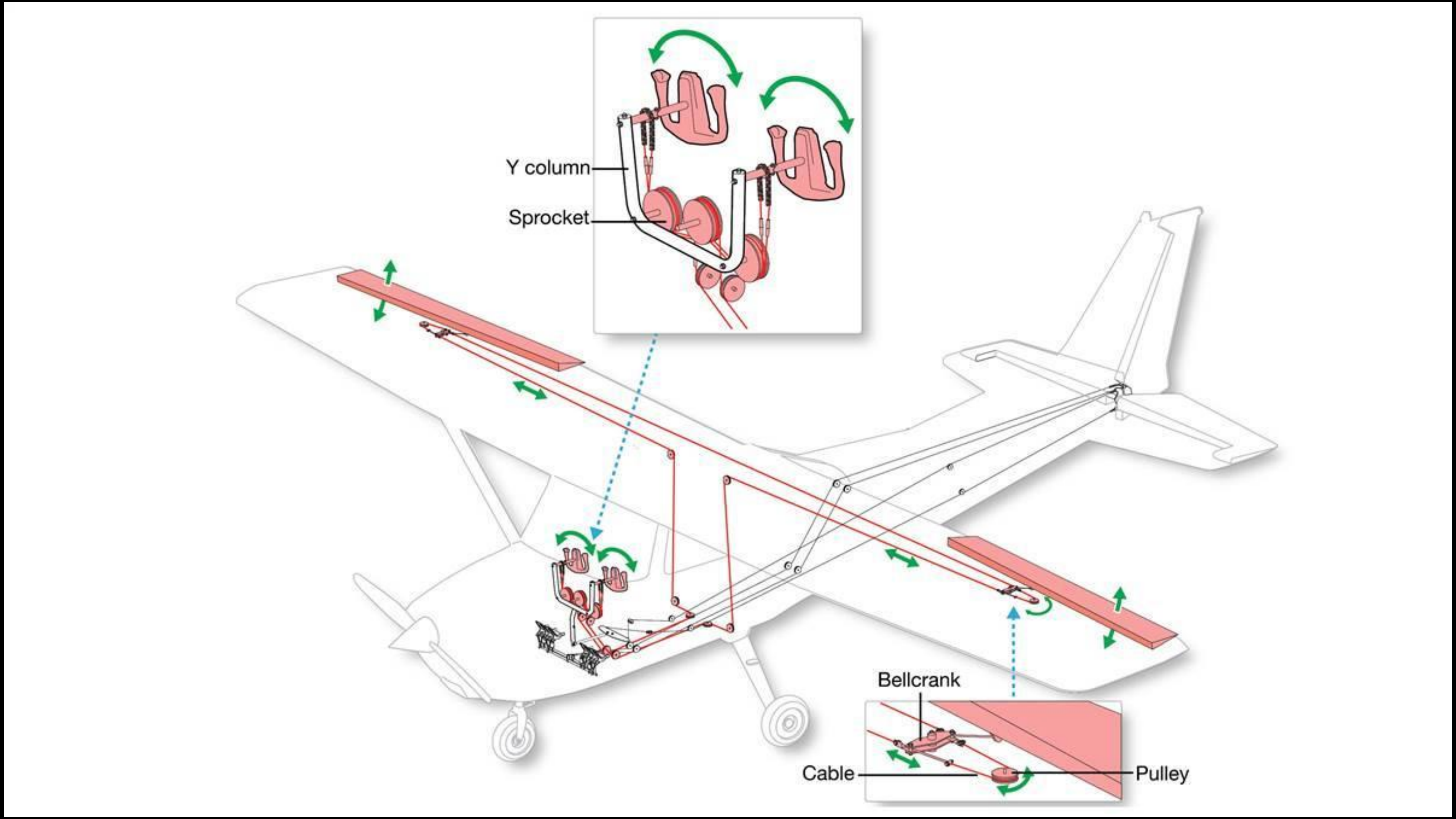
- Other airplane have a different configurations of the elevator location.
- Each design has its own aerodynamic purpose.



Primary Flight Controls - Aileron

- 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, bell cranks, pulleys, and/or push-pull tubes to a control wheel or control stick.

Primary Flight Controls - Aileron



Primary Flight Controls - Aileron

- Moving the control wheel, or control stick, 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 aircraft to roll to the right.

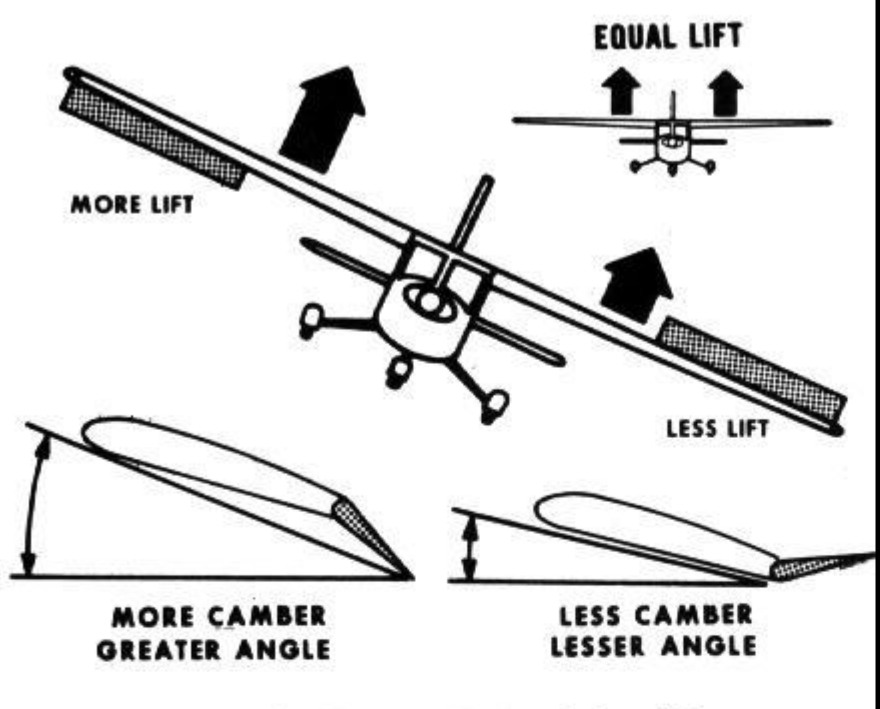
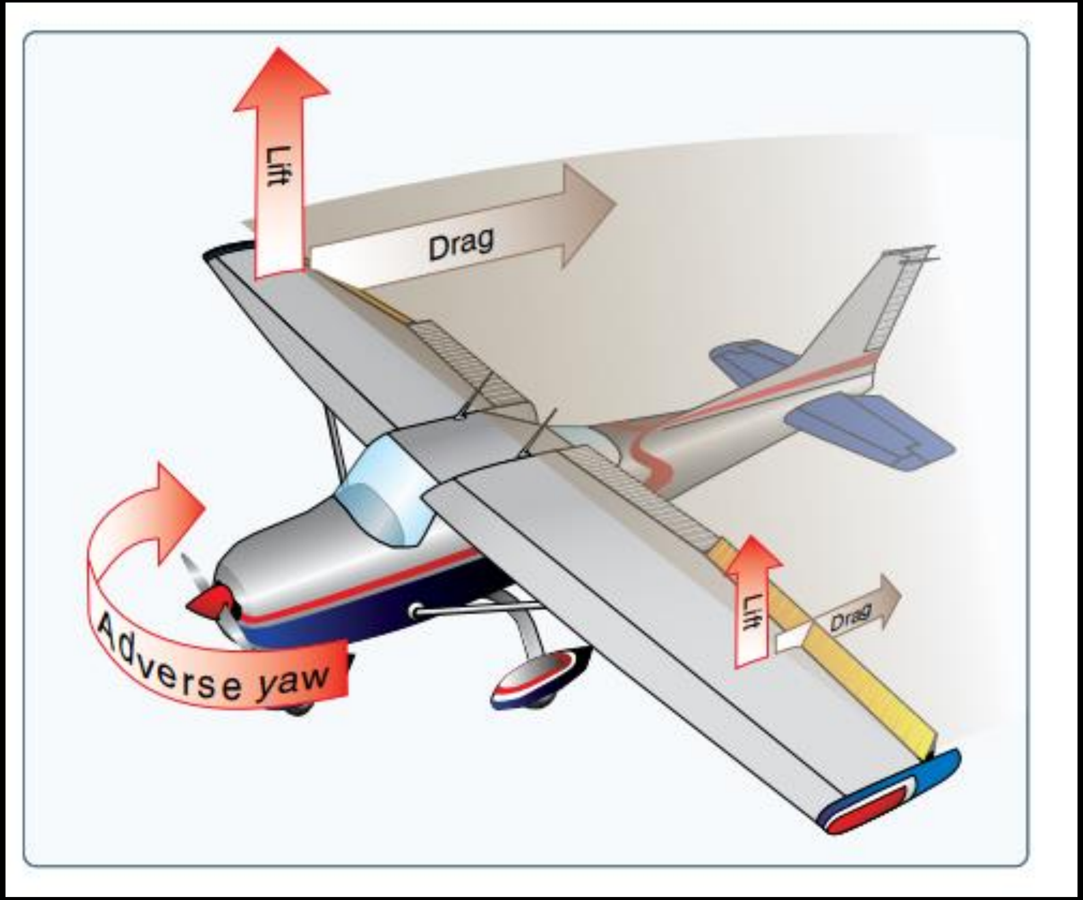


Figure 4–3 Forces Exerted by Ailerons

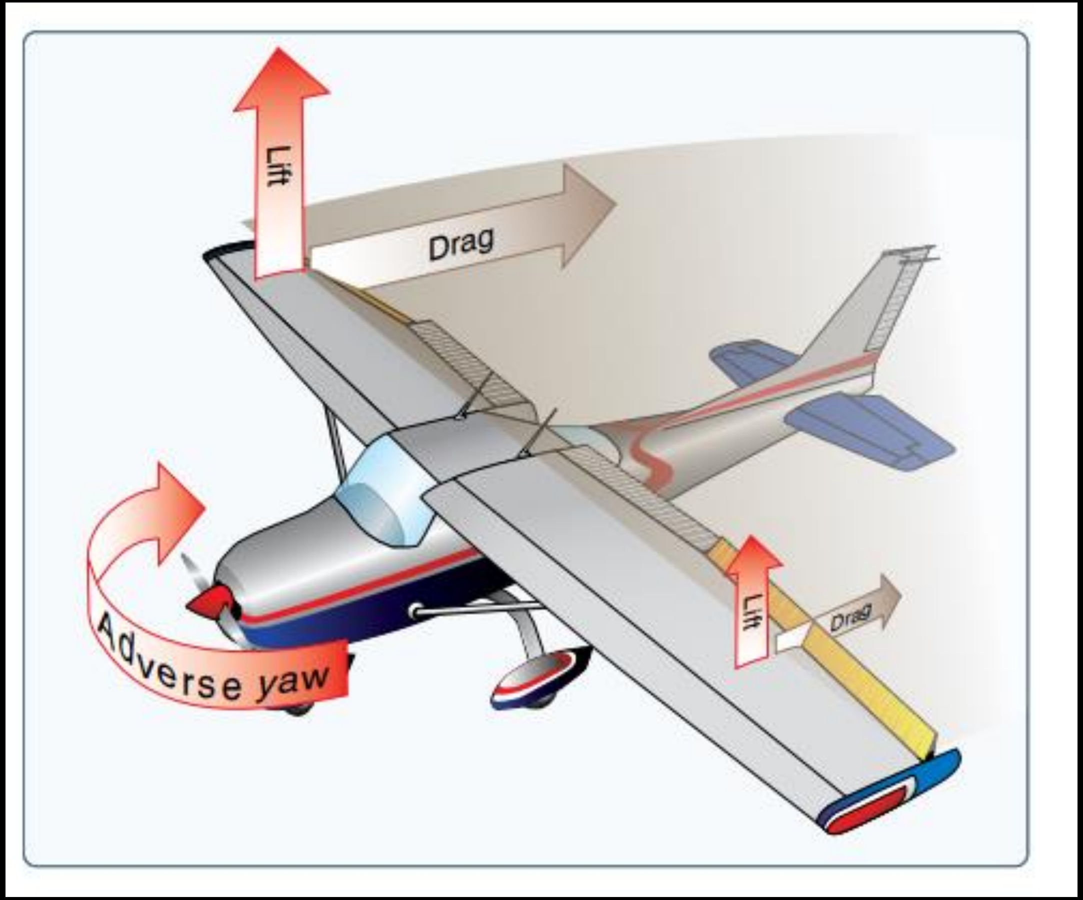
Primary Flight Controls - Aileron

- One MAJOR drawback…
- Adverse Yaw
- Since the downward deflected aileron produces more lift as evidenced by the wing raising, it also produces more drag. This added drag causes the wing to slow down slightly. This results in the aircraft yawing toward the wing which had experienced an increase in lift (and drag).



Primary Flight Controls - Aileron

- What is the solution?
- Rudder and aileron design!



Primary Flight Controls - Aileron

- Four (4) major types of aileron designs exist.
  - Frise-Type
  - Differential
  - Coupler Aileron and Rudder
  - Flaperon
- Each has their own aerodynamic purposes
- All designed to assist control and reduce adverse yaw

Primary Flight Controls - Aileron

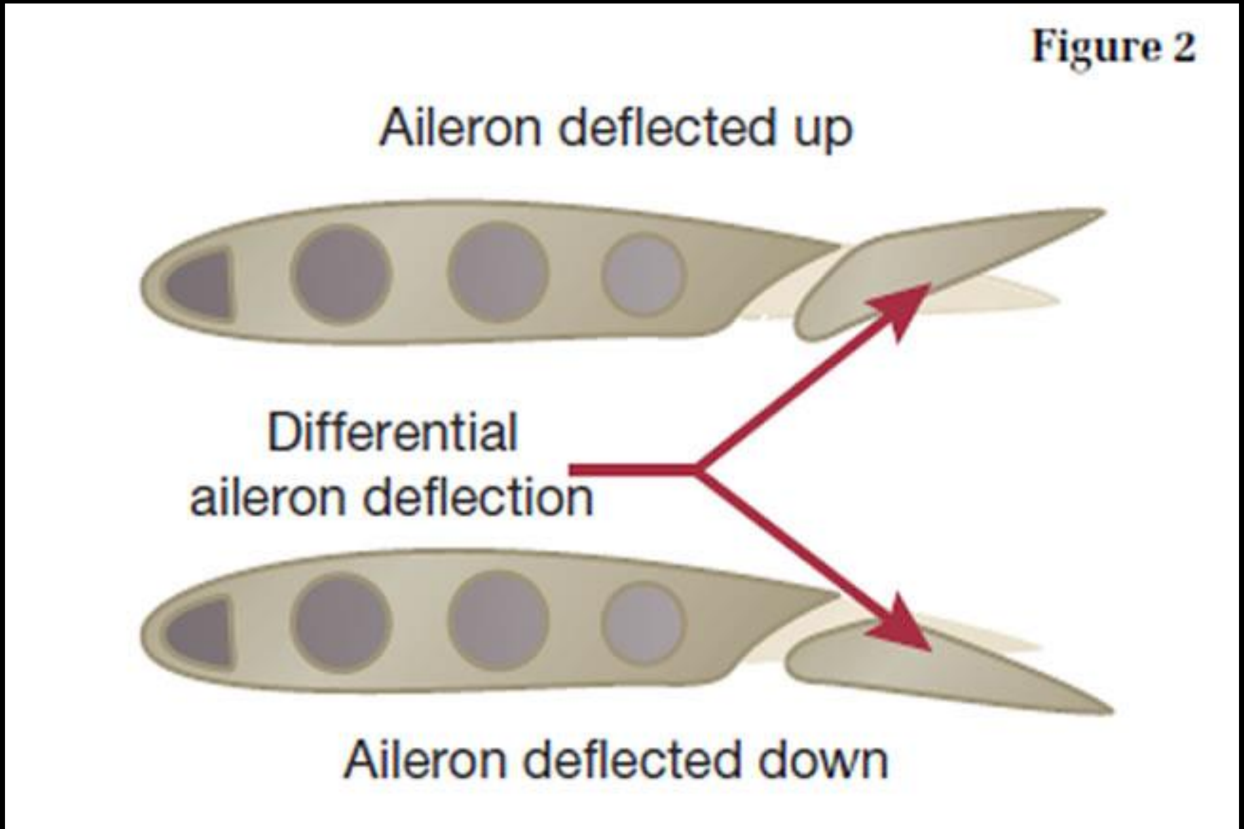
Differential

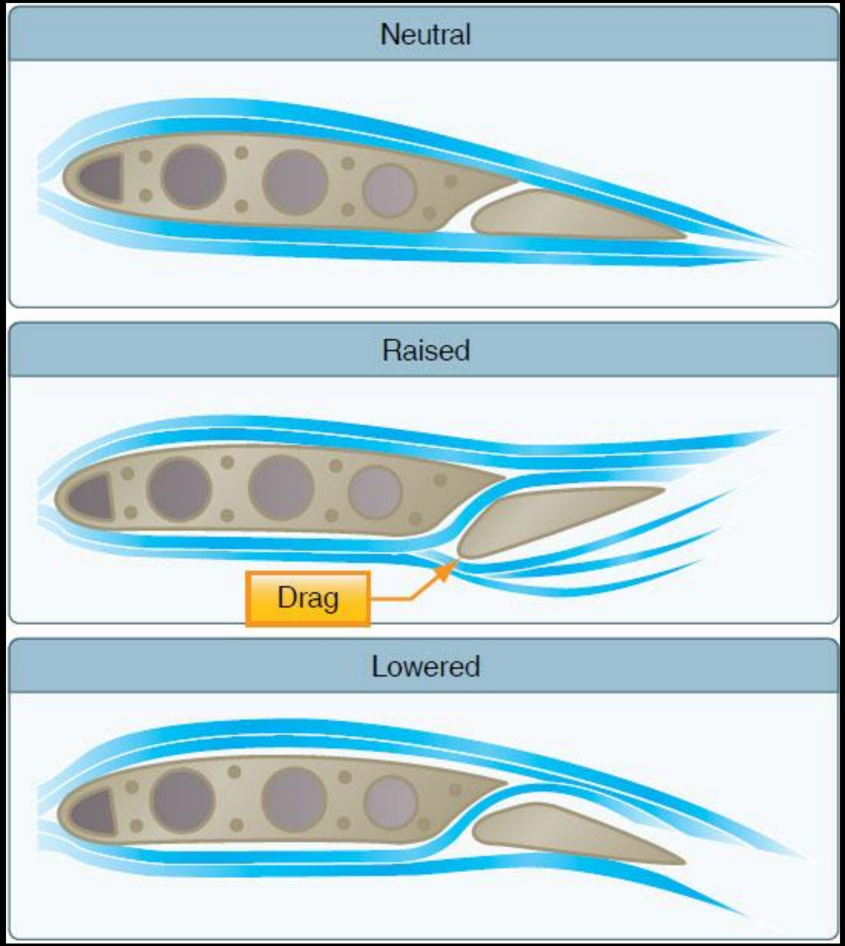
- One aileron is raised a greater distance than the other aileron and is lowered for a given movement of the control wheel or control stick.

Frise-Type

- Pressure is applied to the control wheel, or control 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.

Primary Flight Controls - Aileron





Primary Flight Controls - Aileron

Coupled Aileron and Rudder

- Coupled ailerons and rudder are linked controls.
- 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.

Flaperon

- Flaperons combine both aspects of flaps and ailerons. In addition to controlling the bank angle of an aircraft like conventional ailerons, flaperons can be lowered together to function much the same as a dedicated set of flaps
- Discuss flaps soon

Primary Flight Controls - Aileron

Primary Flight Controls – Aileron/Elevator

- How can we control these two surfaces?
- “Control Wheel” or “Yoke.”
- Most planes have dual controls for instructional purposes

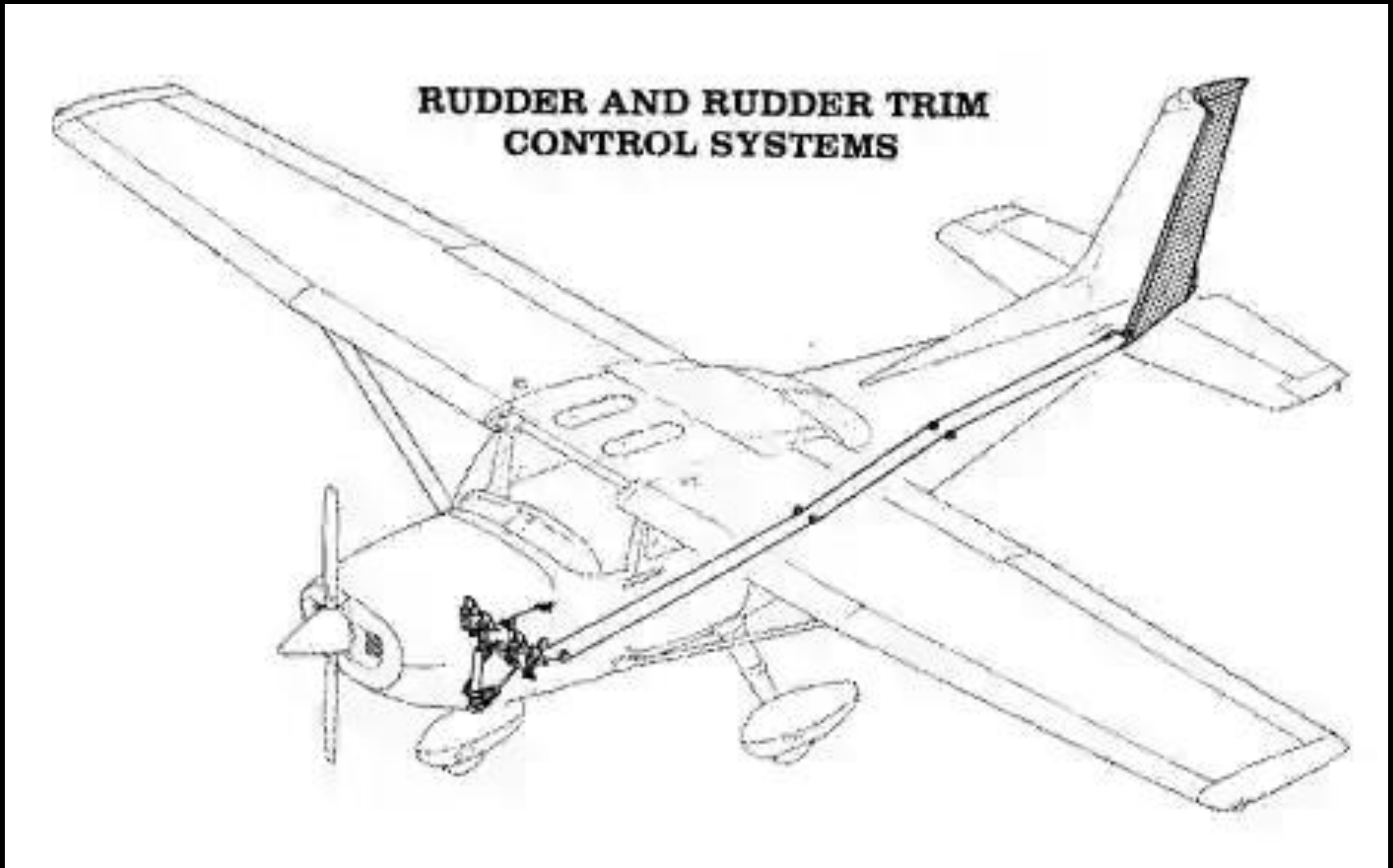
Primary Flight Controls – Aileron/Elevator

- Some airplanes have single control set-up.
- Some airplanes utilize a “stick” instead of a control wheel.

Primary Flight Controls - Rudder

- The rudder controls movement of the aircraft 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.
- The rudder is controlled by the left and right rudder pedals.
- The rudder is actuated using a series of cables and mechanic linkages.

Primary Flight Controls - Rudder



Primary Flight Controls - Rudder

- The top of the rudder pedals control the brakes.
- The bottom of the rudder pedals control the rudder.
- Not all airplanes are the same, some have “Heel Brakes”

Primary Flight Controls - Rudder

- Applying pressure on the left rudder pedal deflects the rudder to the left forcing the tail to the right. (Left Yaw)
- Applying pressure on the right rudder pedal deflects the rudder to the right forcing the tail to the left. (Right Yaw)

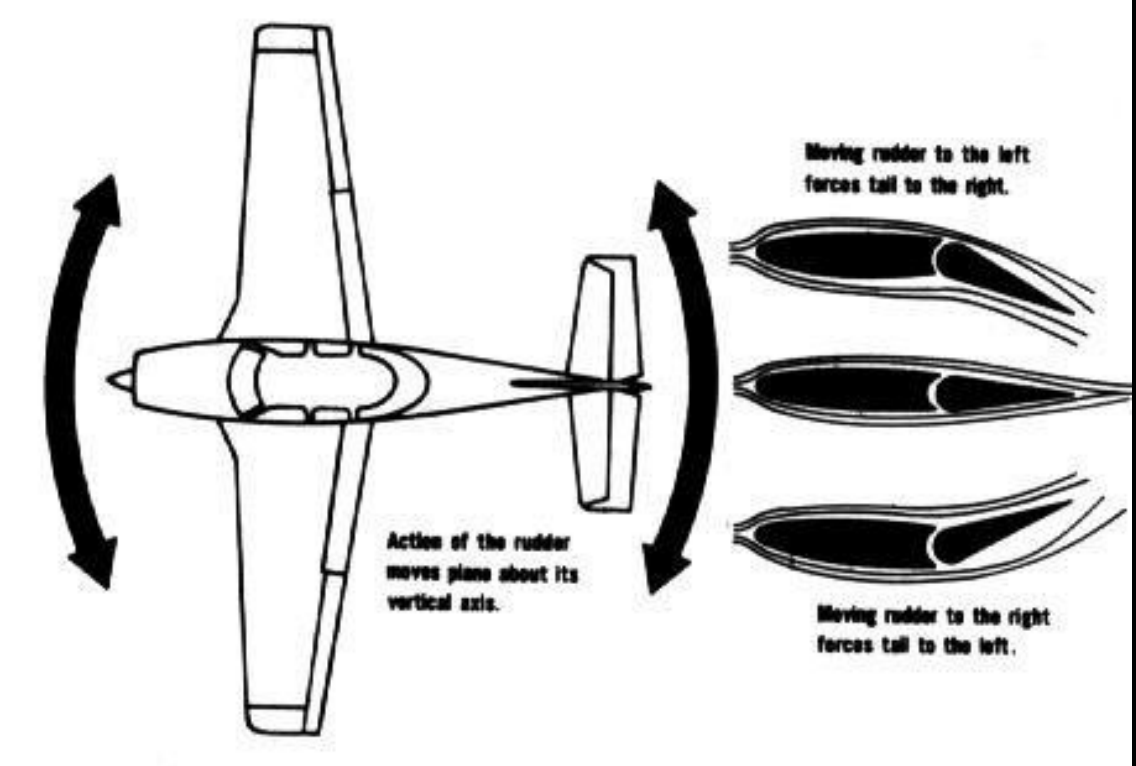


Figure 4–6 Use and Effect of Rudder

Primary Flight Controls - Rudder

Secondary Flight Controls

- Secondary flight control systems may consist of wing flaps, leading edge devices, spoilers, and trim systems.
- Remember, these controls improve the performance characteristics of the airplane or relieve the pilot of excessive control forces.

Secondary Flight Controls – Flaps

- Flaps are the most common high-lift devices used on aircraft.
- These surfaces, which are attached to the trailing edge of the wing, increase both lift and induced drag for any given AOA.
- Flaps allow a compromise between high cruising speed and low landing speed because they may be extended when needed and retracted into the wing’s structure when not needed.
- Four major types of flaps exist:
  - Plain
  - Split
  - Slotted
  - Fowler

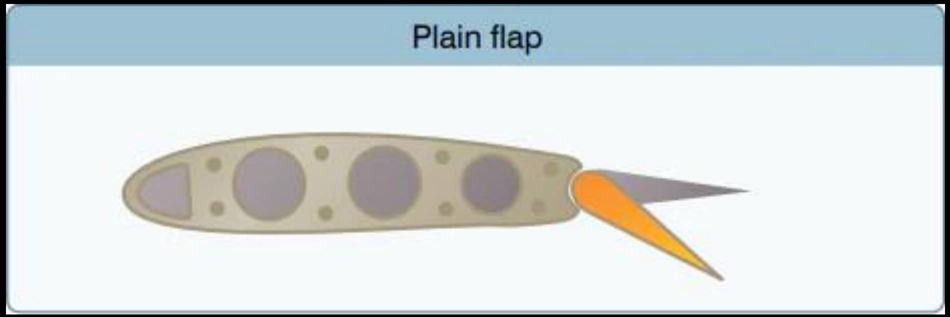
How flaps improve lift

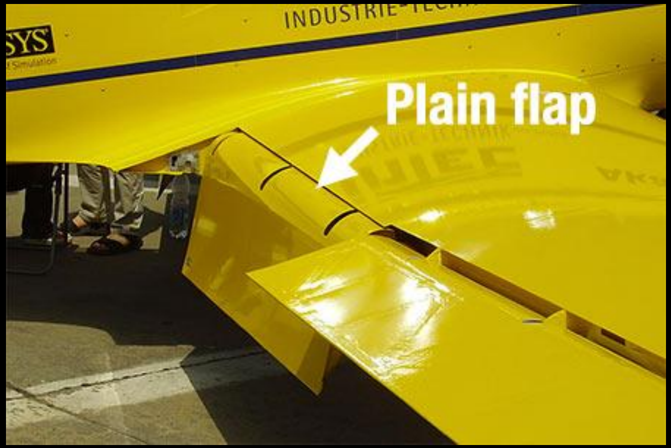
- Chord line change
- Boundry layer separation control
- Wing area increase

Secondary Flight Controls – Flaps

Plain Flaps

- 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.

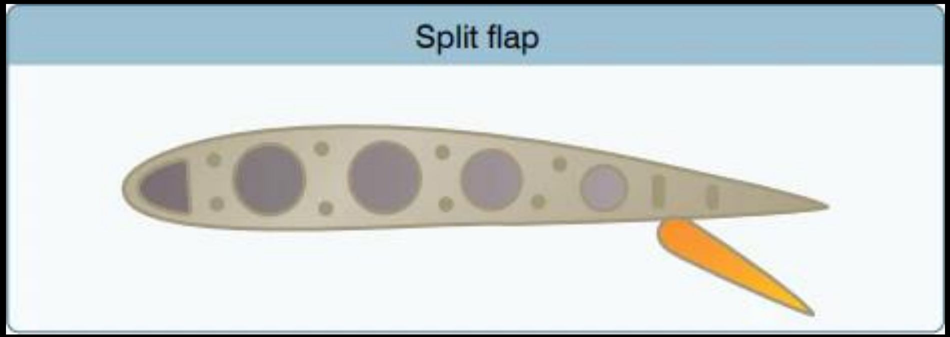




Secondary Flight Controls – Flaps

Split Flaps

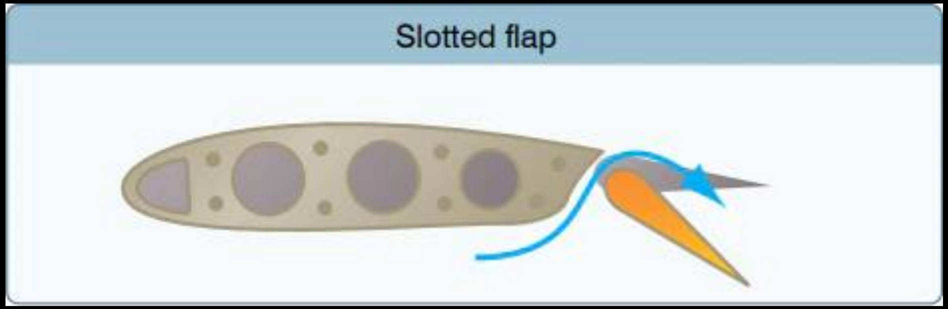
- The split flap is deflected from the lower surface of the airfoil and produces a slightly greater increase in lift than the plain flap.
- More drag is created because of the turbulent air pattern produced behind the airfoil. When fully extended, both plain and split flaps produce high drag with little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



Secondary Flight Controls – Flaps

Slotted Flaps

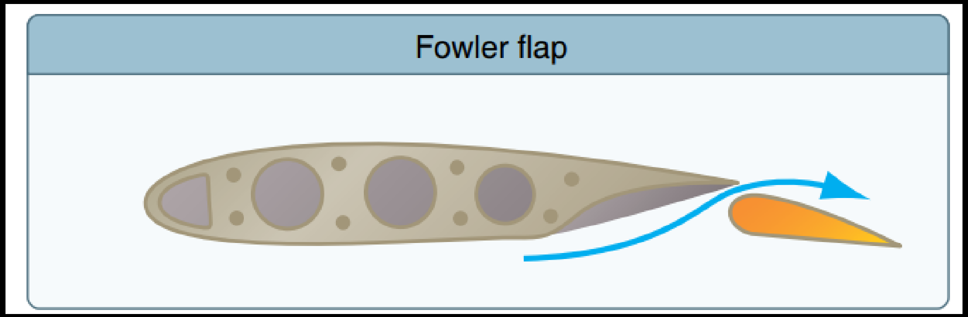
- Slotted flaps increase the lift coefficient significantly more than plain or split flaps. On small aircraft, the hinge is located below the lower surface of the flap, and when the flap is lowered, a duct forms between the flap well in the wing and the leading edge of the flap.
- Air allowed to escape increases lift/drag



Secondary Flight Controls – Flaps

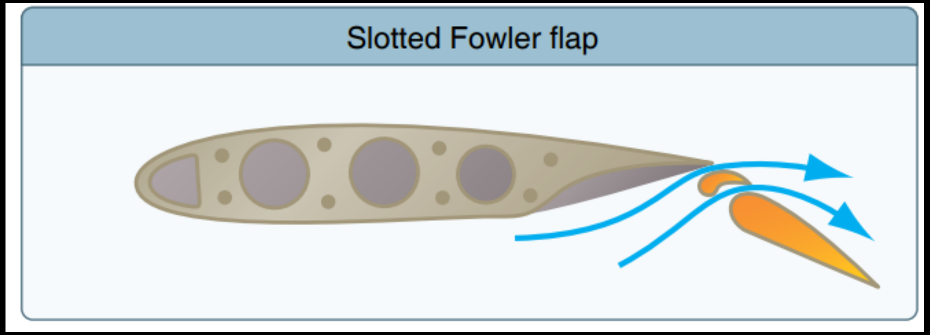
Fowler Flaps

- 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



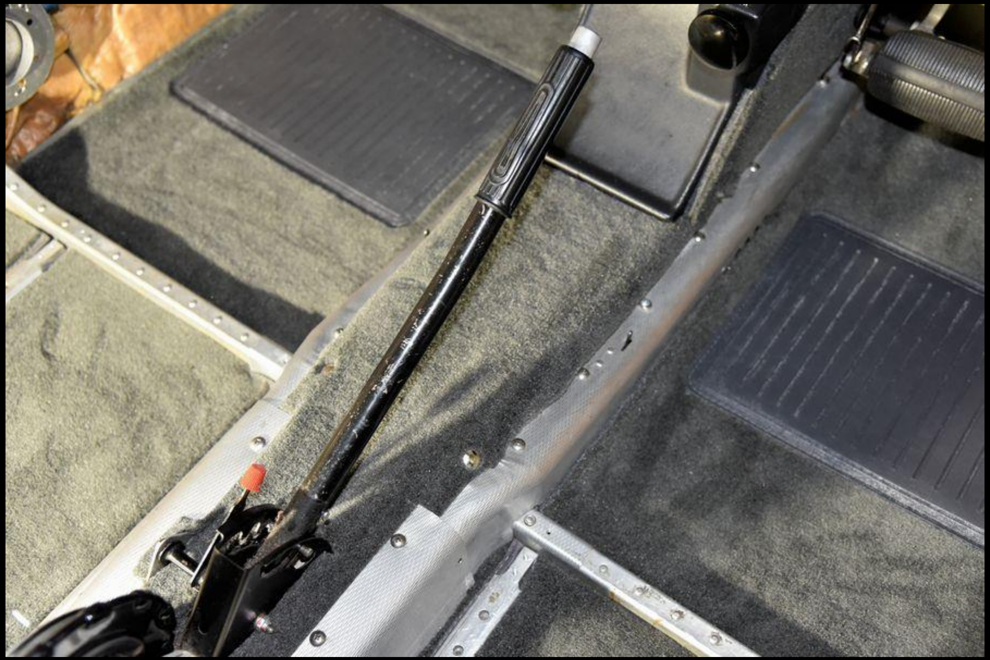
Secondary Flight Controls – Flaps

- Any combination of these flap configurations can exist too.
- Most common is the slotted-fowler



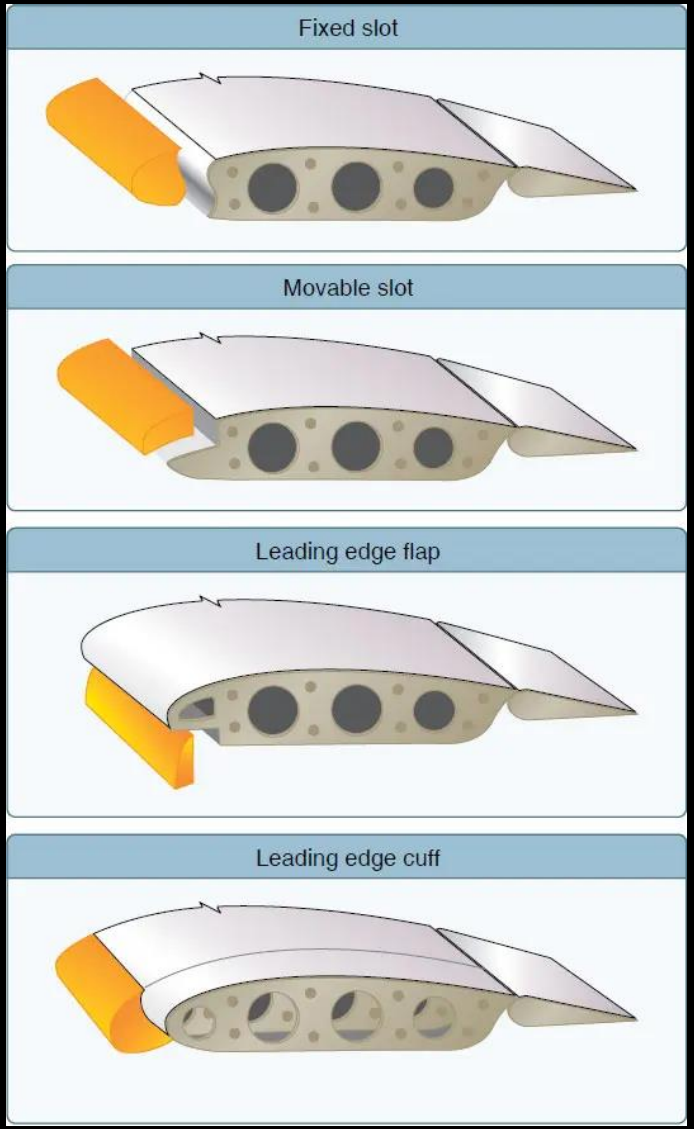
Secondary Flight Controls – Flaps

- Flaps can be operated electrically, hydraulically, or manually.
- Cockpit control of the flaps may also vary from airplane to airplane.



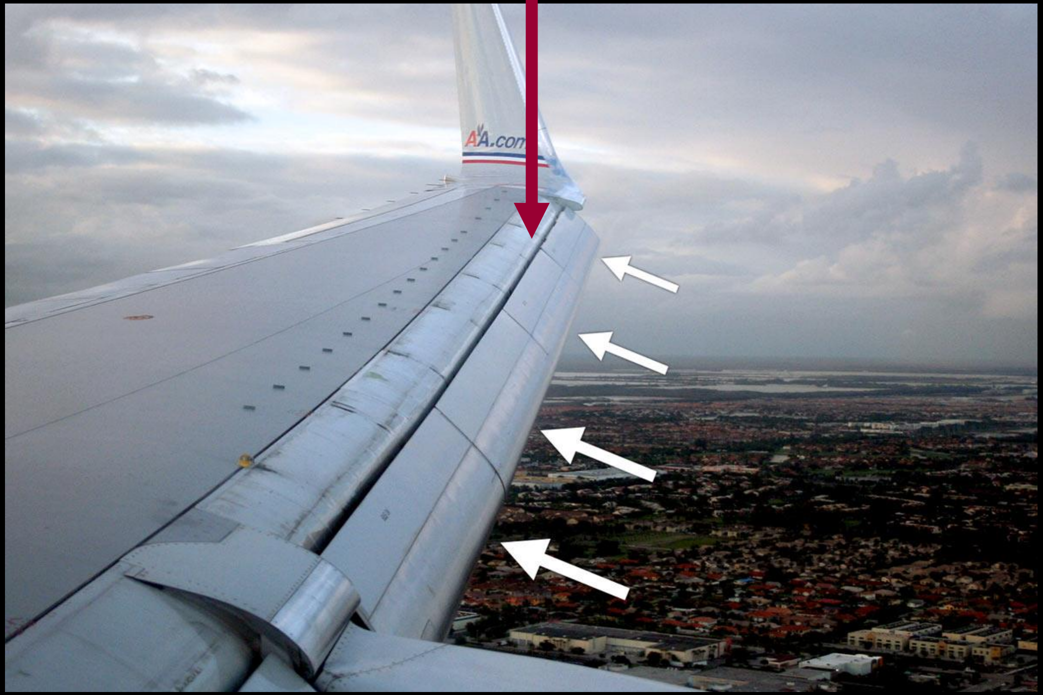
Secondary Flight Controls – LE Devices

- High-lift devices also can be applied to the leading edge of the airfoil. The most common types are fixed slots, movable slats, leading edge flaps, and cuffs.
- Common on larger aircraft but can be seen on smaller ones.

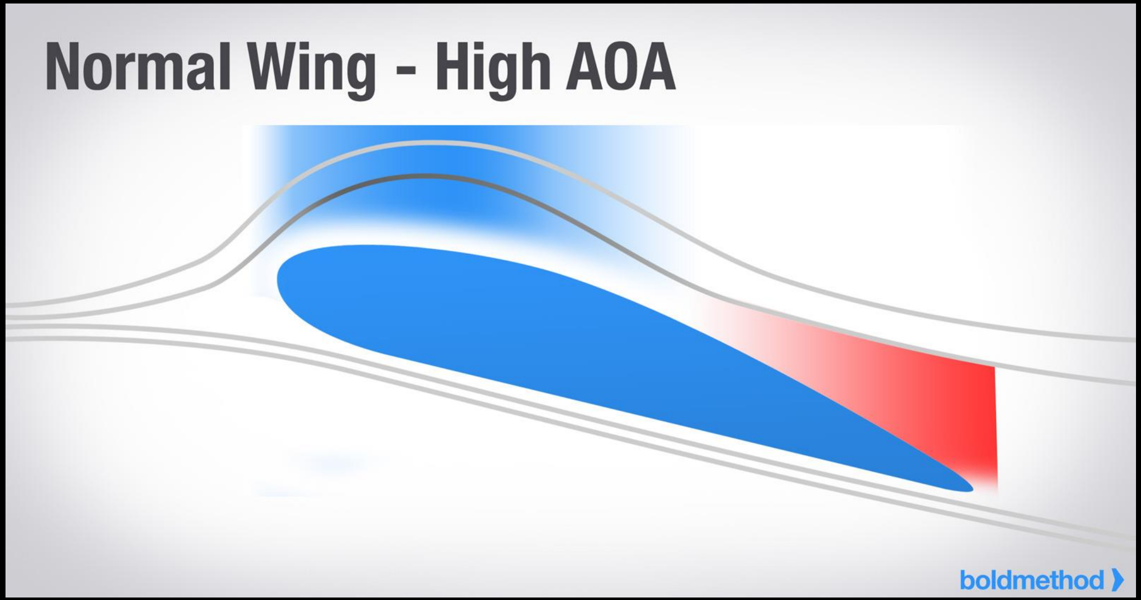


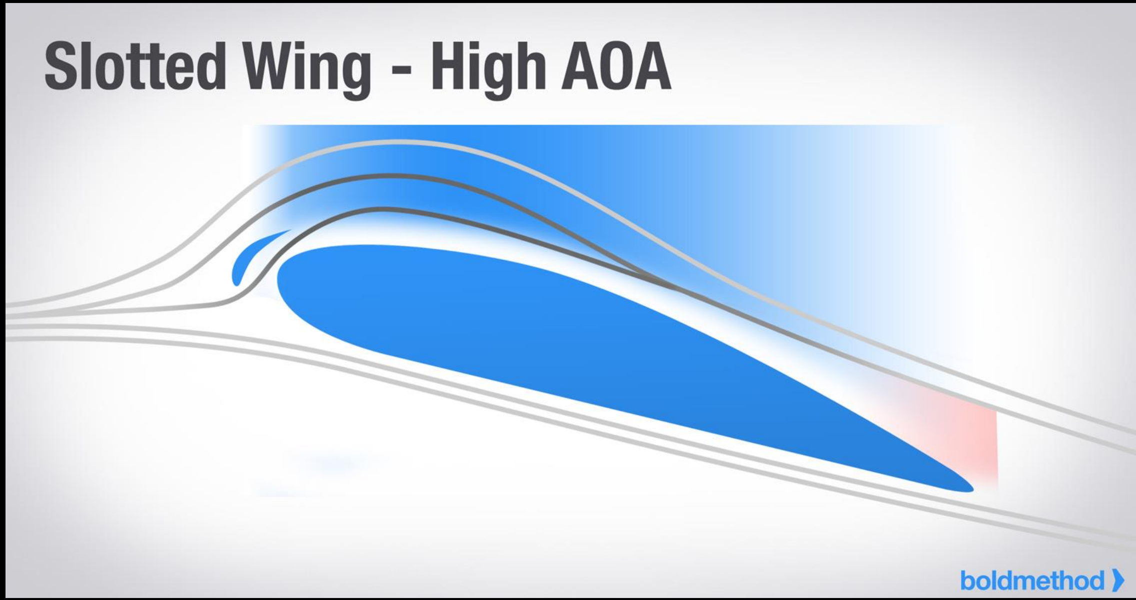
Secondary Flight Controls – LE Devices

- LE fixed slot
- LE moveable slats

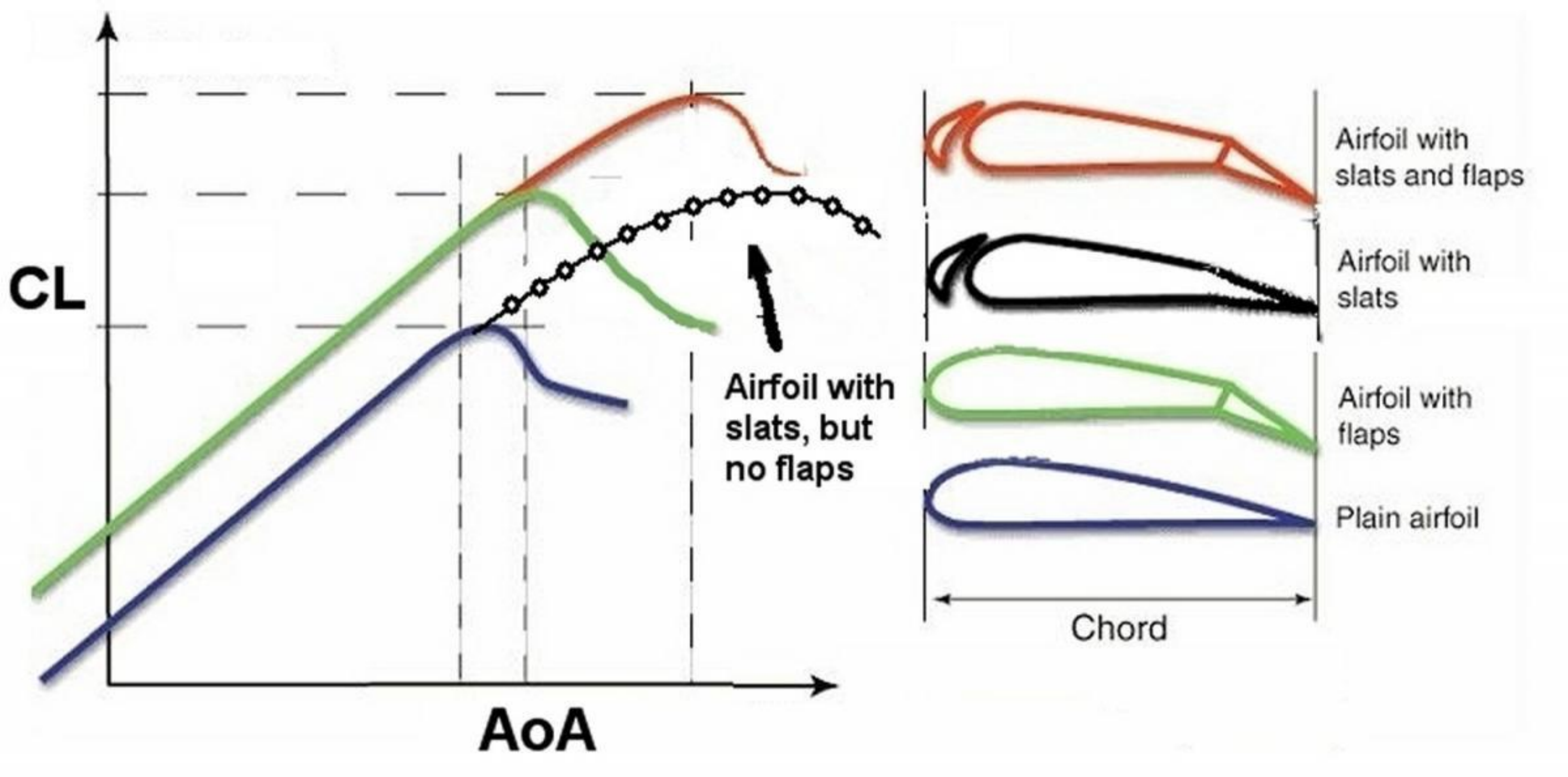


Secondary Flight Controls – LE Devices





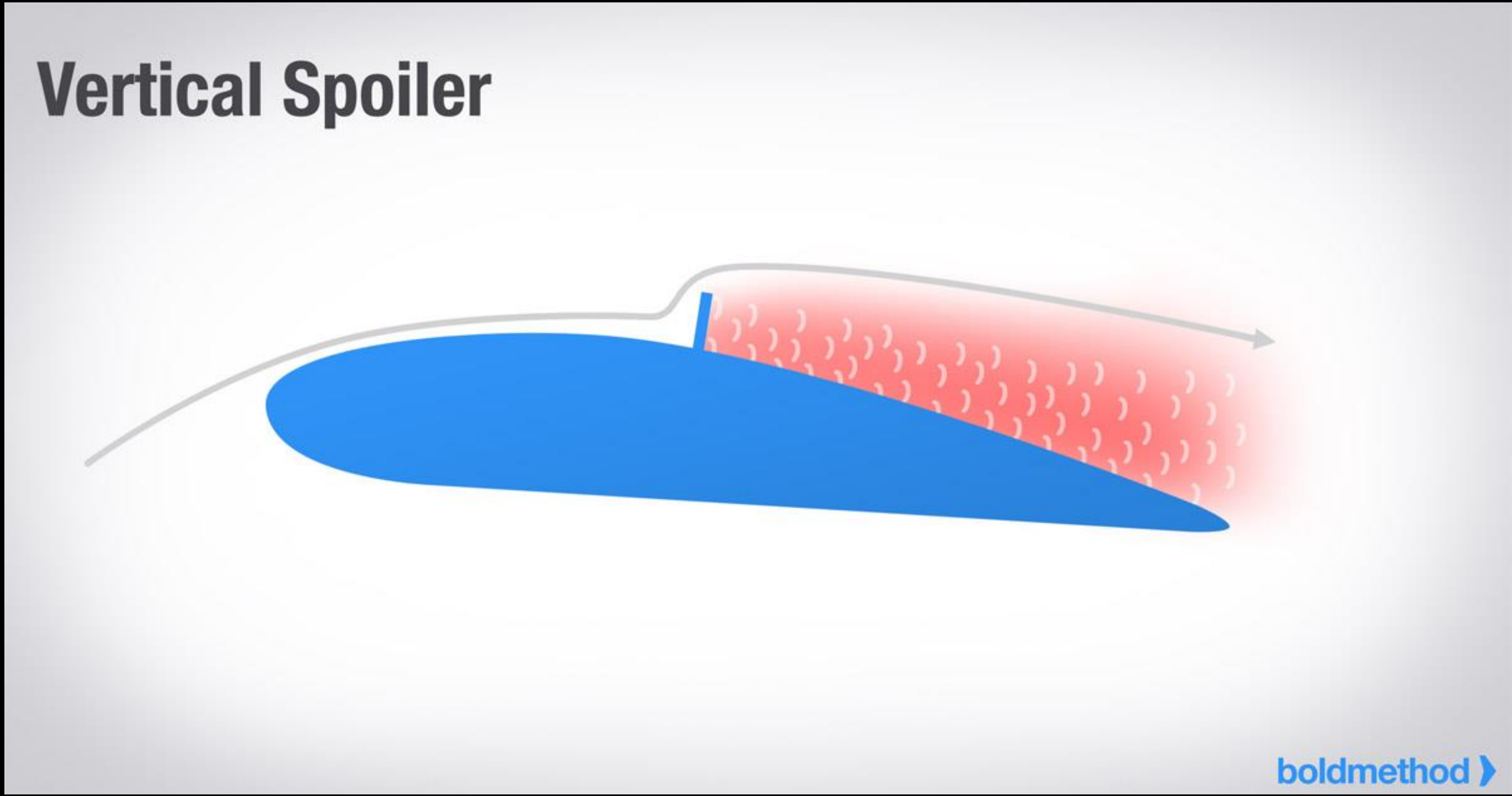
Secondary Flight Controls – LE Devices



Secondary Flight Controls – Spoilers

- Found on some fixed-wing aircraft, 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.

Secondary Flight Controls – Spoilers



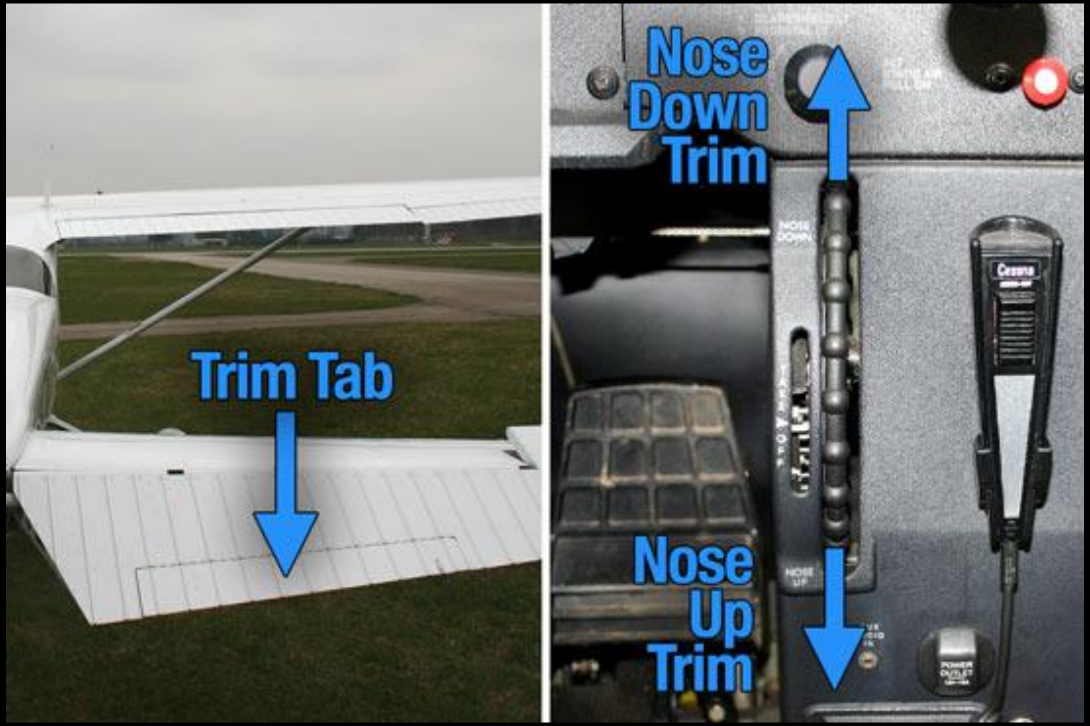
Secondary Flight Controls – Trim

- 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.
- Designed to help minimize a pilot’s workload, trim systems aerodynamically assist 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.

Secondary Flight Controls – Trim

Trim Tab

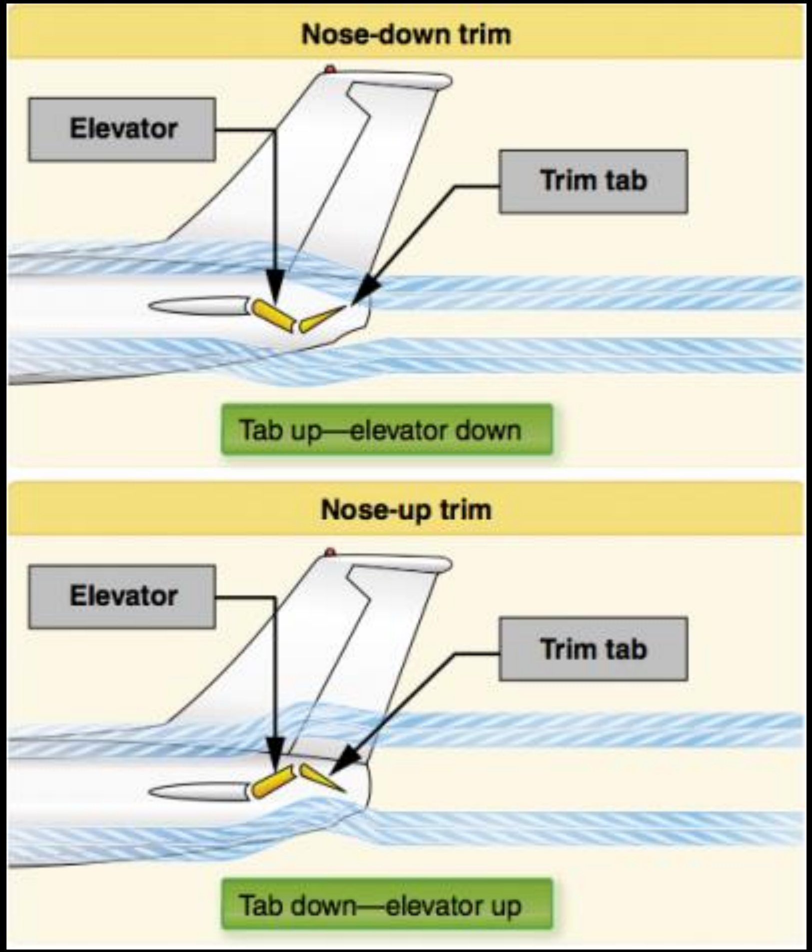
- The most common installation on small aircraft is a single trim tab attached to the trailing edge of the elevator.
- Most trim tabs are manually operated by a small, vertically mounted control wheel. However, a trim crank may be found in some aircraft.
- The flight deck control includes a trim tab position indicator.



Secondary Flight Controls – Trim

Trim Tab – Nose Down

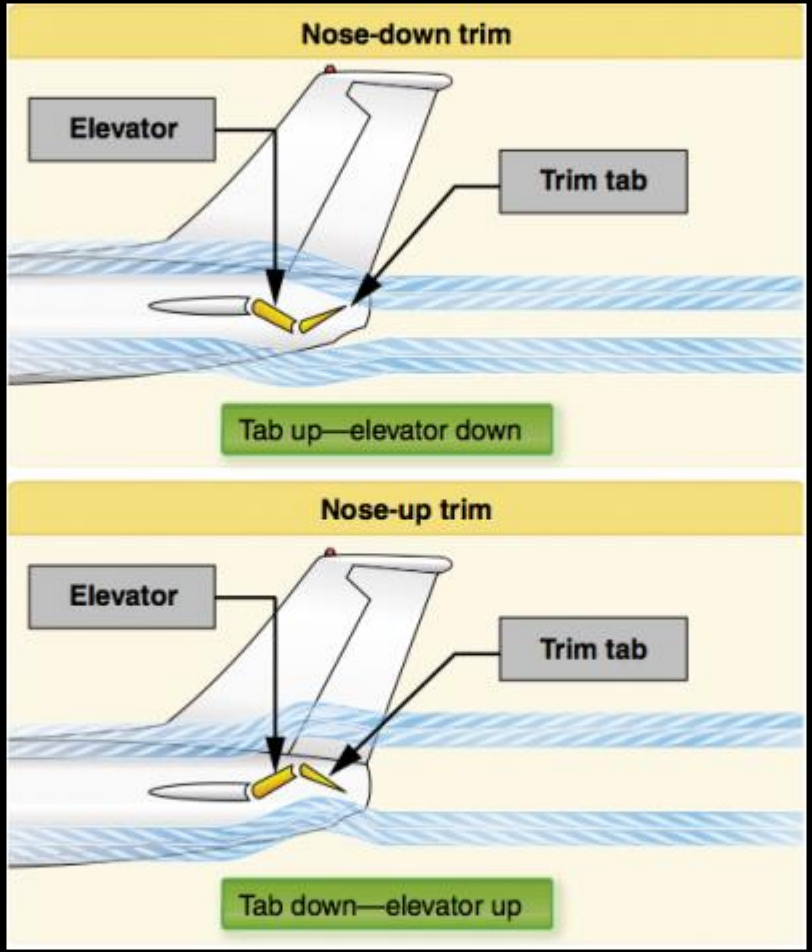
- Placing the trim control in the full nose-down position moves the trim tab to its full up position.
- With the trim tab up and into the airstream, the airflow over the horizontal tail surface tends to force the trailing edge of the elevator down.
- This causes the tail of the aircraft to move up and the nose to move down.



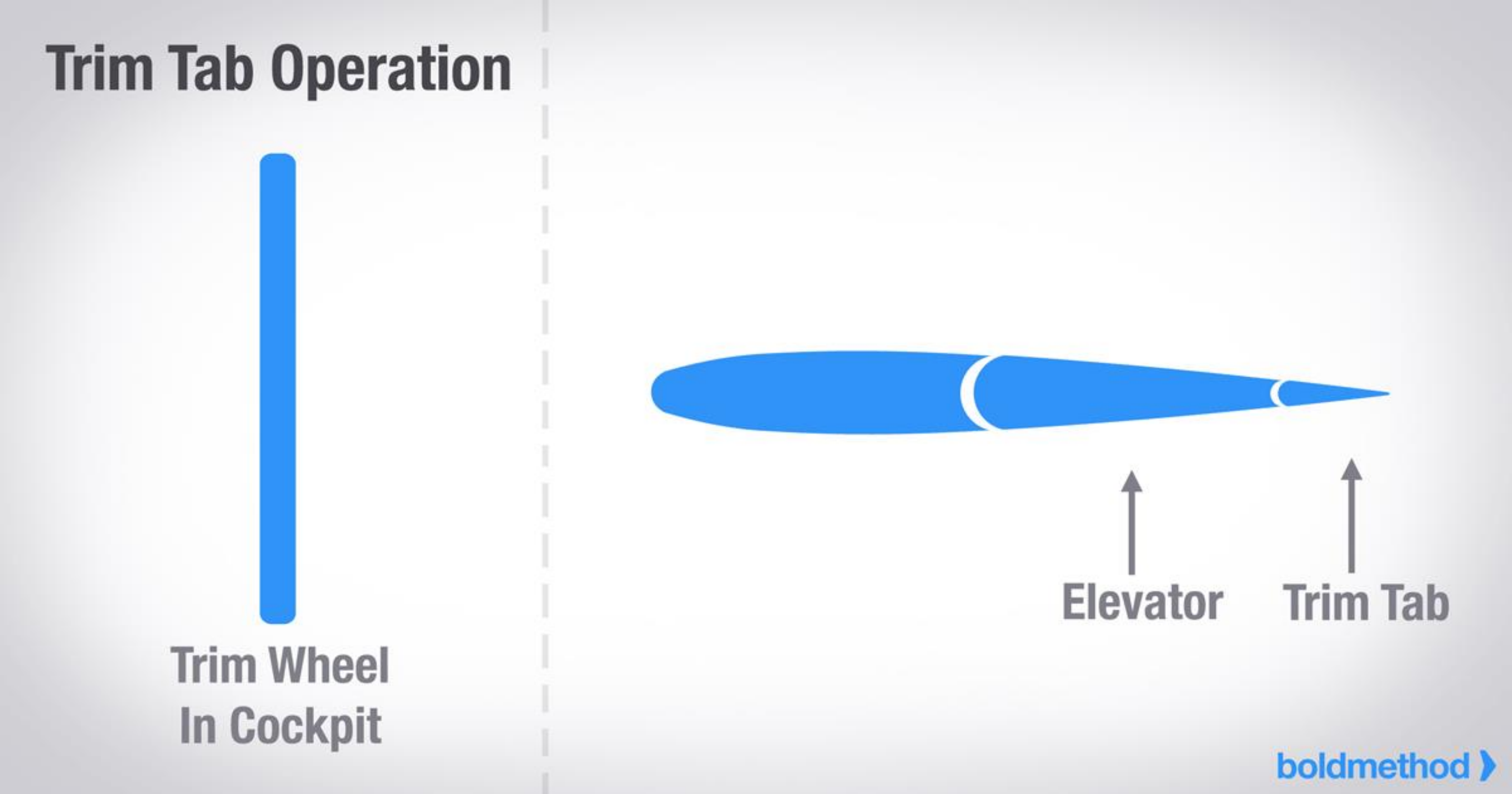
Secondary Flight Controls – Trim

Trim Tab – Nose Up

- If the trim tab is set 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 forces the trailing edge of the elevator up, reducing the elevator's AOA.
- This causes the tail of the aircraft to move down and the nose to move up.



Secondary Flight Controls – Trim

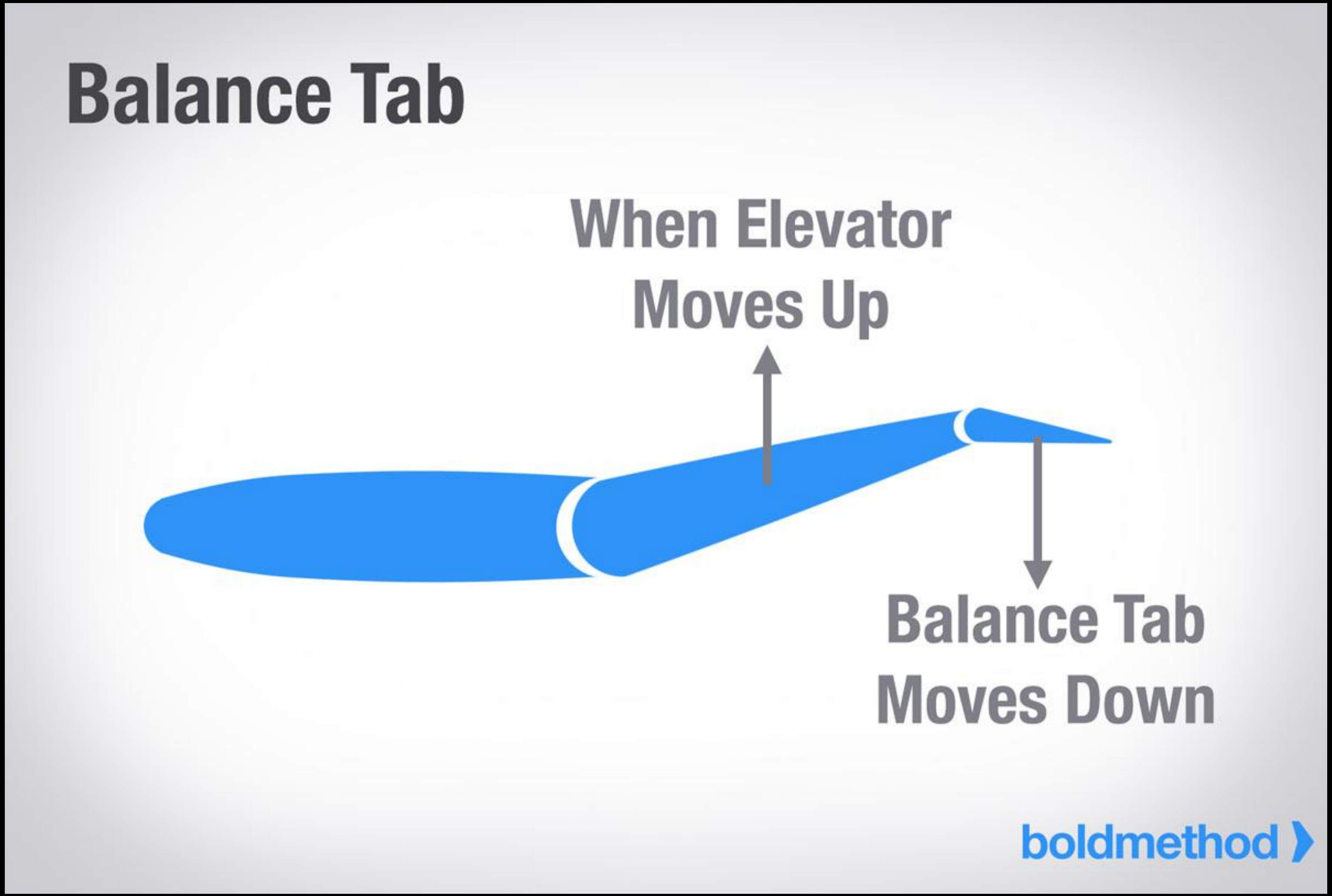


Secondary Flight Controls – Trim

Balance Tab

- The control forces may be excessively high in some aircraft, 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

Secondary Flight Controls – Trim



Secondary Flight Controls – Trim

Fixed Trim Tab

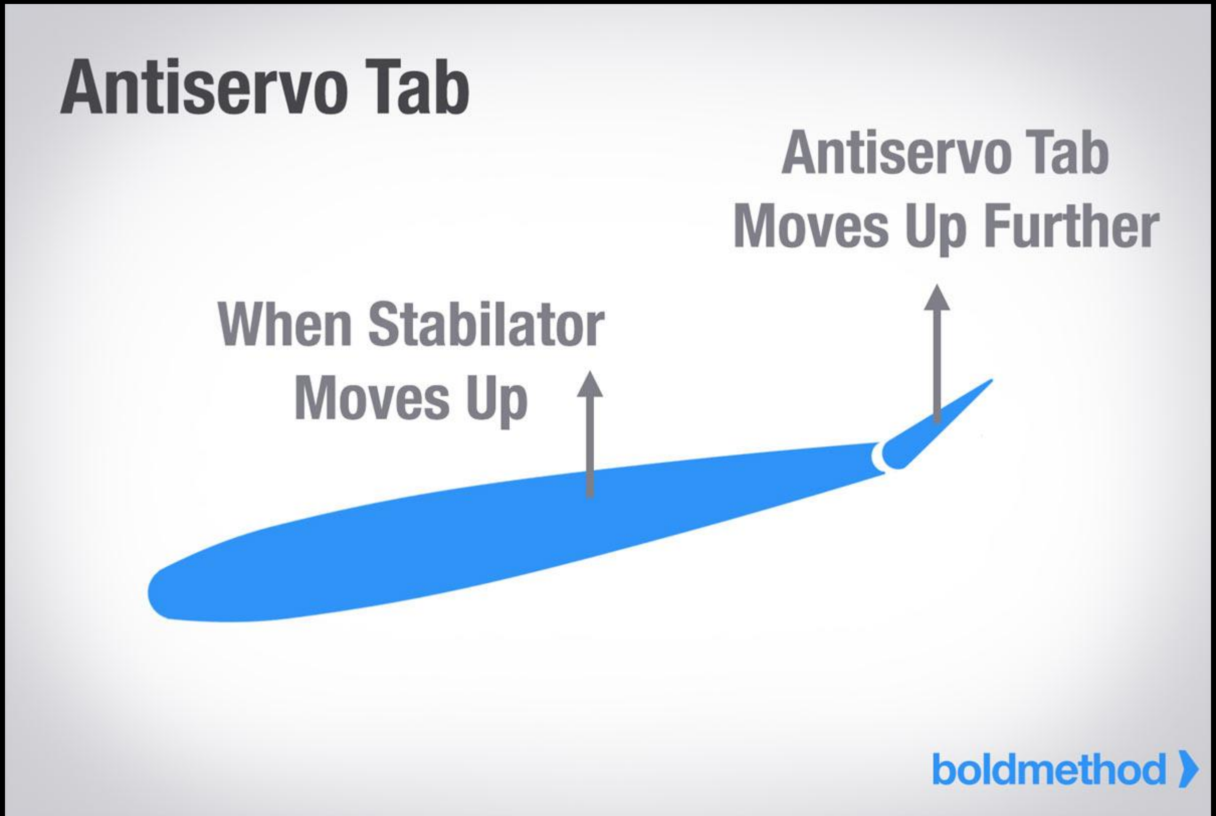
- A servo tab is a small portion of a flight control surface that deploys in such a way that it adjustments are necessary until the aircraft no longer skids left or right during normal cruising flight.

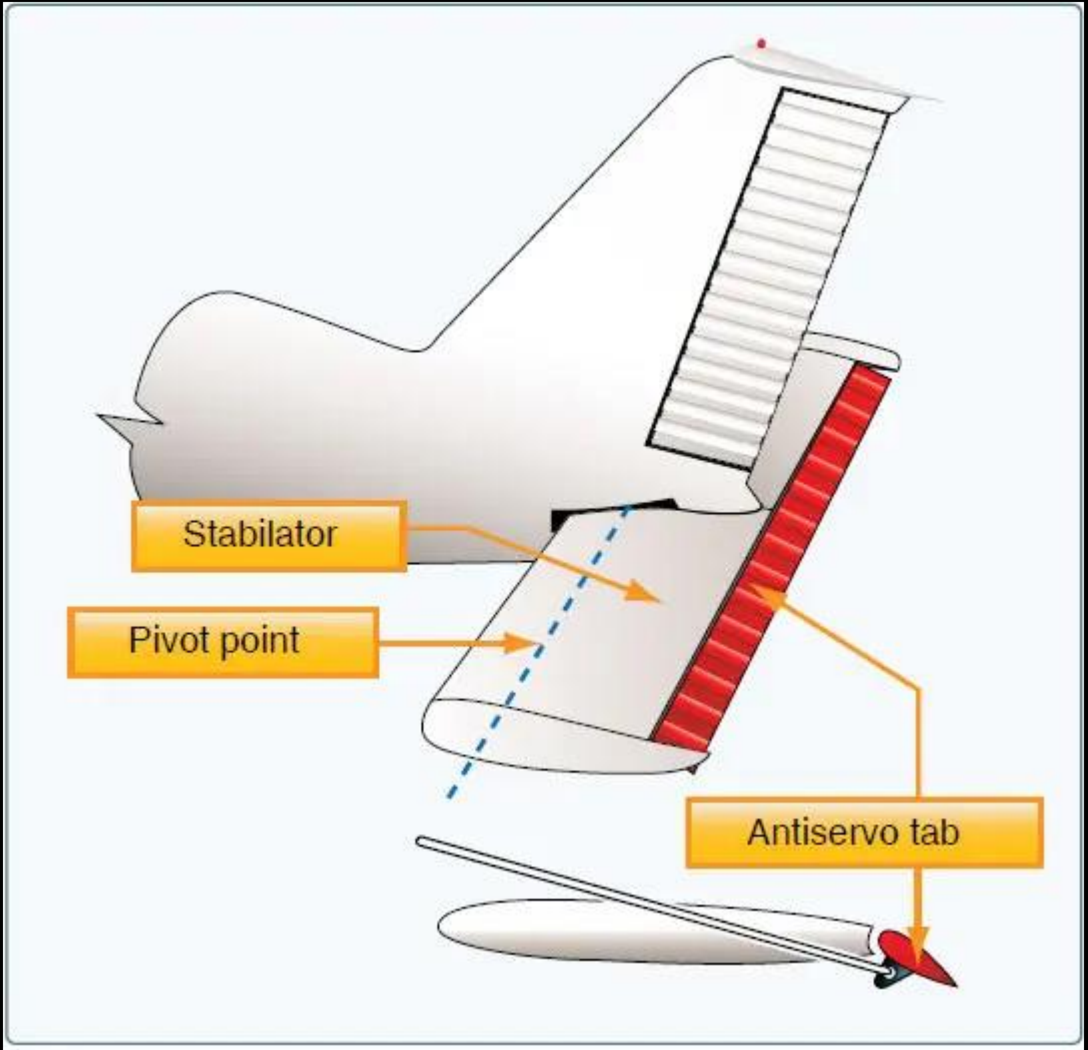
Secondary Flight Controls – Trim

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.

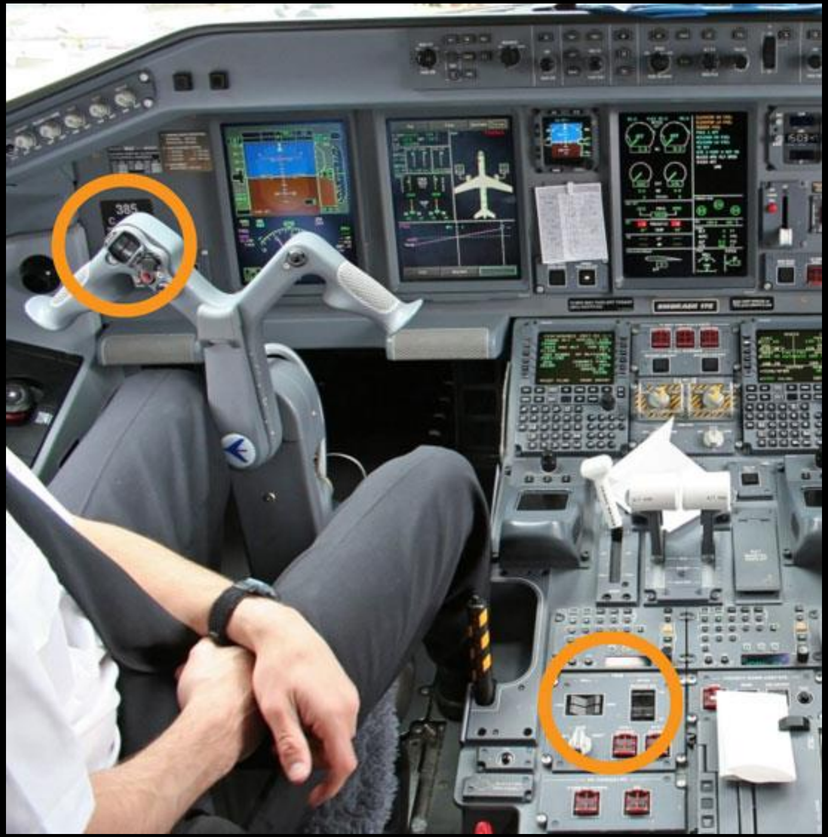
Secondary Flight Controls – Trim





Secondary Flight Controls – Trim

- Not all aircraft trim is operated manually. Many can be operated through manual and electrical sources.
- Comes with risk…



Autopilot

- Autopilot is an automatic flight control system that keeps an aircraft in level flight or on a set course.
- It can be directed by the pilot, or it may be coupled to a radio navigation signal.
- Autopilot reduces the physical and mental demands on a pilot and increases safety.
- The common features available on an autopilot are altitude and heading hold.

Autopilot

COBHAM
FIFTY FIVE X
HDG NAV APR REV TRIM ALT GS VS
FD
HDG
IAS
NAV
GPSS
VS
ALT
GS
STRAIGHT & Level
AP
AVIDYNE
PUSH SYNC
PUSH SYNC
APPR
DFC90
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BENDIX/KING
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Electrical System

Aircraft Flight Controls and Systems

Electrical System

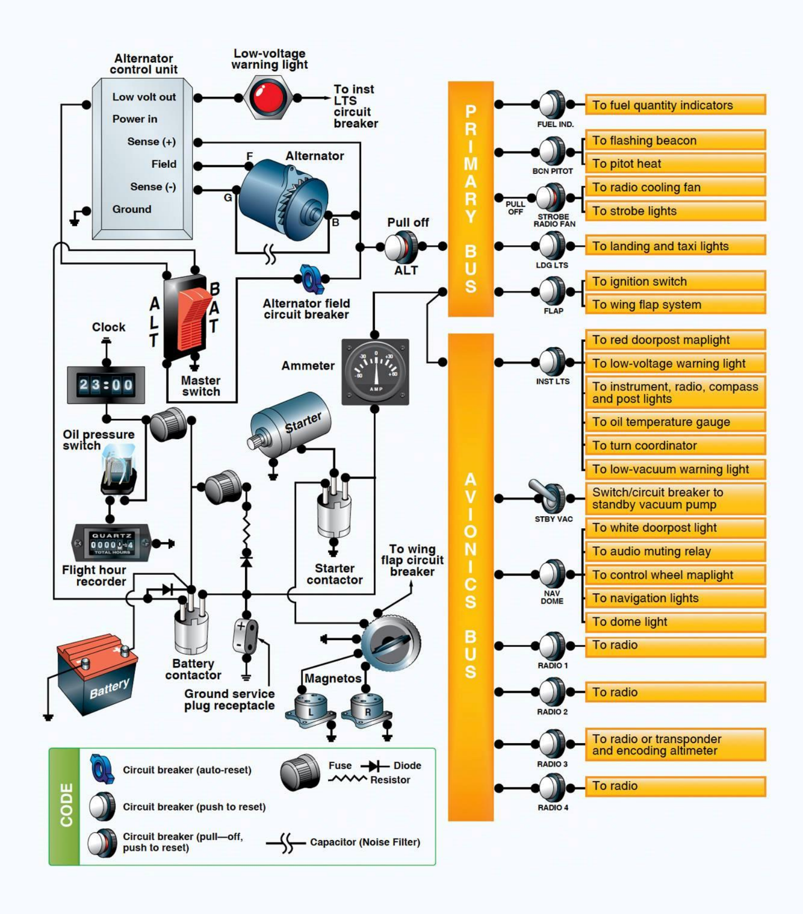
- Most small aircraft are equipped with either a 14 or 28-volt direct current (DC) electrical system
- Engine-driven alternators or generators supply electric current to the electrical system
- They also maintain a sufficient electrical charge in the battery

Electrical System

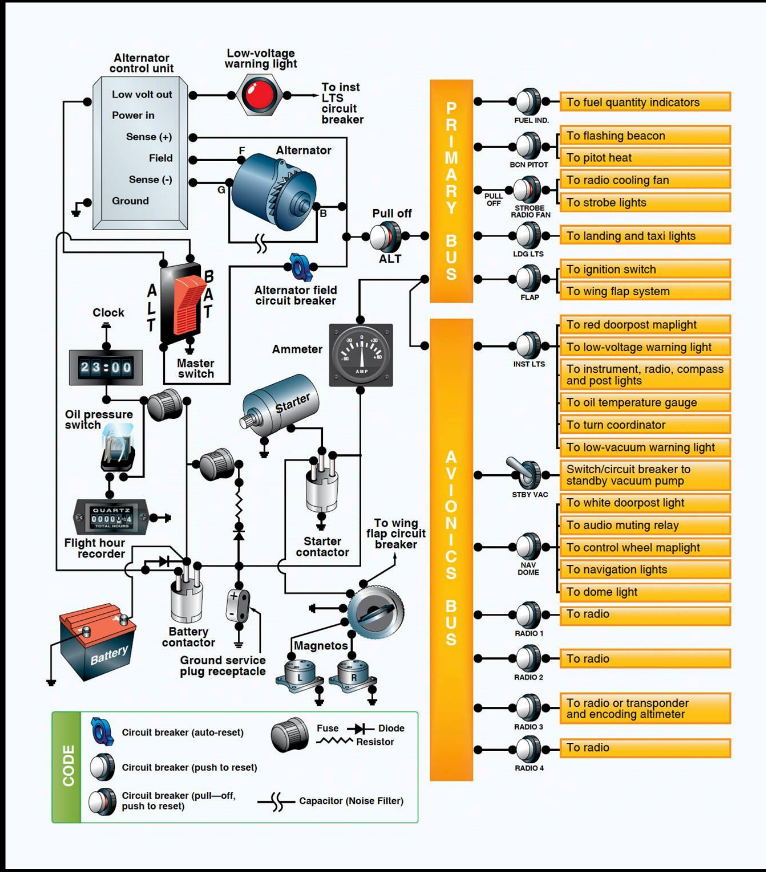
- Electrical energy stored in a battery provides a source of electrical power for starting the engine and a limited supply of electrical power for use in the event the alternator fails
- Alternators produce sufficient current to operate the entire electrical system, even at slower engine speeds by producing alternating current (AC) which is converted to DC
- Output of an alternator is more constant throughout a wide range of engine speeds

Electrical System Components

- Alternator/generator
  Battery
  Master/battery switch
  Alternator/generator switch
  Bus bar, fuses, and circuit breakers
  Voltage regulator
  Ammeter/loadmeter
  Associated electrical wiring



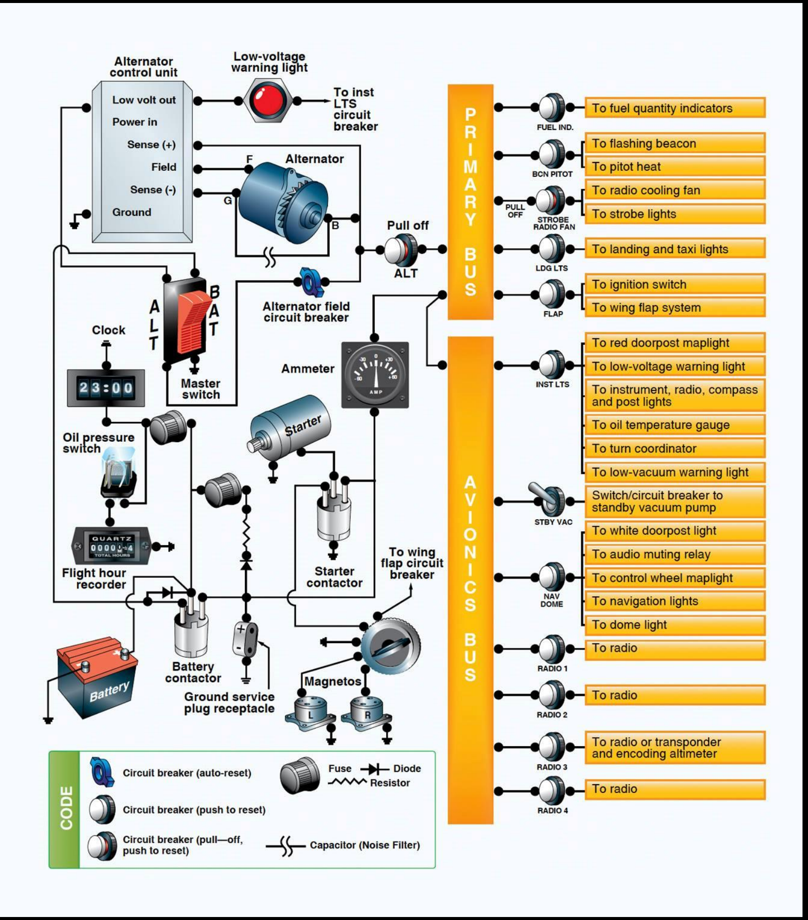
External Ground Power



- Some aircraft have receptacles for an external ground power unit (GPU) connection to provide electrical energy for starting
- Useful during cold weather starting

Voltage Regulator

- Controls the rate of charge to the battery by stabilizing the alternator electrical output
- The alternator voltage output should be higher than the battery voltage
- A 12-volt battery would be fed by a generator/alternator system of approximately 14 volts
- The difference in voltage keeps the battery charged

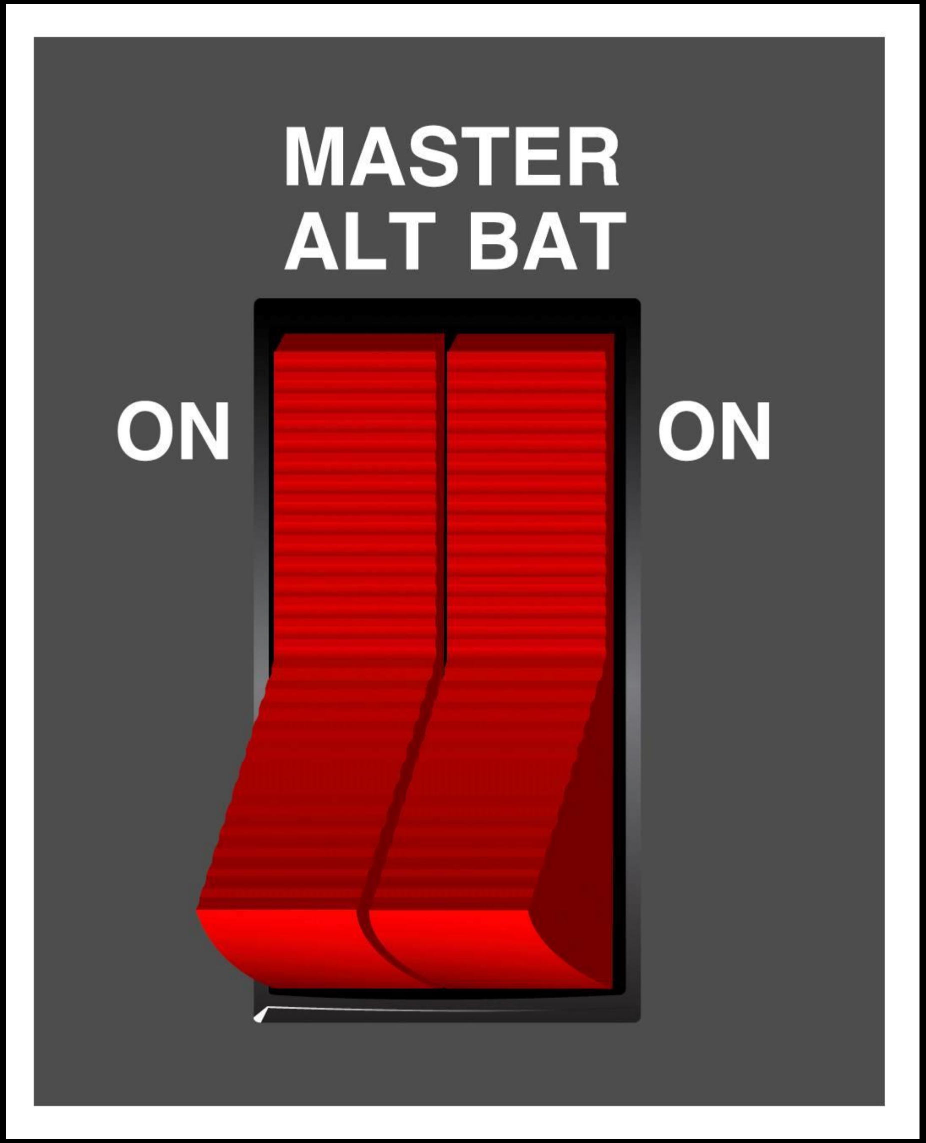


Master Switch

- Master switch to the ON position provides electrical energy to all the electrical equipment circuits except the ignition system:
  - Position lights
  - Anti-collision lights
  - Landing lights
  - Taxi lights
  - Interior cabin lights
  - Instrument lights
  - Radio equipment
  - Turn indicator
  - Fuel gauges
  - Electric fuel pump
  - Stall warning system
  - Pitot heat
  - Starting motor

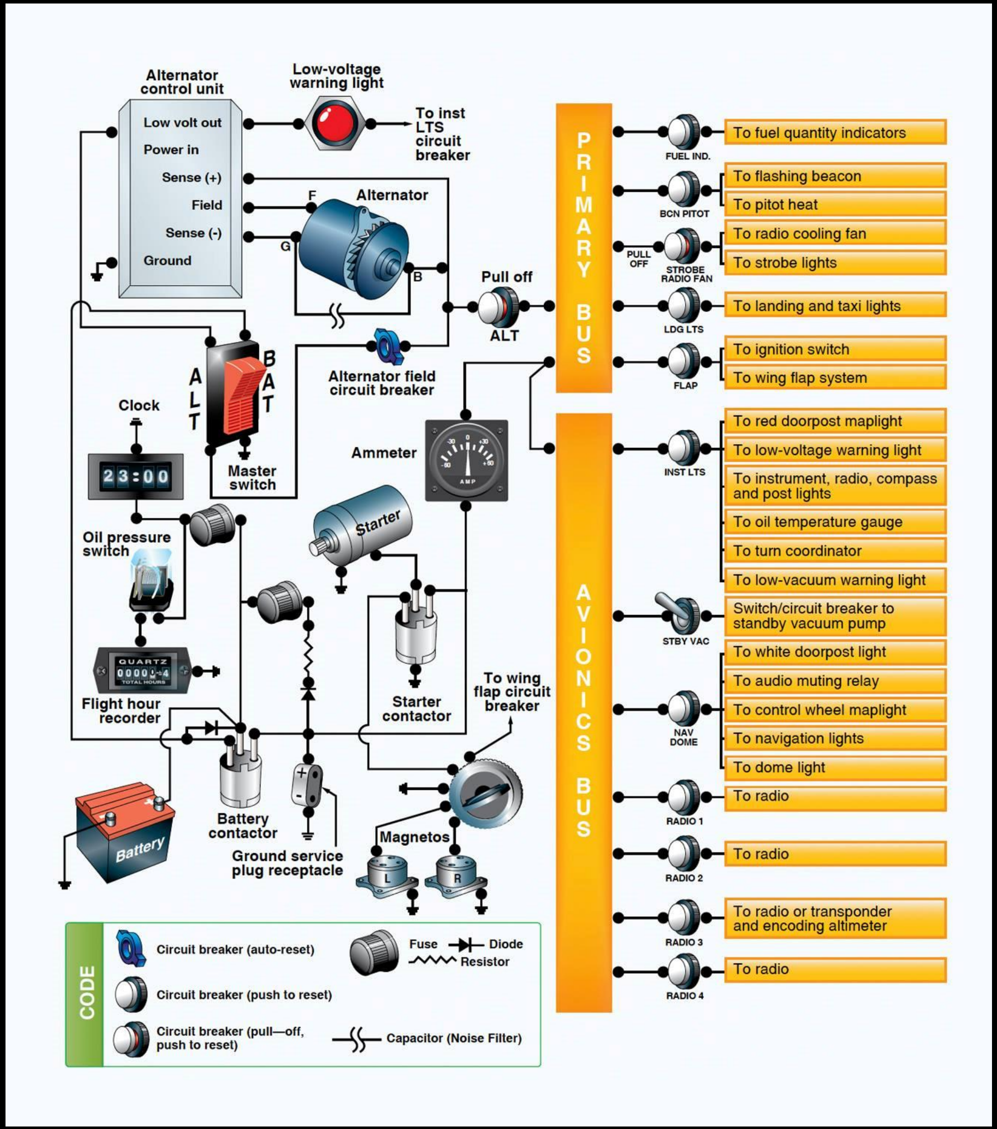
ALT BAT Switch

- Battery switch controls the electrical power to the aircraft in a manner like master switch
- Alternator switch permits the pilot to exclude the alternator from the electrical system in the event of alternator failure
- With the alternator half of the switch in the OFF position the entire electrical load is placed on the battery
- All nonessential electrical equipment should be turned off to conserve battery power

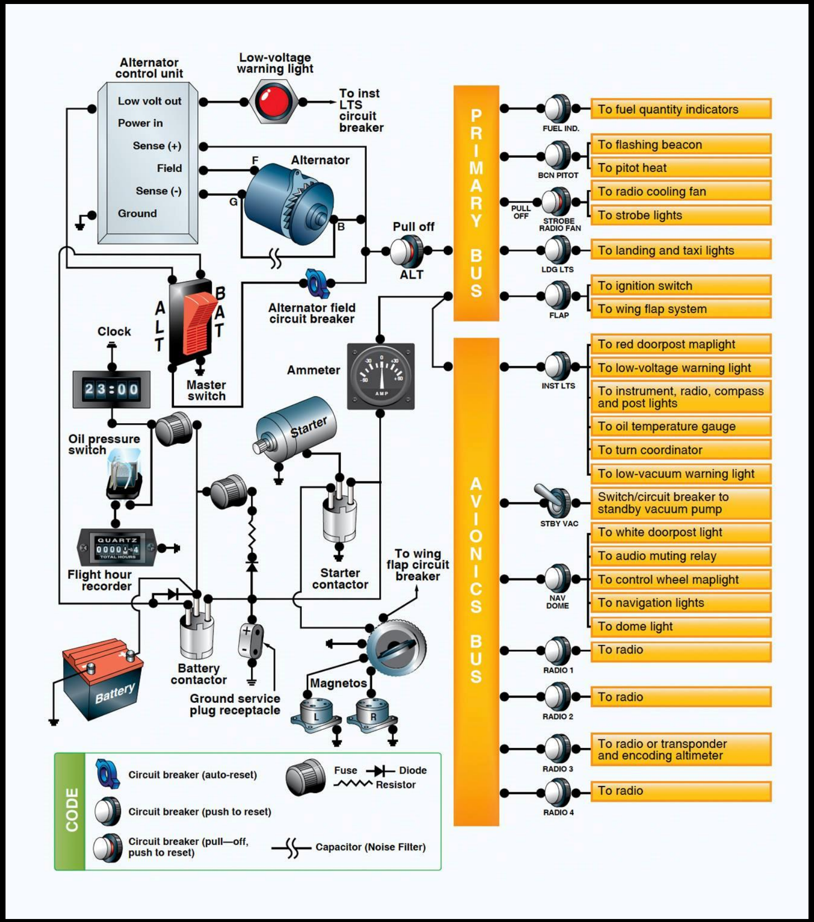


Bus Bar

- Used as a terminal in the electrical system to connect the main electrical system to the equipment using electricity as a source of power
- Simplifies the wiring system and provides a common point from which voltage can be distributed throughout the system



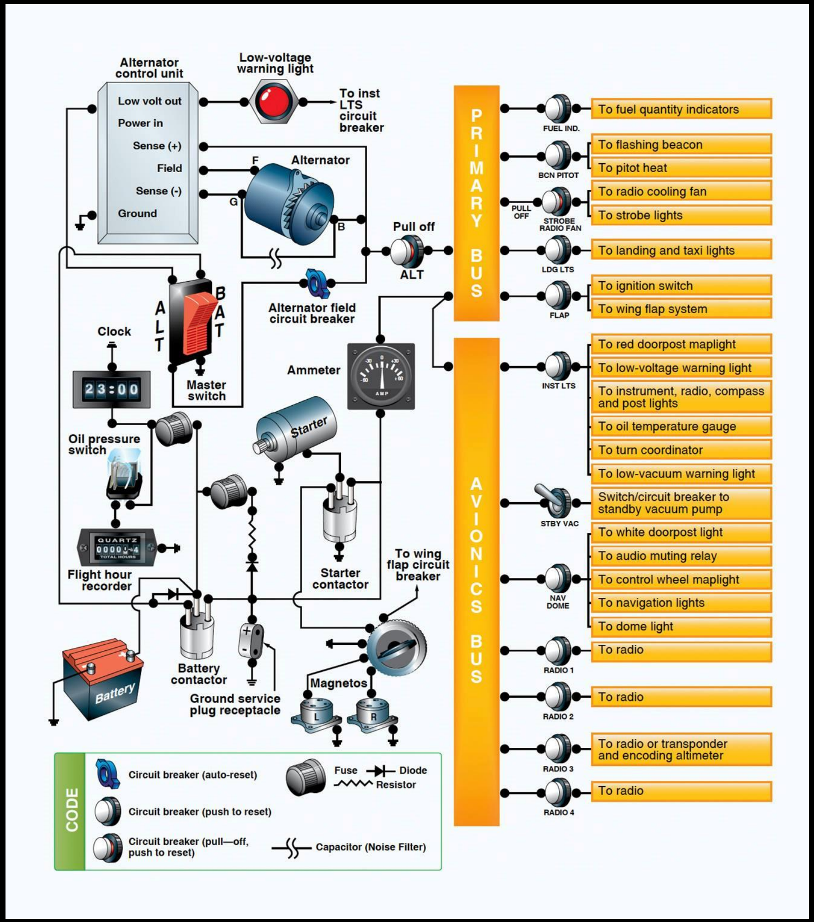
Fuses or Circuit Breakers



- Used to protect the circuits and equipment from electrical overload
- Spare fuses of the proper amperage limit must be carried in the aircraft to replace defective or blown fuses
- Circuit breakers have the same function as a fuse but can be manually reset if an overload condition occurs
- Placards at the fuse or circuit breaker panel identify the circuit by name and show the amperage limit

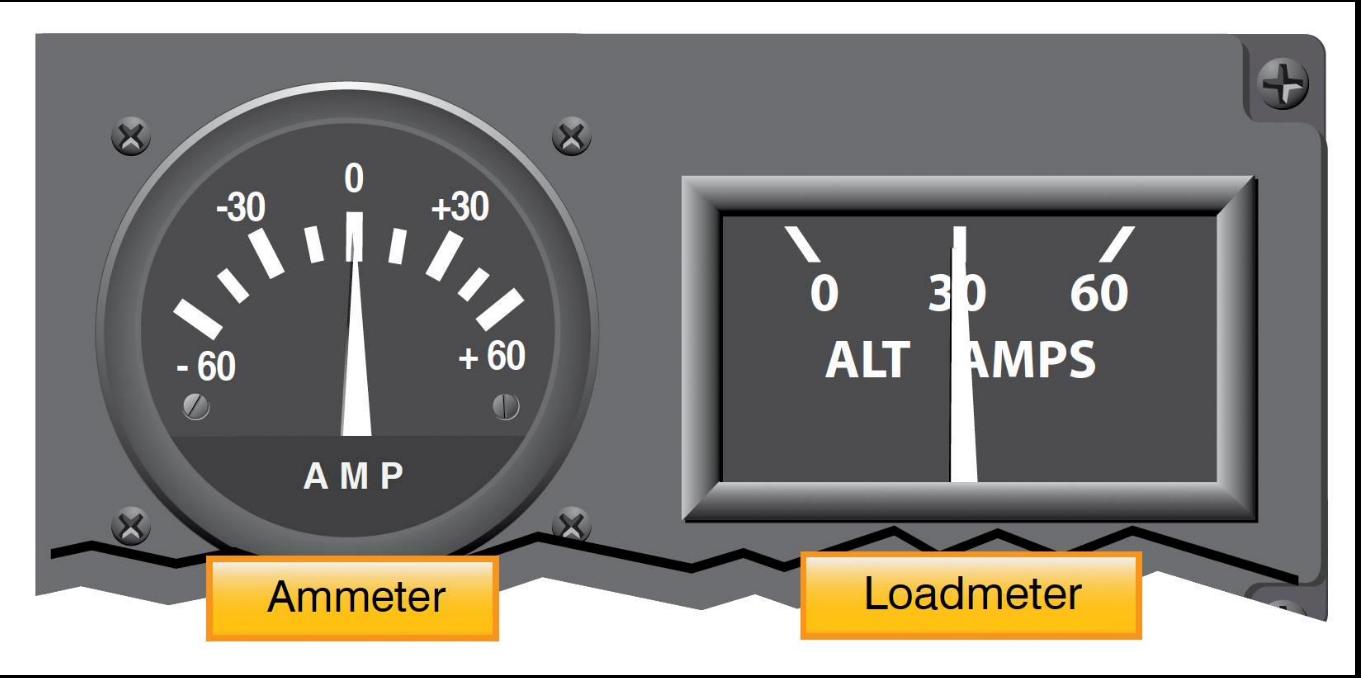
Ammeter

- Used to monitor the performance of the aircraft electrical system
- Shows if the alternator is producing an adequate supply of electrical power
- Indicates whether the battery is receiving an electrical charge
- Some aircraft have a warning light that indicates a discharge in the system as a alternator malfunction



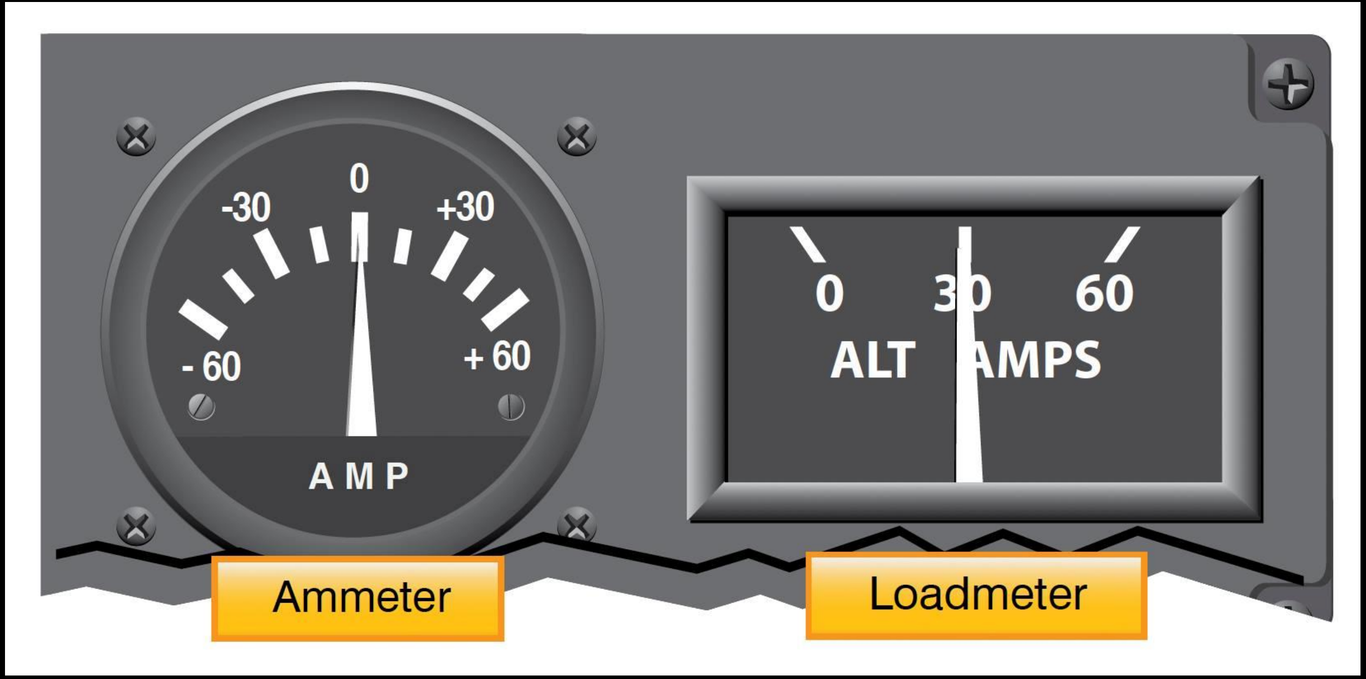
Ammeter

- Zero point in the center of the face and a negative or positive indication on either side
- When the pointer is on the plus side it shows the charging rate of the battery
- A minus indication means more current is being drawn from the battery than is being replaced
- Full-scale minus deflection indicates a malfunction of the alternator
- Full-scale positive deflection indicates a malfunction of the regulator



Loadmeter

- Scale begins with zero and shows the load being placed on the alternator
- Shows the total percentage of the load placed on the generating capacity of the electrical system by the electrical accessories and battery
- When all electrical components are turned off, it reflects only the amount of charging current demanded by the battery



Hydraulic System

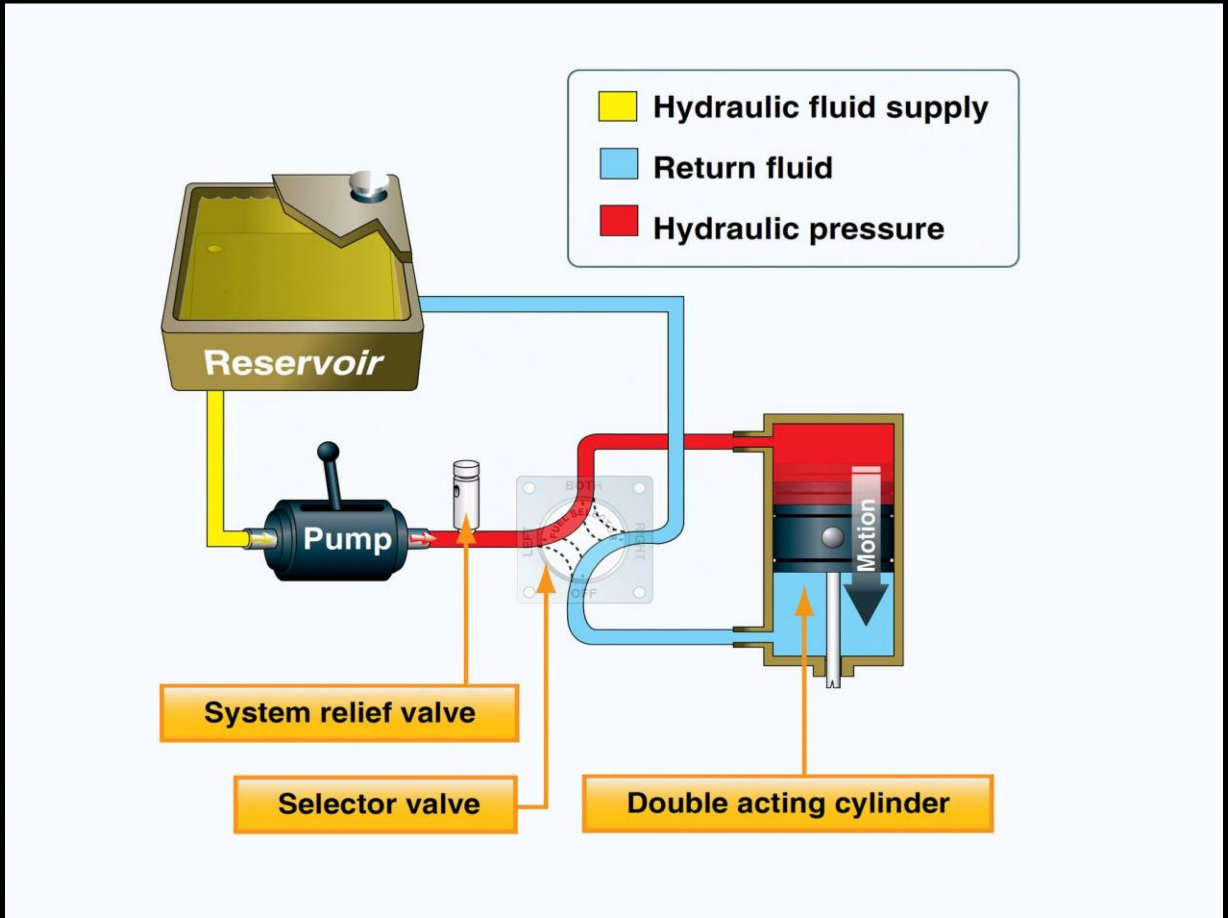
Aircraft Flight Controls and Systems

Hydraulic Systems

- There are multiple applications for hydraulic use depending on the complexity of the aircraft
- A hydraulic system is often used on small airplanes to operate wheel brakes, retractable landing gear, and some constant-speed propellers
- On large airplanes the hydraulic system is used for flight control surfaces, wing flaps, spoilers, and other systems

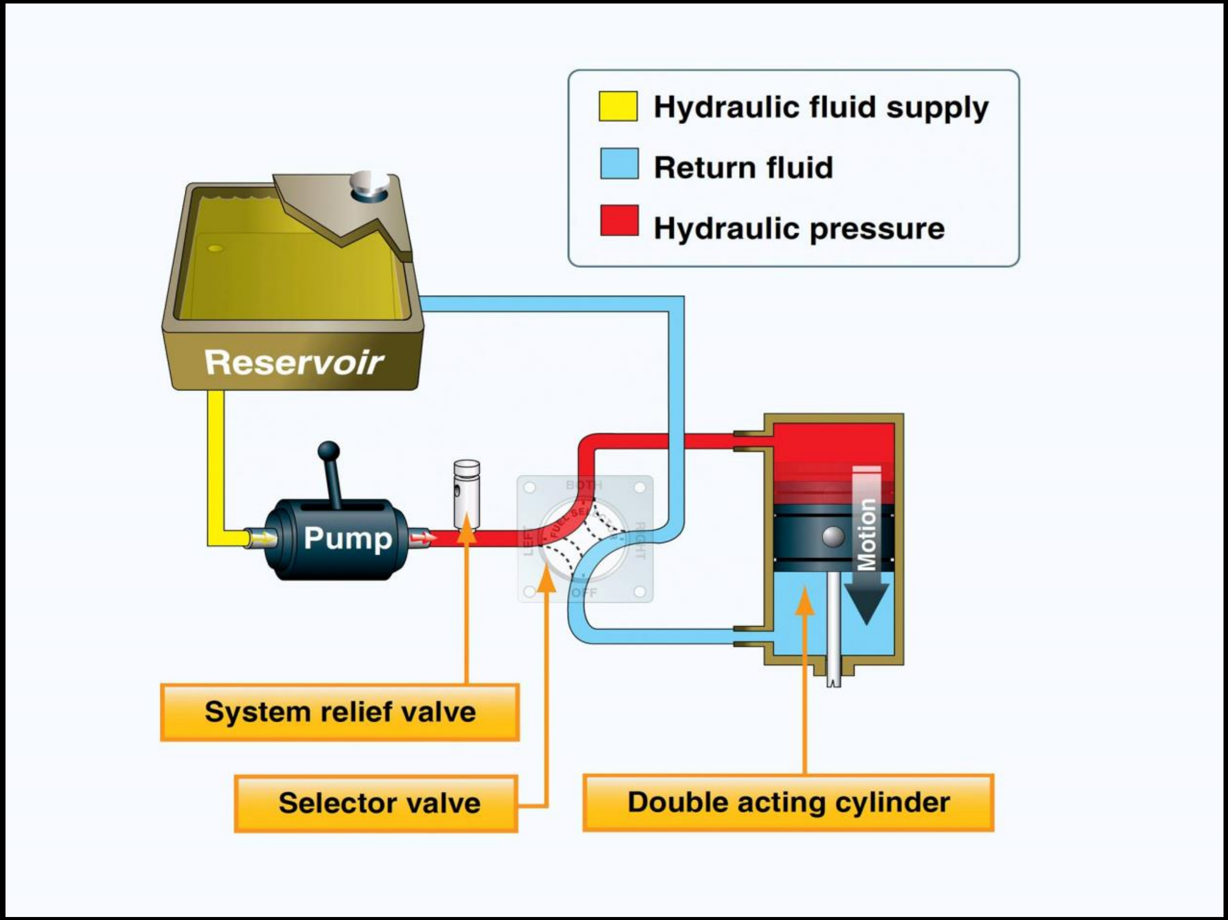
Basic Hydraulic System

- Pump (either hand, electric, or engine-driven)
- Filter
- Selector valve to control direction of flow
- Relief valve to relieve excess pressure
- Actuator(s)

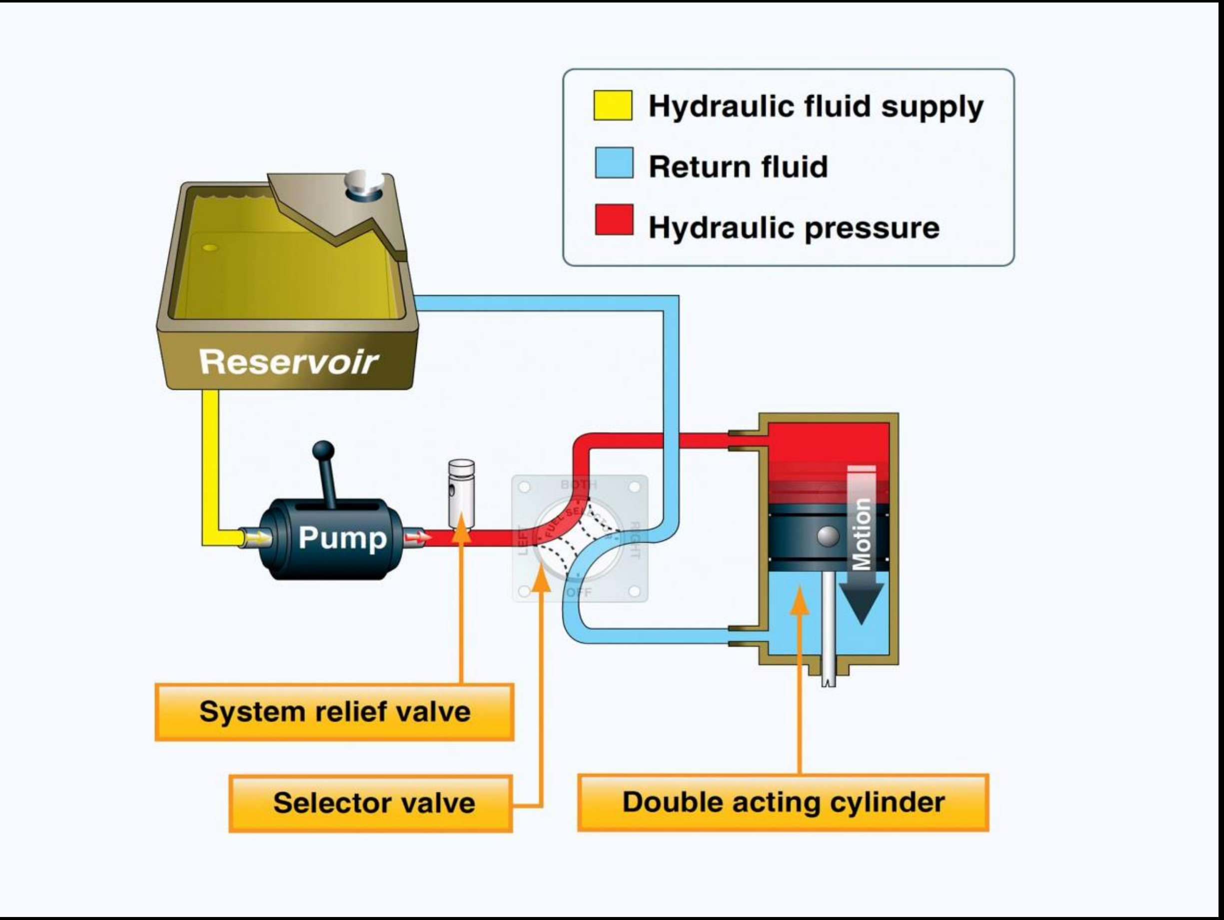


Actuator/Servo

- Hydraulic fluid is pumped through the system to an actuator or servo
- A servo is a cylinder with a piston inside that turns fluid power into work and creates the power needed to move an aircraft system or flight control
- Servos can be either single-acting or double-acting
- Fluid can be applied to one or both sides of the servo, depending on the servo type
- A single-acting servo provides power in one direction



Selector Valve



- Selector valve allows the fluid direction to be controlled
- Necessary for operations such as the extension and retraction of landing gear where the fluid must work in two different directions
- The relief valve provides an outlet

Knowledge Check

What is the difference between an elevator and stabilator? (Common GA Trainer)

A. The Elevator is a simple one-piece design
B. The Stabilator uses a balance tab to increase control effectiveness
C. The Elevator has trim control on the entire surface
D. The Stabilator is commonly equipped with an anti-servo tab and the entire surfaces moves

Knowledge Check

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Knowledge Check

Which of the following is NOT a primary flight control?

A. Ailerons
B. Rudder
C. Flaps
D. Elevator

Knowledge Check

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~~A. Ailerons~~
~~B. Rudder~~
C. Flaps
~~D. Elevator~~

Knowledge Check

An aircraft alternator produces DC power?

A. True
B. False

Knowledge Check

An aircraft alternator produces DC power?

~~A. True~~
B. False

Knowledge Check

Adverse yaw is a result of?

A. Proper pilot technique
B. Changes in AOA on the aileron, therefore, drag resulting in a yawing moment
C. Byproduct of the left-turning tendencies of the propeller resulting in an adverse yawing moment
D. Improper fixed tab alignment on propeller driven airplanes

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