Stage 1 Lesson 2

- Introduction to Flight & High Altitude Maneuvers -

FLIGHT CONTROLS

Tiziano Bernard, CFI

Mission Objectives

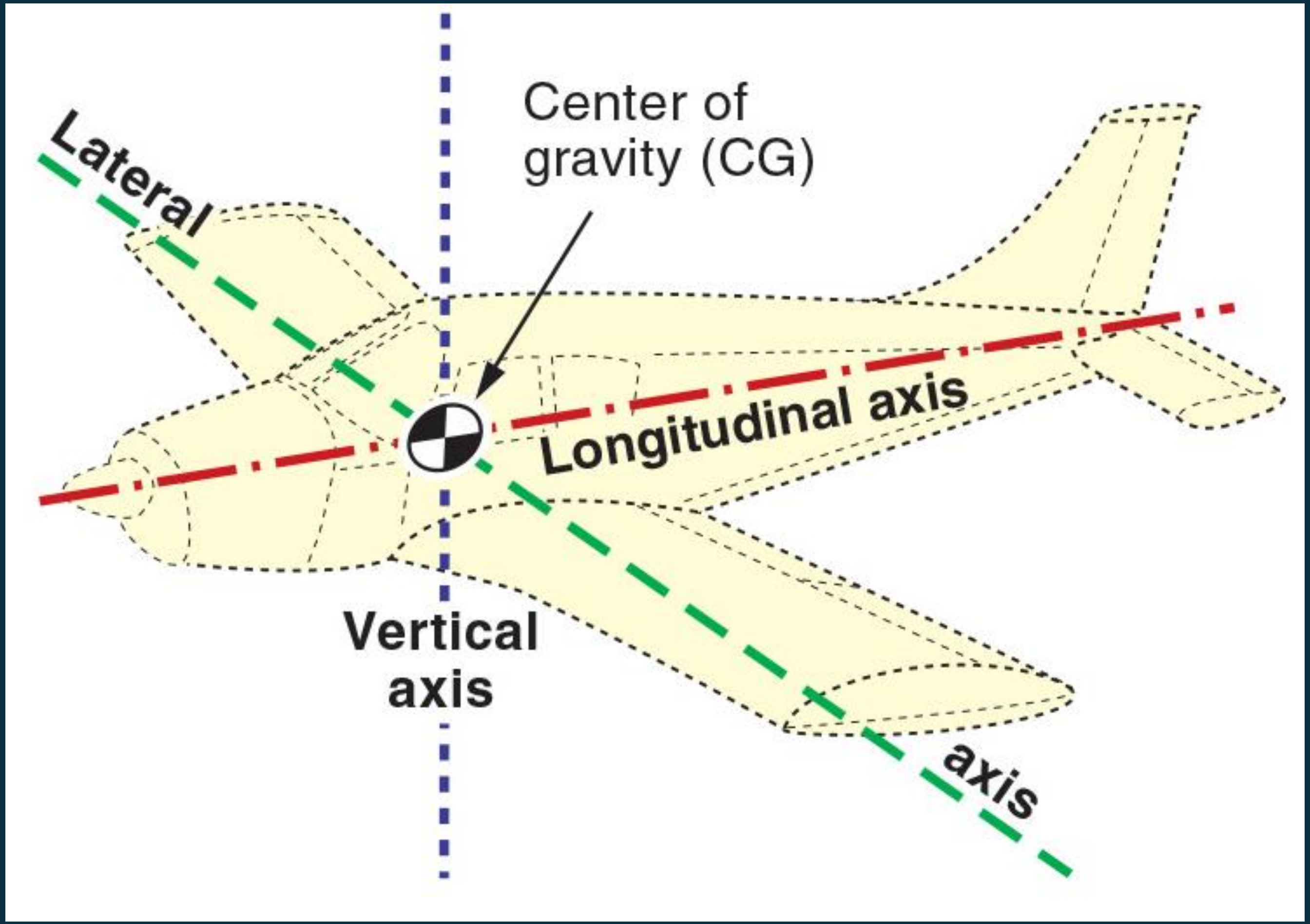
- Learn the different types of flight controls:
  - Primary Flight Controls
  - Secondary Flight Controls
  - Trim Controls
- Learn the various reference systems to define airplane motion.
- Understand their critical role in aiding airplane control.
- Understand their critical role in aiding pilot control.
- Discuss Simplified Flight Control aircraft.
- Discuss autopilot purposes.

REFERENCE SYSTEMS

“So… rolling requires yawing?”– new student pilot

Axes and Motions

- Motion about the longitudinal axis is called **ROLL**.
- Motion about the lateral axis is called **PITCH**.
- Motions about the vertical axis is called **YAW**.
- **Flight controls** allow aerodynamic effects to make these motions happen.



Axes and Motions

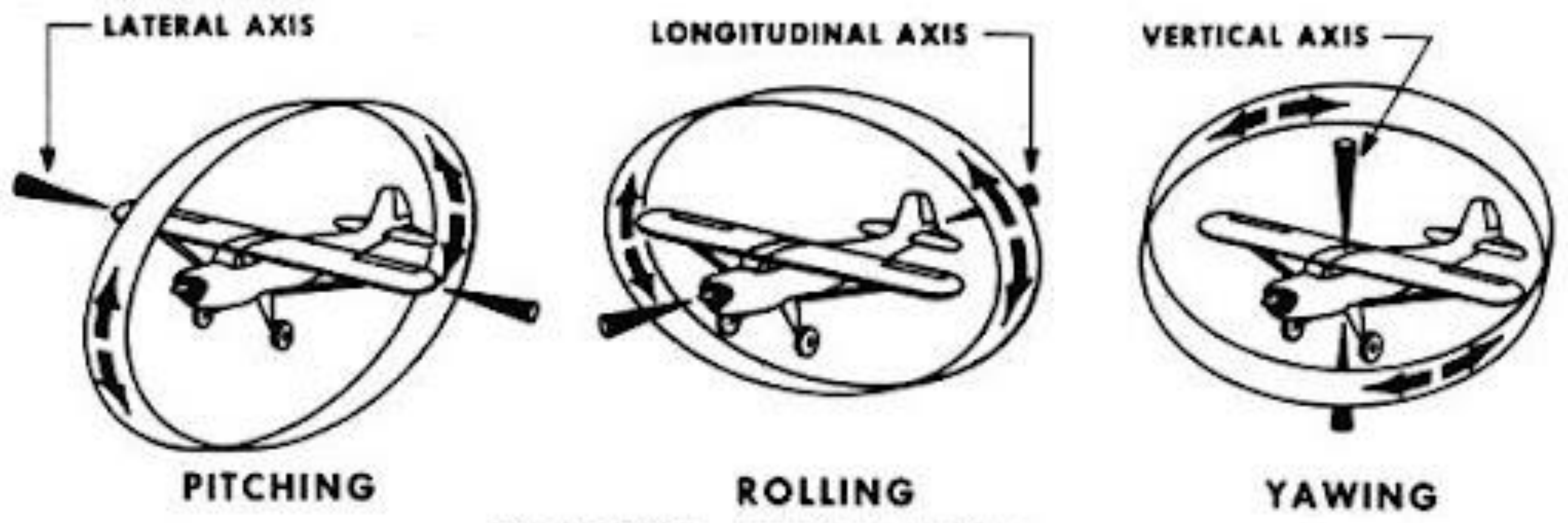
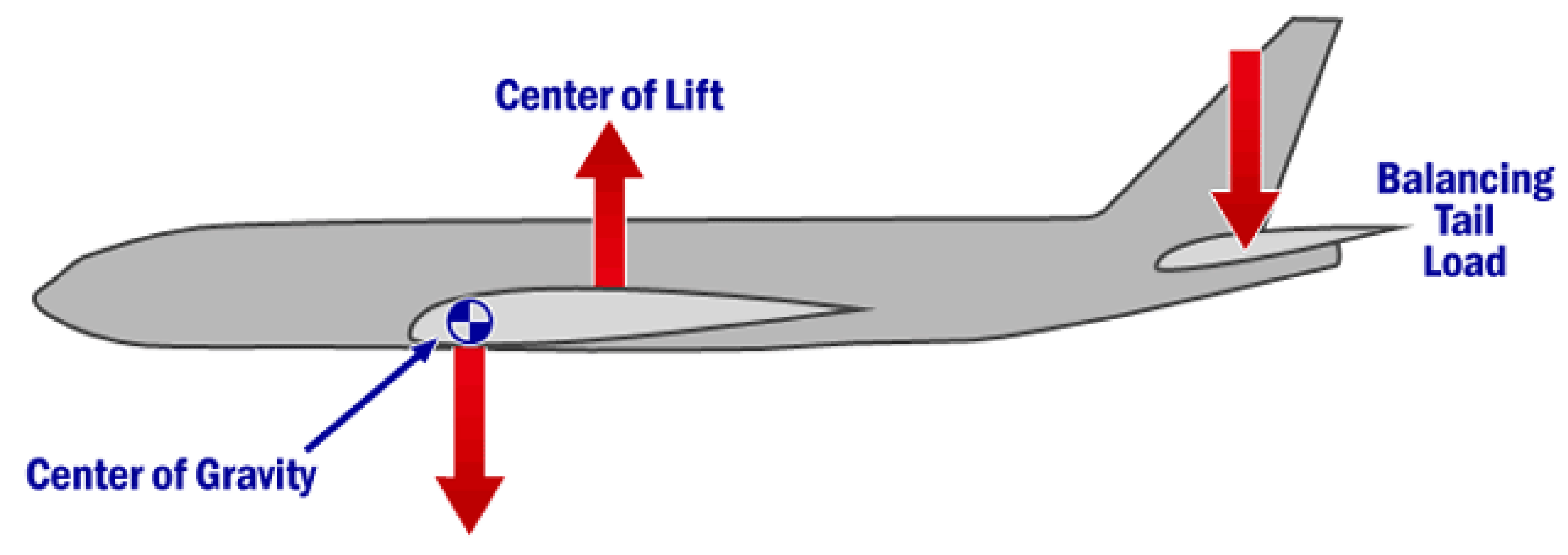


Figure 17-21 Axes of an Airplane

Basic Aerodynamic Forces

- The CG is usually forward of center of lift, causing a nose down moment.
- The tail is normally generating a downward force to counteract that.



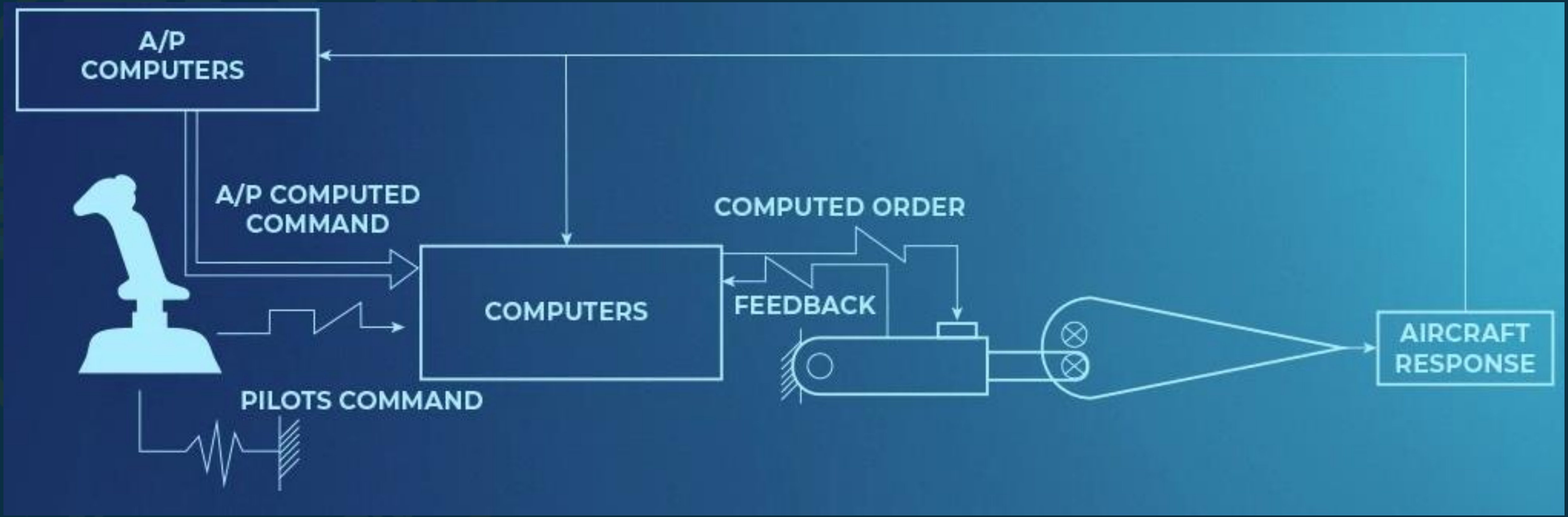
PRIMARY FLIGHT CONTROLS

"That's a horizontal stabil..izer...ator?"– new student pilot

Cables & Pulleys vs. Fly-By-Wire

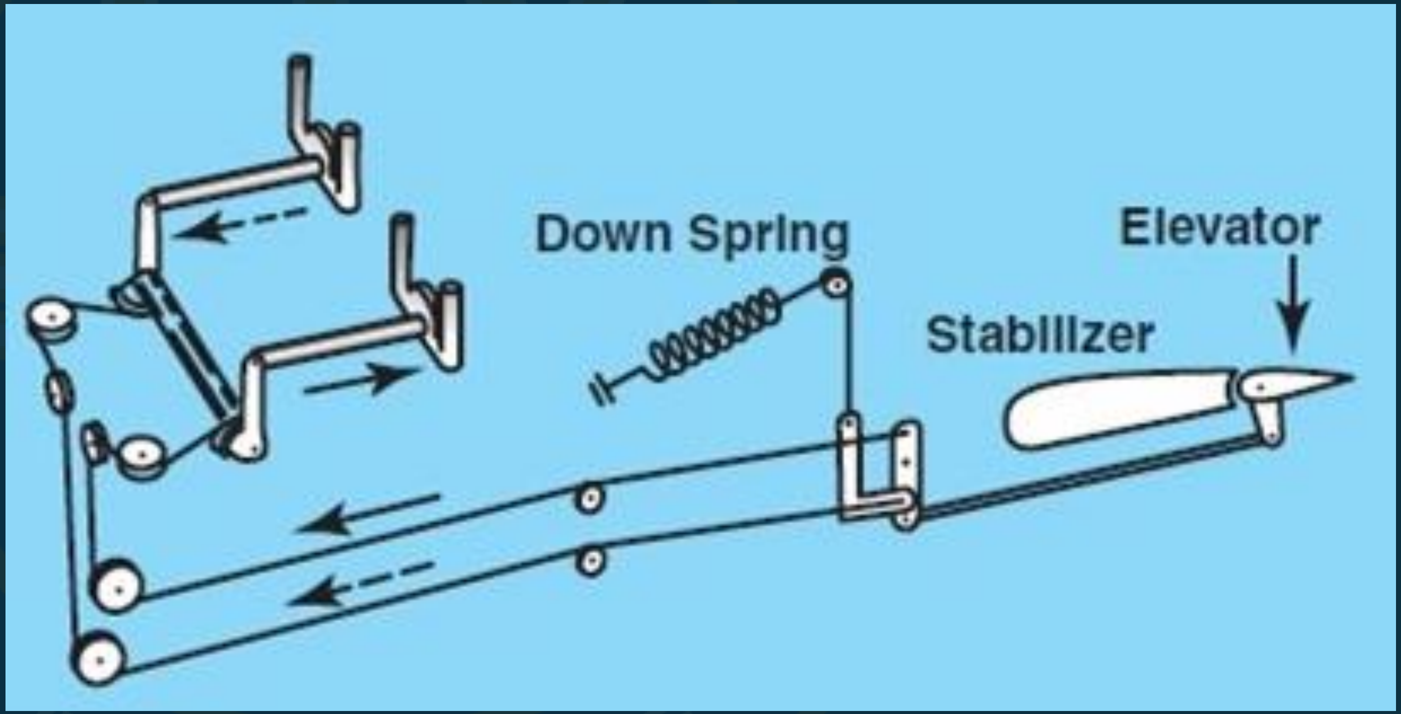
- Large advanced aircraft work with fly-by-wire control systems.
  - Control inputs output a digital signal that is transmitted via wires to the control surfaces.
  - Control laws are designed to augment the flight characteristics of the aircraft.
  - These are often referred to as **irreversible control systems**.
- Small and older airplanes work by cables and pulleys.
  - The pilot controls are physically/mechanically linked to the control surfaces.
  - These are often referred to as **reversible control systems**.

Fly By Wire



A/P
COMPUTERS
A/P COMPUTED
COMMAND
COMPUTED ORDER
COMPUTERS
FEEDBACK
AIRCRAFT
RESPONSE
PILOTS COMMAND

Cables and Pulleys

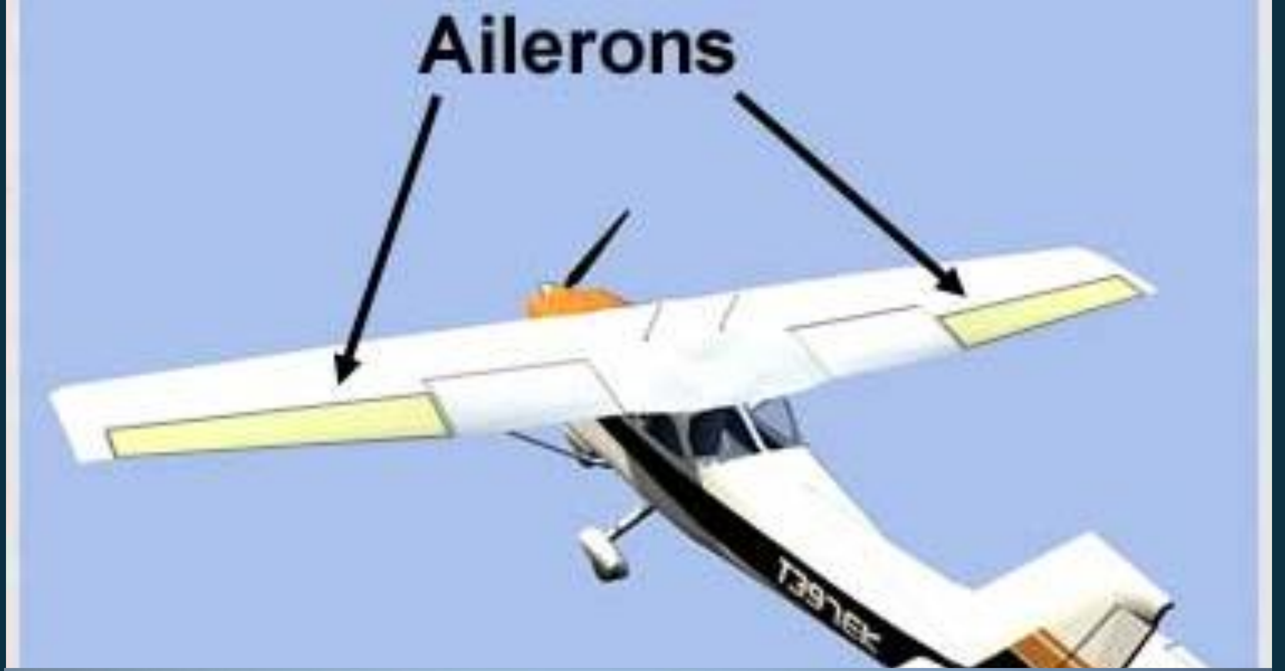


Ailerons, Elevator, and Rudder

- Primary flight controls provide a way to aerodynamically cause motion about the three axes.
- The primary flight controls are:
  - Ailerons, which control the roll motion
  - Elevator, which control the pitch motion
  - Rudder, which control the yaw motion
- These are the most simple primary flight controls. There are hybrids which we will talk about later.

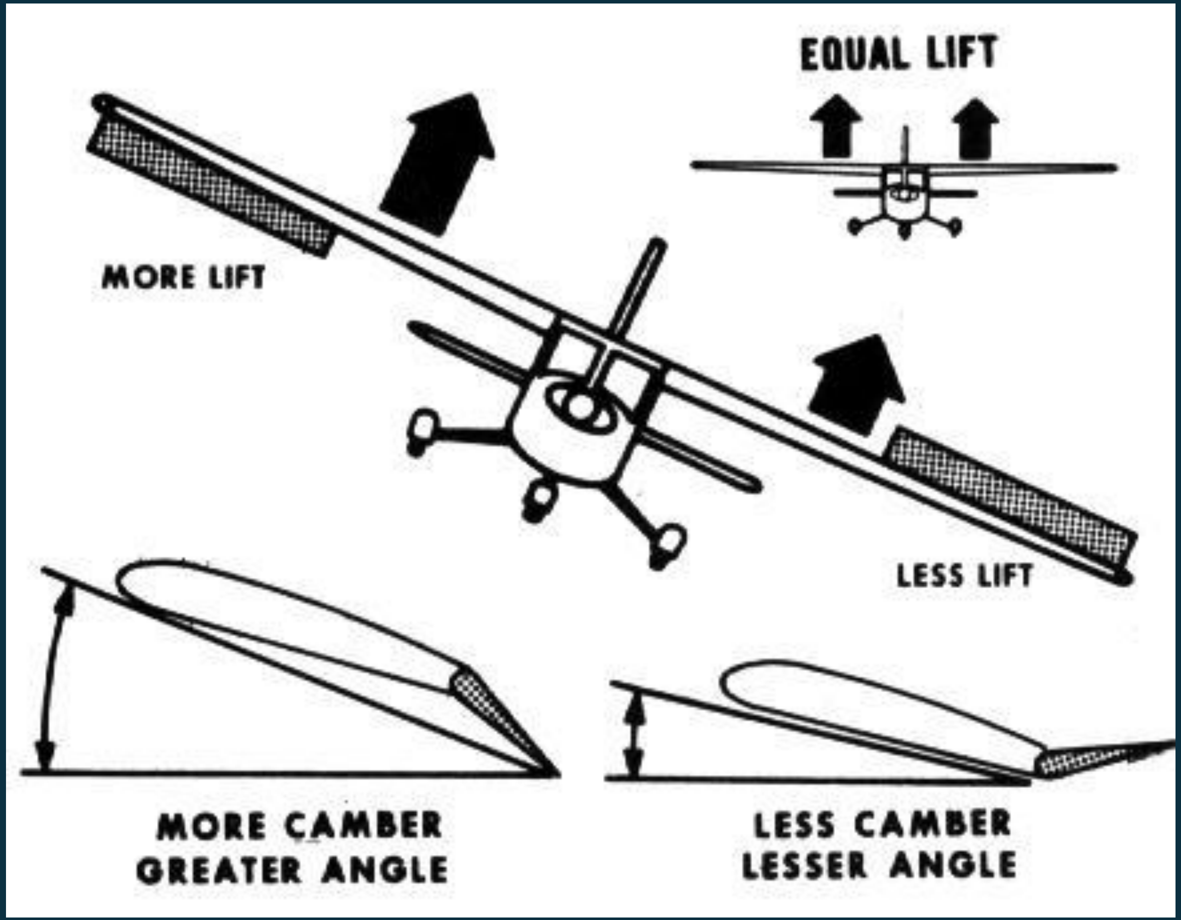
Ailerons

- Ailerons are located outboard on the trailing edge of wings.
- Move opposite to one another (one goes up, the other goes down).
- They cause aerodynamic changes by modifying the wing's geometry.



Aileron Movement

- The generic physics governing each is always the same.
- To roll left:
  - Pilot turns the control stick/yoke to the left.
  - The right wing aileron **deflects down** to create more lift on the right wing raising it.
  - The left wing aileron **deflects upward** to reduce lift on the left wing dropping it.

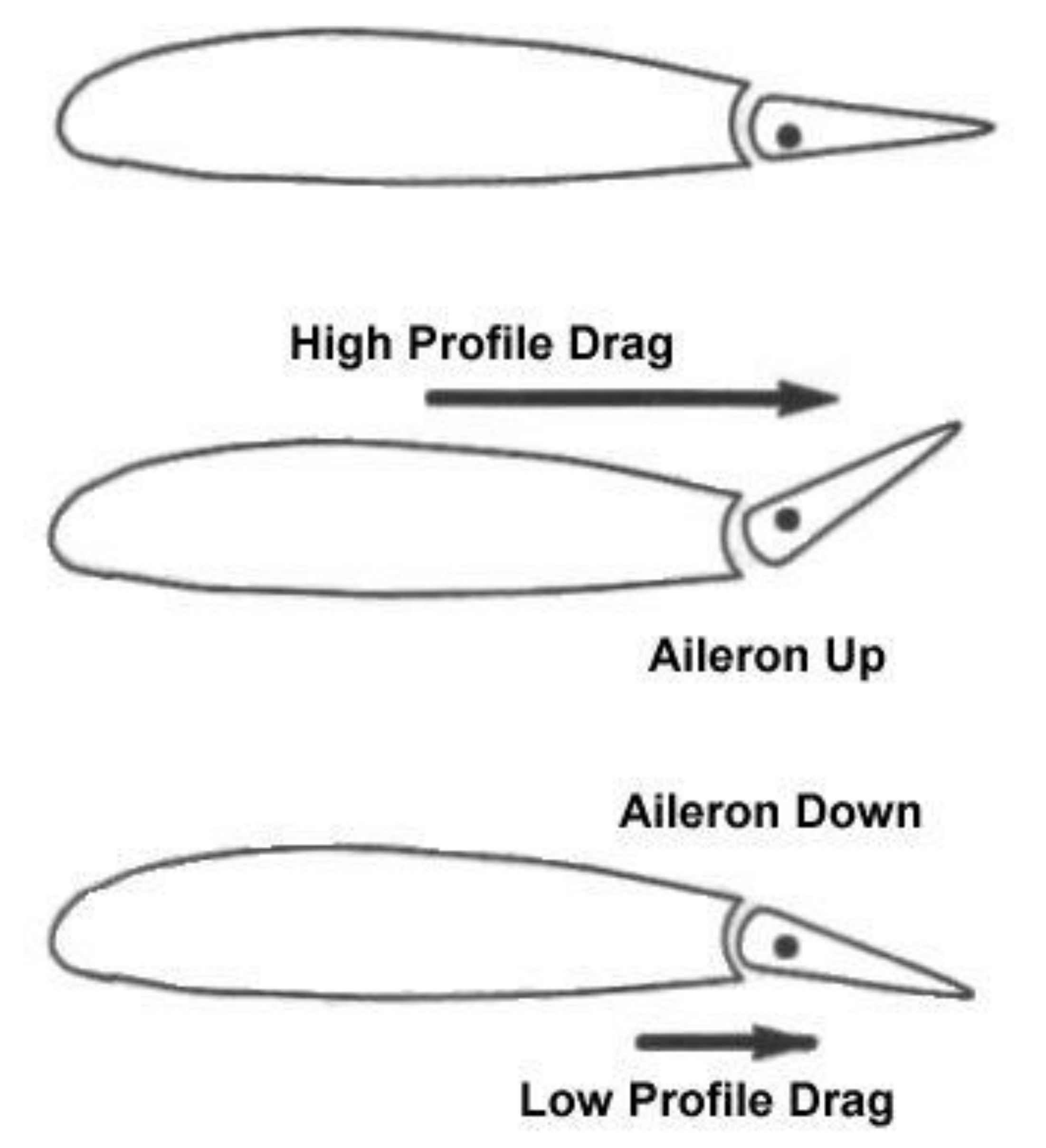


Adverse Yaw

- When an aileron moves down it increases lift. But it also increases drag.
- When an aileron moves up, it decreases lift. But it doesn't increase drag very much.
- This causes a turning tendency known as adverse yaw.
- Many solutions exist for this phenomenon.

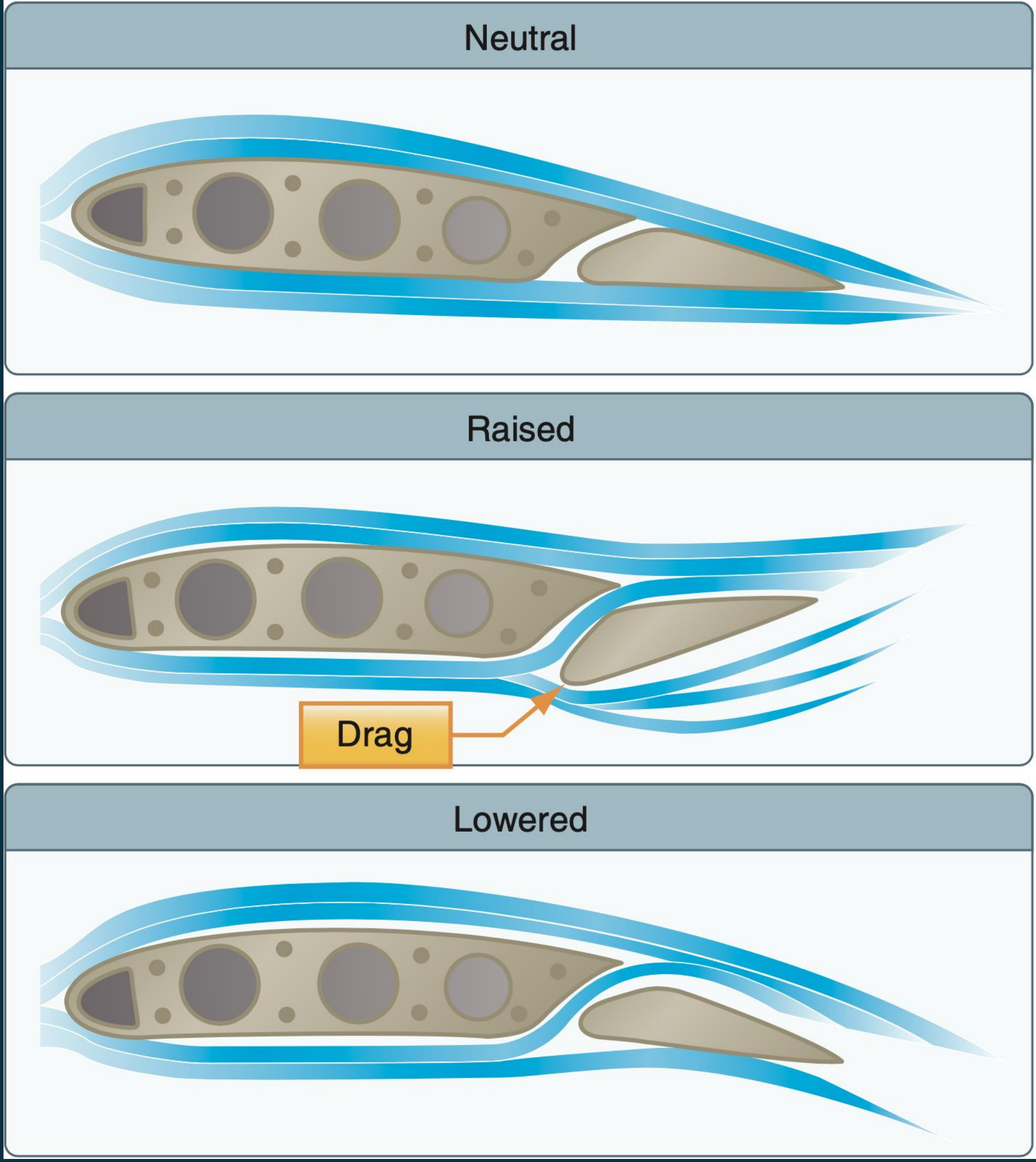
Differential Ailerons

- Differential counteract adverse yaw by changing how much ailerons deflect.
- The upward aileron deflects upwards more than the the downwards one, increasing the amount of drag produced.
- More drag on the upward aileron reduces the effect of adverse yaw.
- These are the most common type.



Frise Ailerons

- Frise ailerons pivot into the airstream, causing drag to increase on the upward moving aileron.
- Just like differential ailerons, drag is increased on the upward aileron counteracting adverse yaw.
- Example: Piper Cub



Coupled Ailerons-Rudder

- Some airplanes couple the motion of ailerons with rudder input.
- The Ercoupe is an extreme example where there aren't any rudder pedals at all (motion of the rudder is only controlled by aileron input).
- Others, like Pilatus PC-12, facilitate the connections between the two.

ERCO Ercoupe

Flaperons

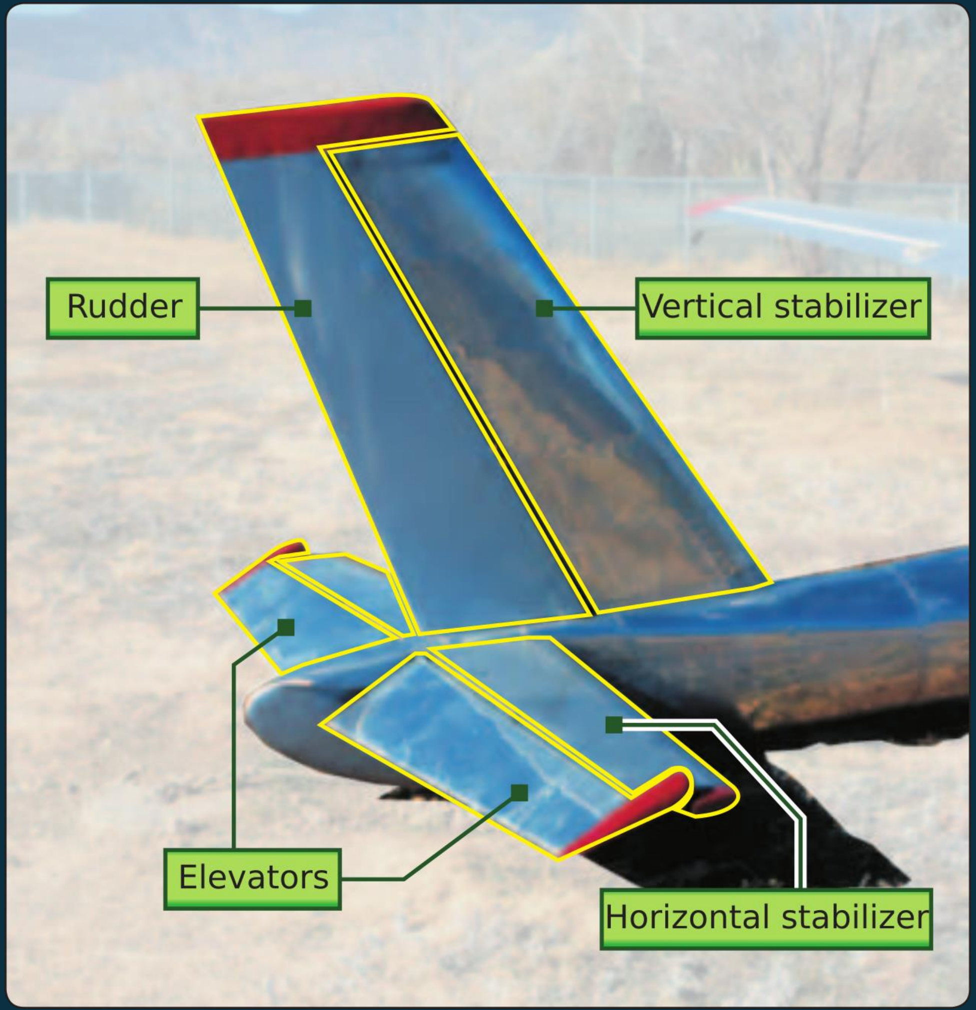
- Flap+Aileron = Flaperon!
- Combine two surfaces into one.
- Controlled independently.
- Move as one surface.

Kitfox

B777

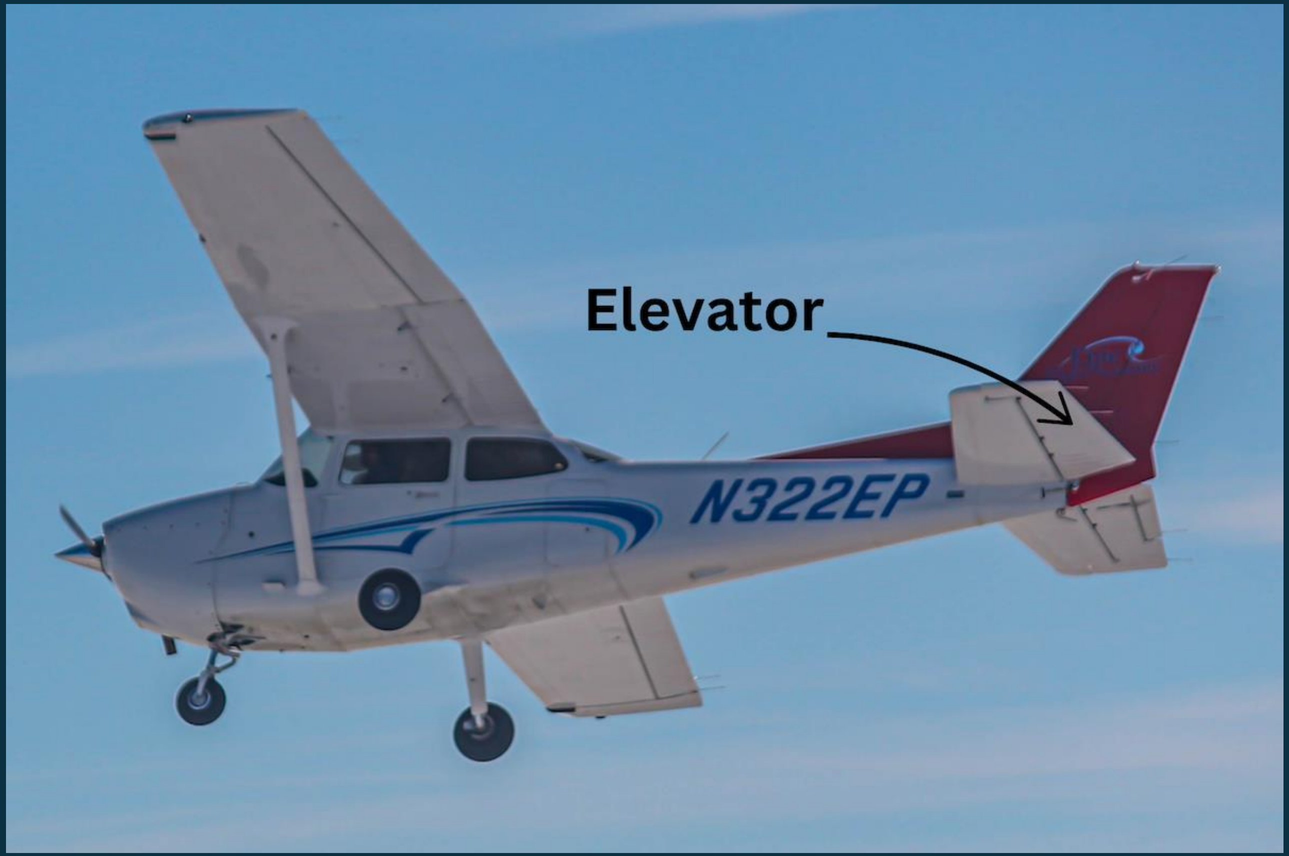
Empennage – Tail Section

- The empennage includes the entire tail and its components:
  - Horizontal Stabilizer
  - Vertical Stabilizer
  - Rudder
  - Elevator
  - Trim Controls



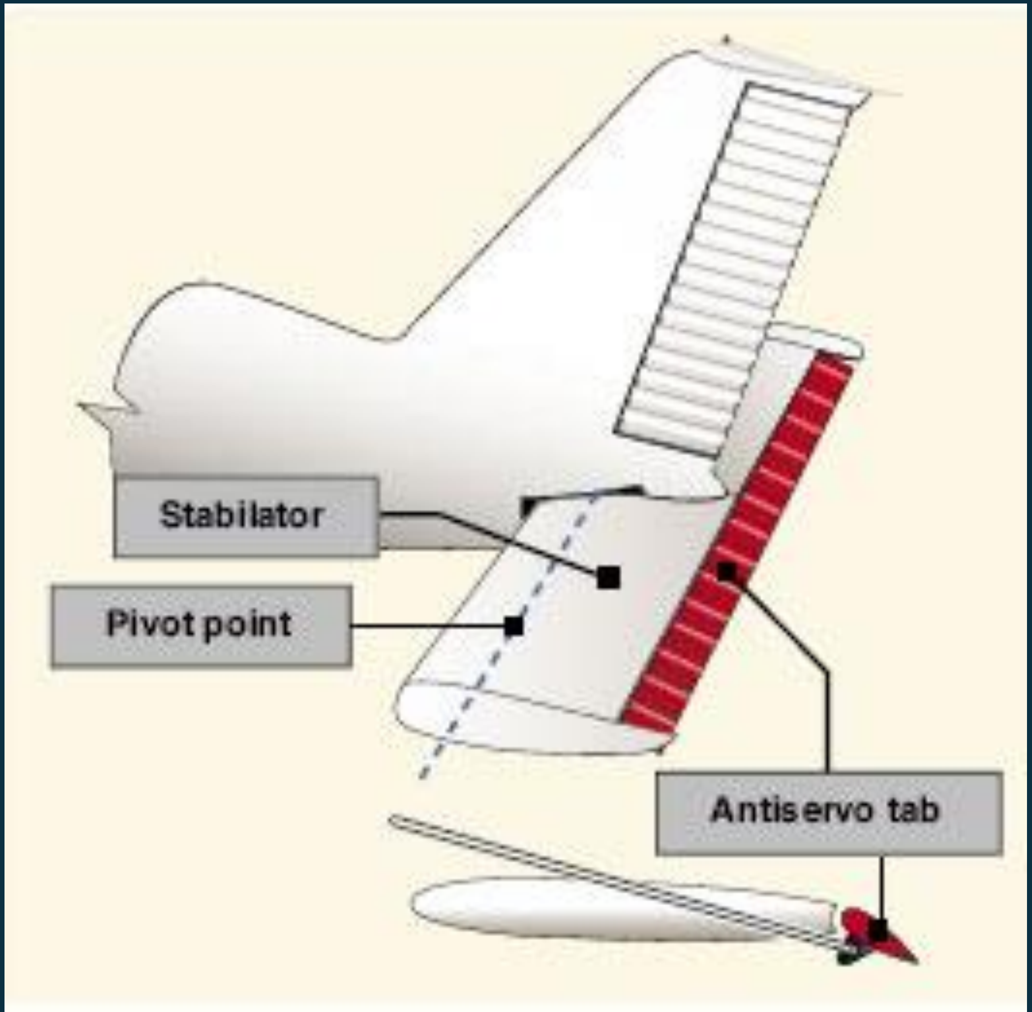
Elevator

- Ailerons are located on the tail on the trailing edge of the horizontal stabilizer.
- They cause aerodynamic changes by modifying the tail's geometry.
- Elevator down raises the tail, causing a pitch down motion.



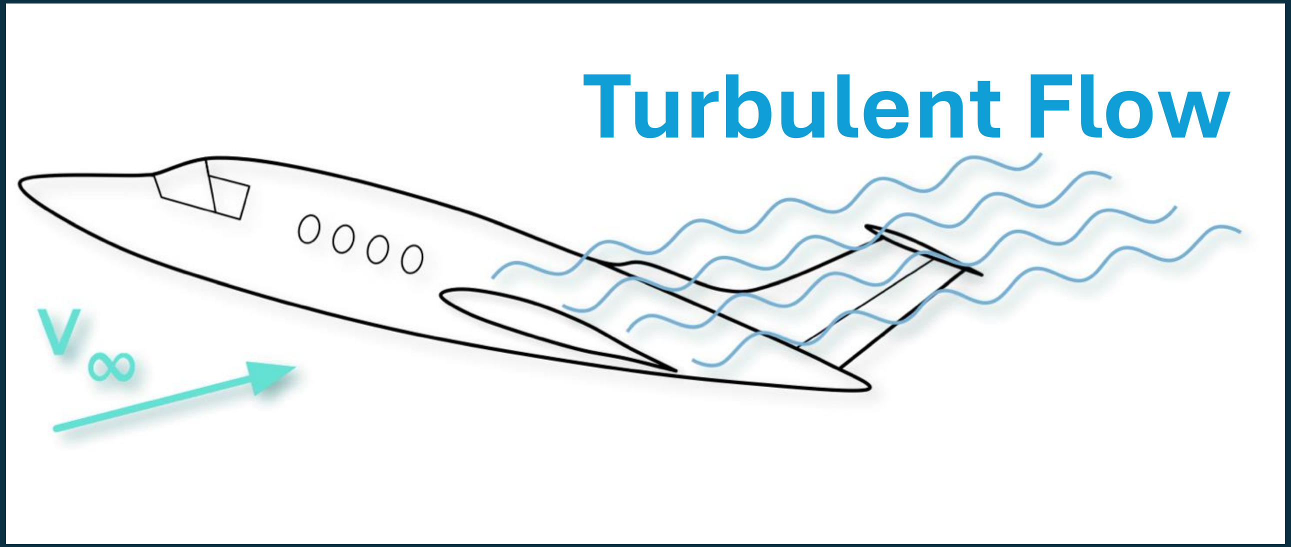
Stabilator

- Elevators are attached to the horizontal stabilizer, which is fixed. That means that the elevator comprises only a small part of the horizontal tail.
- A stabilator is an elevator connected to the stabilizer so that both surfaces move.
- The whole horizontal tail moves.
- Pivot around a single hinge point.
- Very sensitive, since more surface movement results in a larger aerodynamic effect.



T-Tail Elevator

- Some elevators (or stabilators) are installed at the top of the tail, rather than the bottom.
- This allows the tail to feel undisturbed airflow during cruise.
- There are some consequences at high angles of attack, like deep stalls and total ineffectiveness.



Canards

- A canard is a horizontal surface mounted forward of the main wing and serves the purposes of a tail.
- The aerodynamics are generically the same, but the effect is different, as they produce an upward force.
- They can have a "stabilator" or "elevator+stabilizer" configuration.

Eurofighter Typhoon

Beechcraft Starship

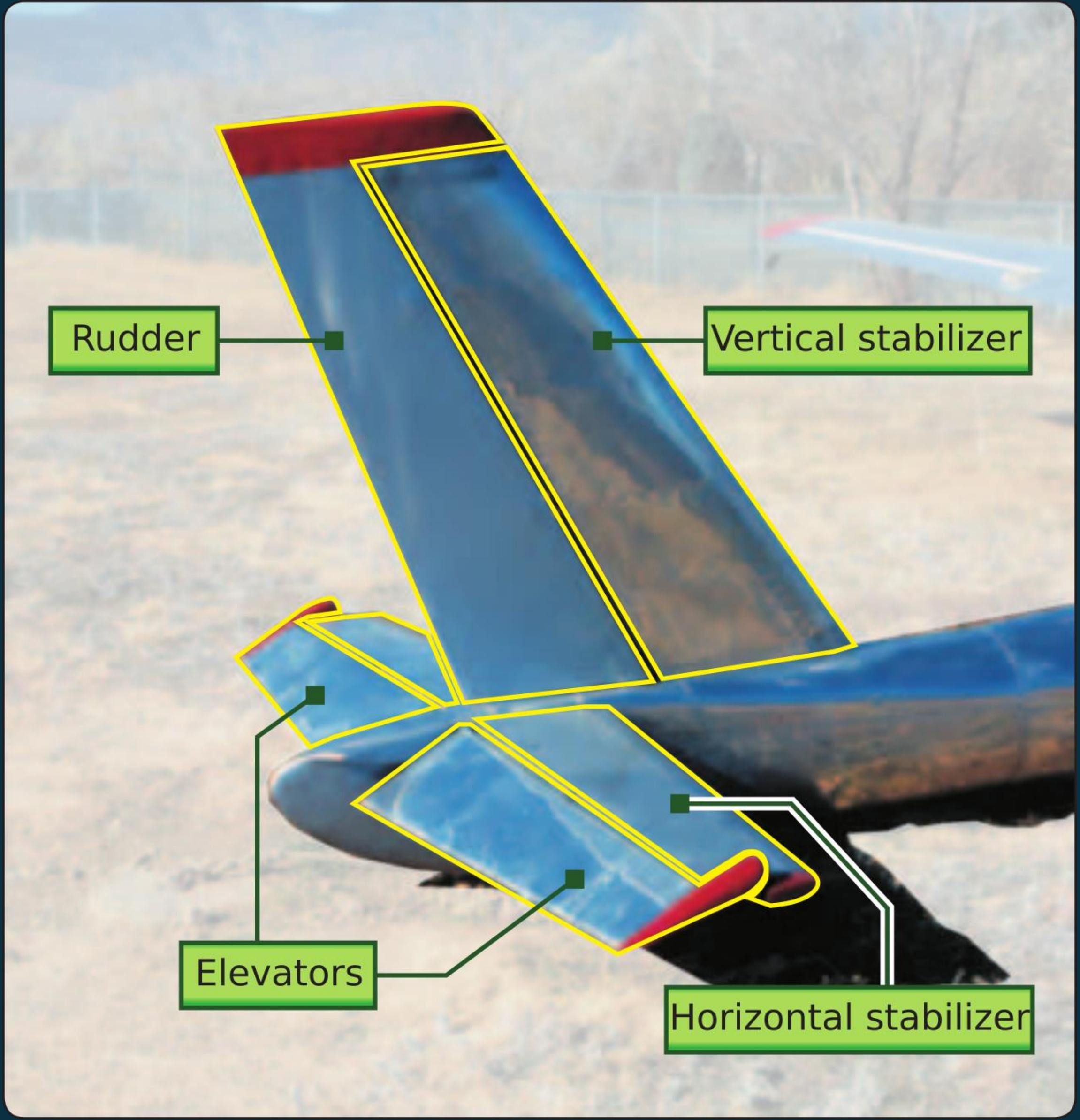
Canards

- Not to be confused with an actual wing, like the Piaggio Avanti.
- That is a second wing with flaps, and not a canard.
- It has a T-Tail, in fact.
- Why? Engine exhaust and turbulence...

Piaggio Avanti

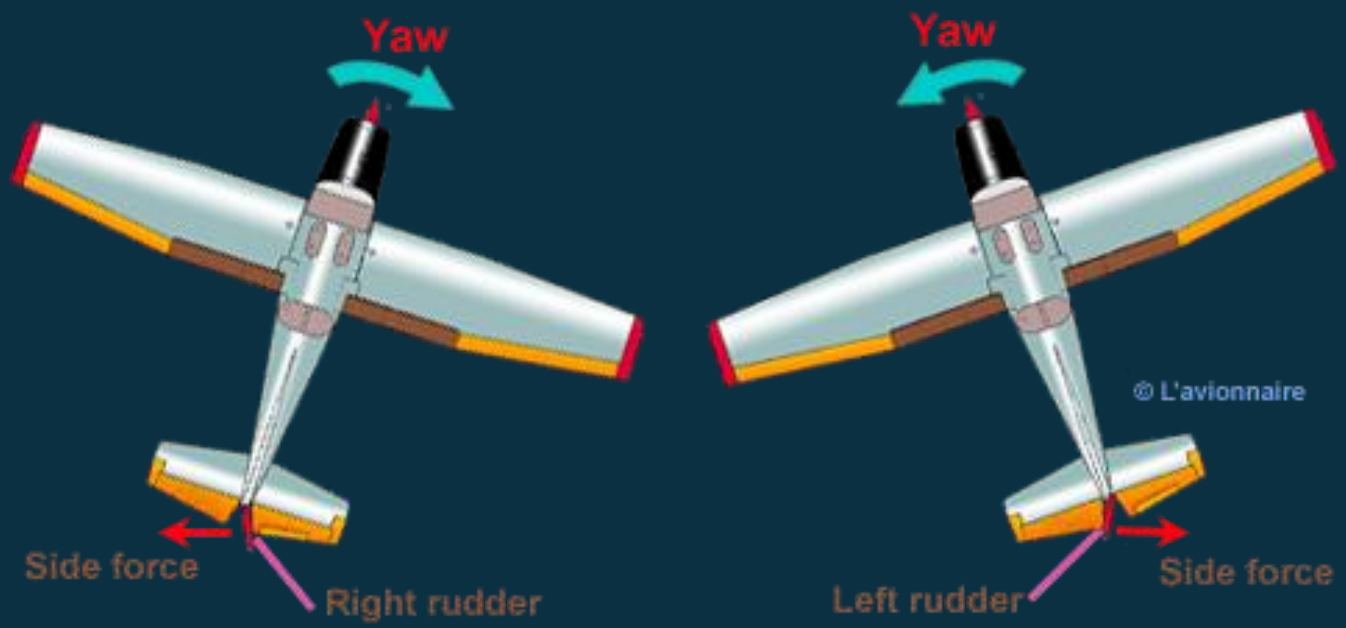
Rudder

- The rudder is located on the trailing edge of the vertical stabilizer.
- Hinged to move left and right and provides motion about the vertical axis of the aircraft.
- The motion is called yaw.



Rudder Movement

- The rudder behaves just like an elevator or aileron, but on the vertical axis.
- To yaw left:
  - Pilot pushes on the left rudder pedal.
  - The rudder deflects to the left, causing more lift (or side force) to be produced on the right side of the tail.
  - The airplane yaws to the left.



Ruddervators (i.e., V Tail)

- Rudder + Elevators = Ruddervators.
- Often referred to as V Tail.
- Surfaces that serve both the purposes of a horizontal and vertical surface.
- Flight controls are paired to assist in coordinated motions.

SECONDARY FLIGHT CONTROLS

"This plane has rudder trim??" – PPL after his checkride

Flaps, Slats, Spoilers, and Trim Systems

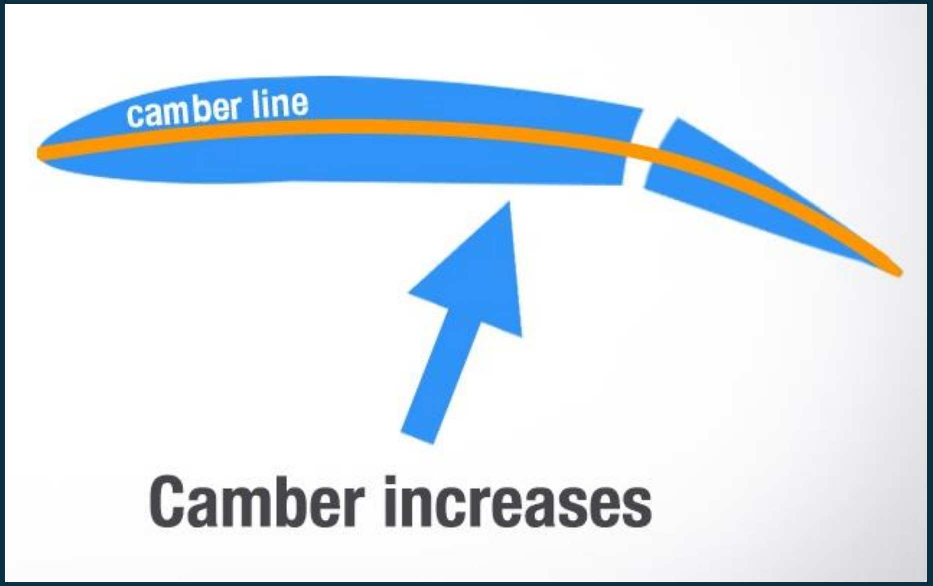
- Secondary flight controls do not directly cause motion about the various axes of the aircraft, but aid the pilot in controlling the aircraft, **significantly enhancing its capabilities**.
- The secondary flight controls are:
  - Flaps, which extend from the wing's trailing edge
  - Slats, which extend from the wing's leading edge
  - Spoilers, which extend above the wing to cause air brakes
  - Trim Systems, located generically on control surface trailing edges to minimize the stick forces felt by the pilot.

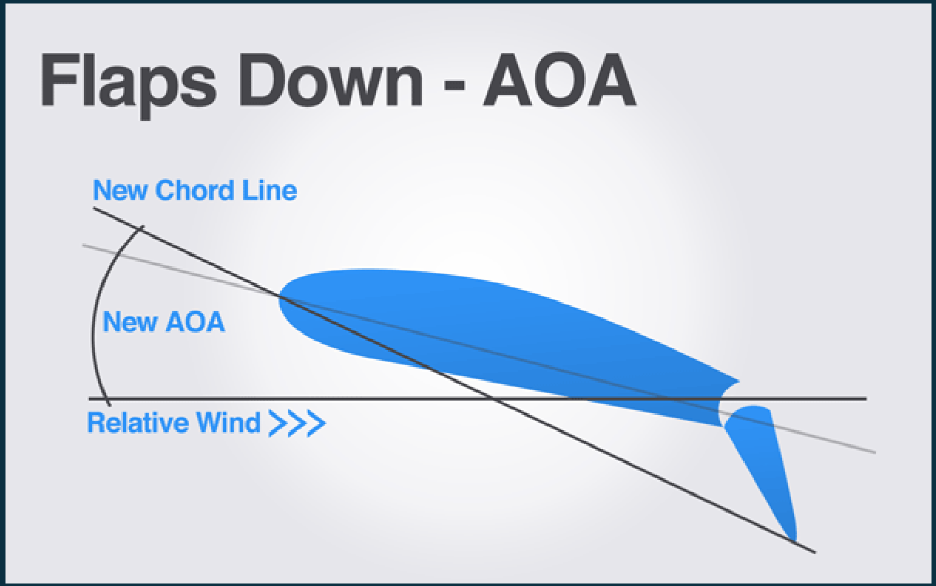
Flaps

- Flaps are high-lift devices.
- Their deployment increase lift for a given angle of attack, allowing aircraft to fly slower without stalling.
- Used during takeoff/landing where the airplane is slow.
- Every airplane has different guidance on flap usage.

Flap Aerodynamics

- Increase in camber, magnifying the effects of Bernoulli's principle.
- Manipulates angle of attack by modifying the chord line.
- Increases both lift and drag.
- The center of pressure moves aft, resulting in a nose down pitching moment.



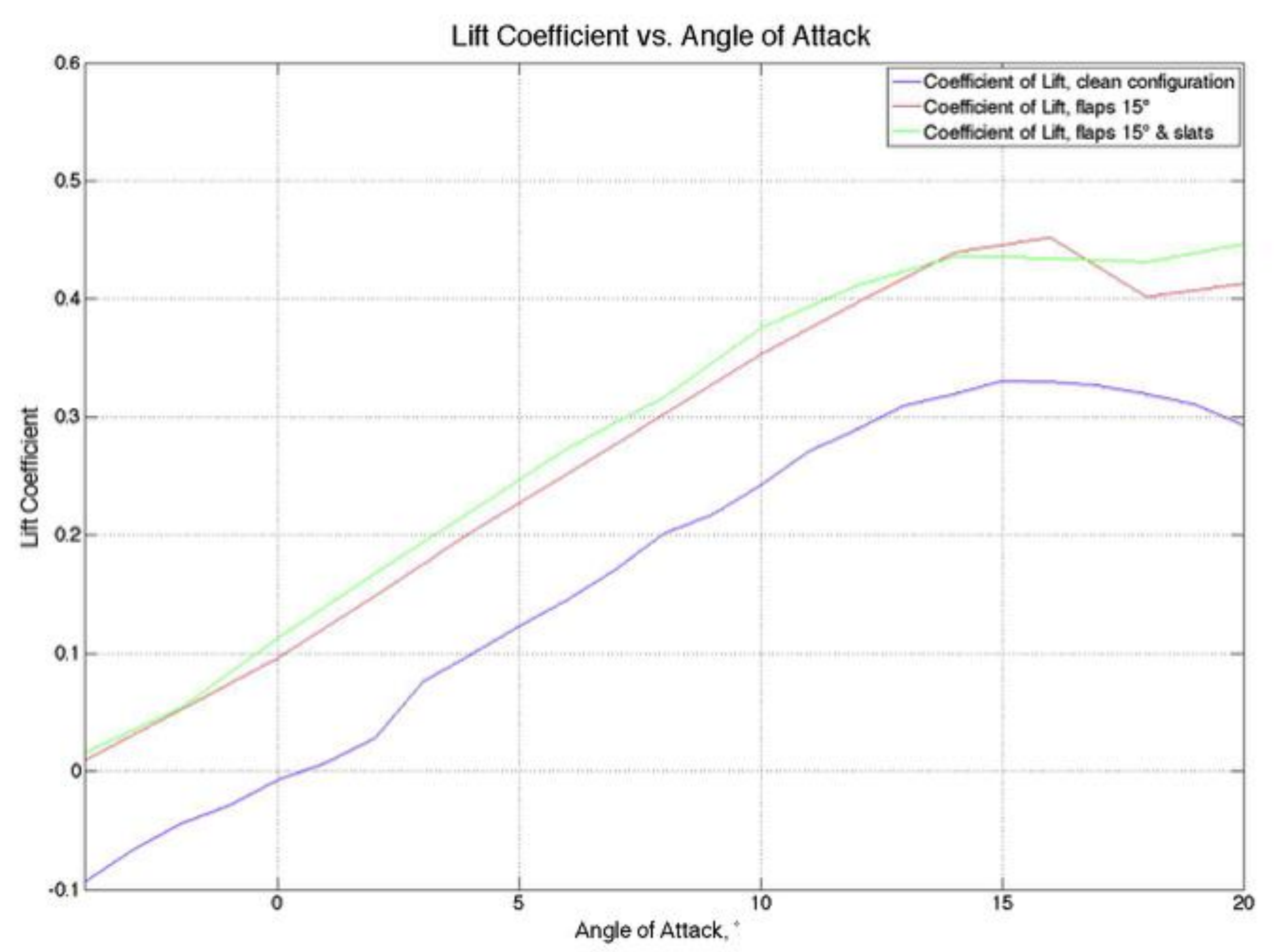


Flap Aerodynamics

- Because of the pitching moment increase, flaps allow pilots to fly at a lower pitch attitude, having better view of what's ahead (e.g., runway).
- Large flap angles are mostly drag compared to lift, allowing for a way to maintain speed control during descents.

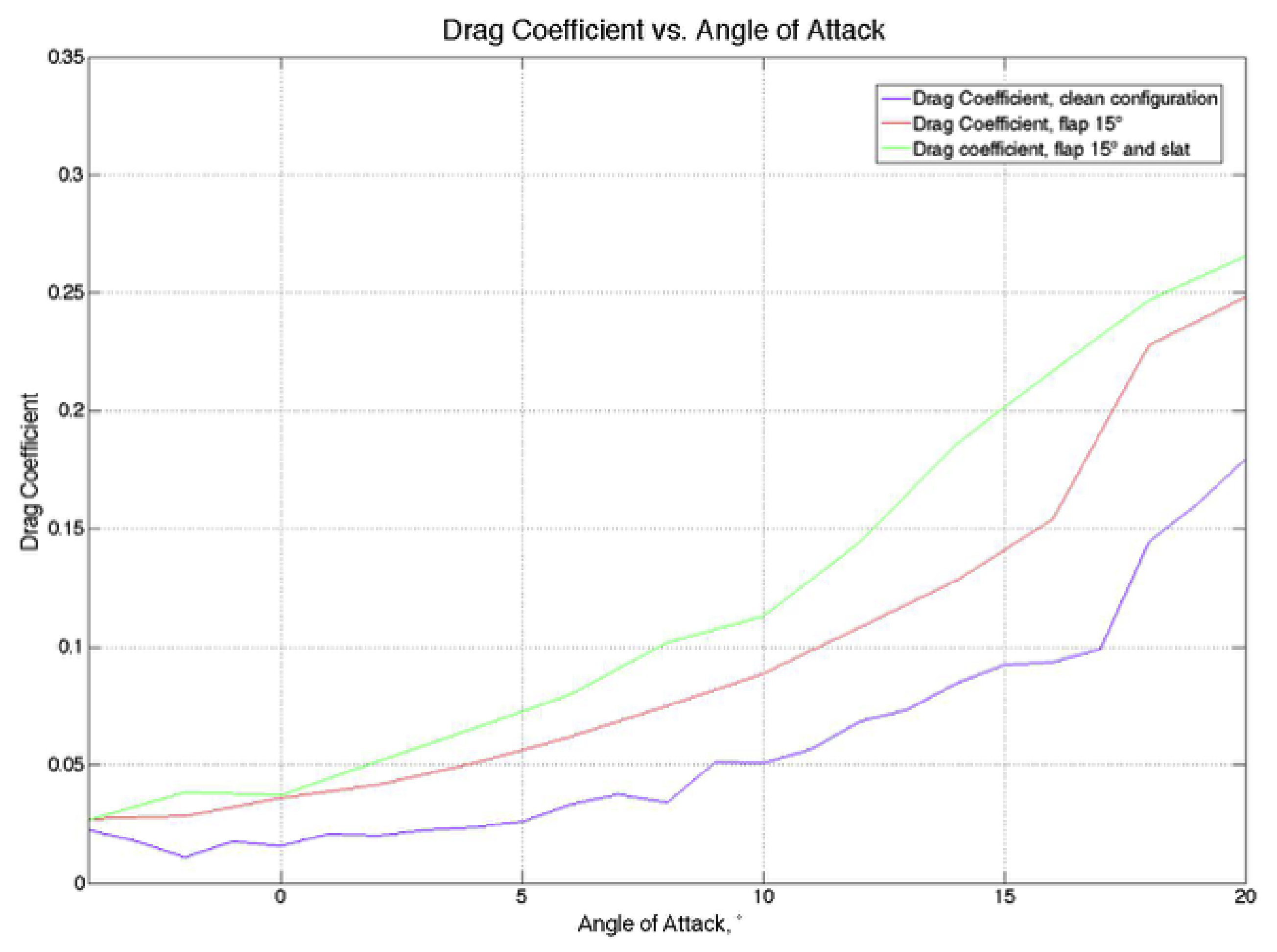
Effects of Flaps

- Plain flaps increase **lift** for a given angle of attack.
- The plot on the right is experimental data collected at the Florida Tech wind tunnel.

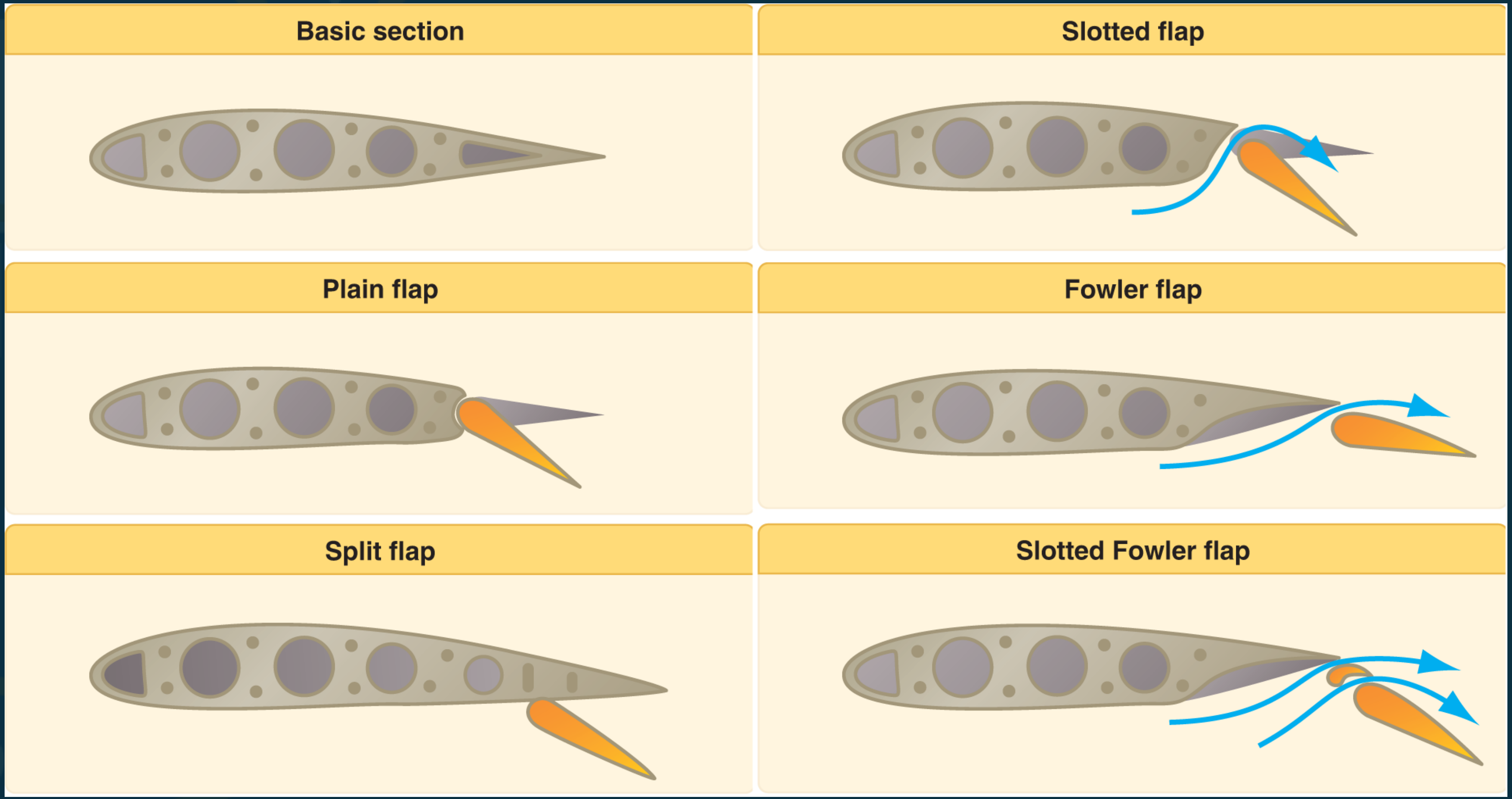


Effects of Flaps

- Plain flaps increase **drag** for a given angle of attack.
- The plot on the right is experimental data collected at the Florida Tech wind tunnel.
- As flaps angles increase, drag increases more compared to lift.
- On a PA-28, flaps 40 is mostly drag compared to lift.

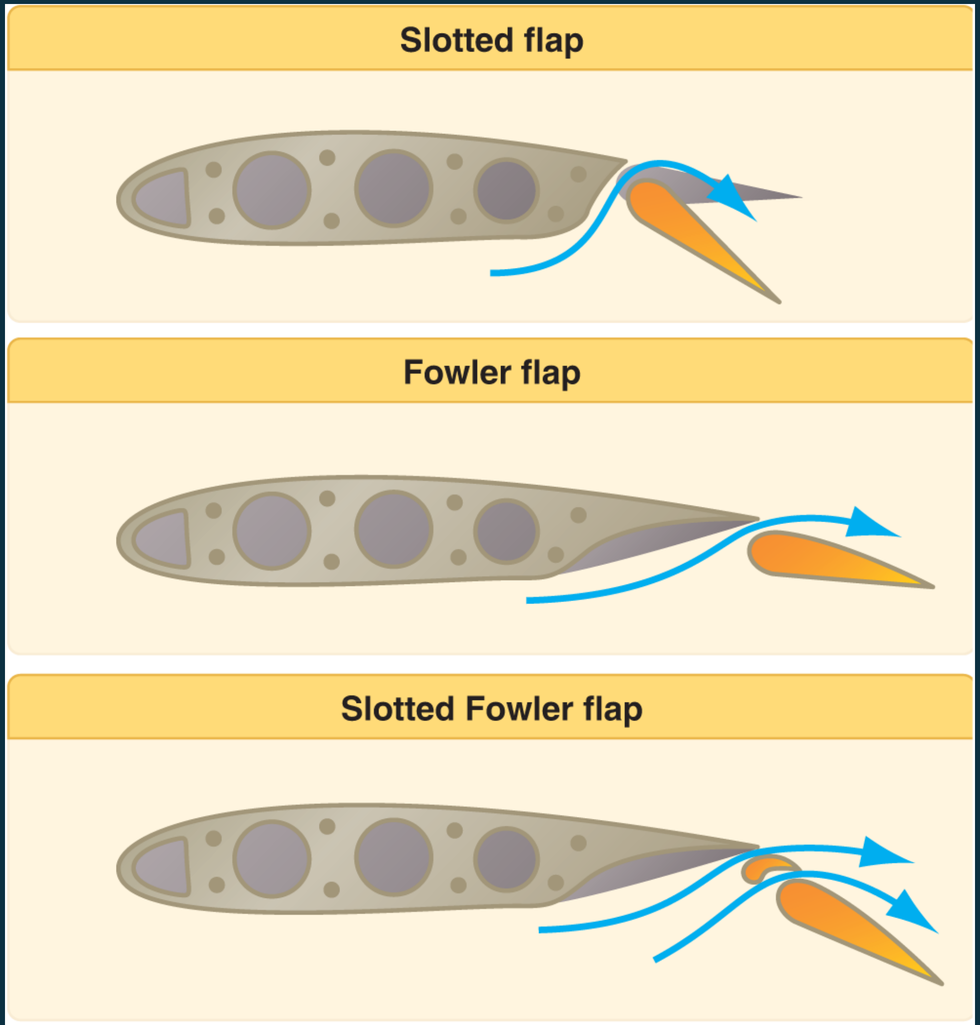


Kinds of Flaps



Kinds of Flaps

- Flaps generically change the shape of the airfoil producing more lift.
- Some flaps are designed to extend the surface area of the wing as well.
- Some are extended so much that premature flow separation occurs. Slotted and fowler flaps have gaps to allow air to flow in between the surfaces and energize the flow again.



Leading Edge Flaps

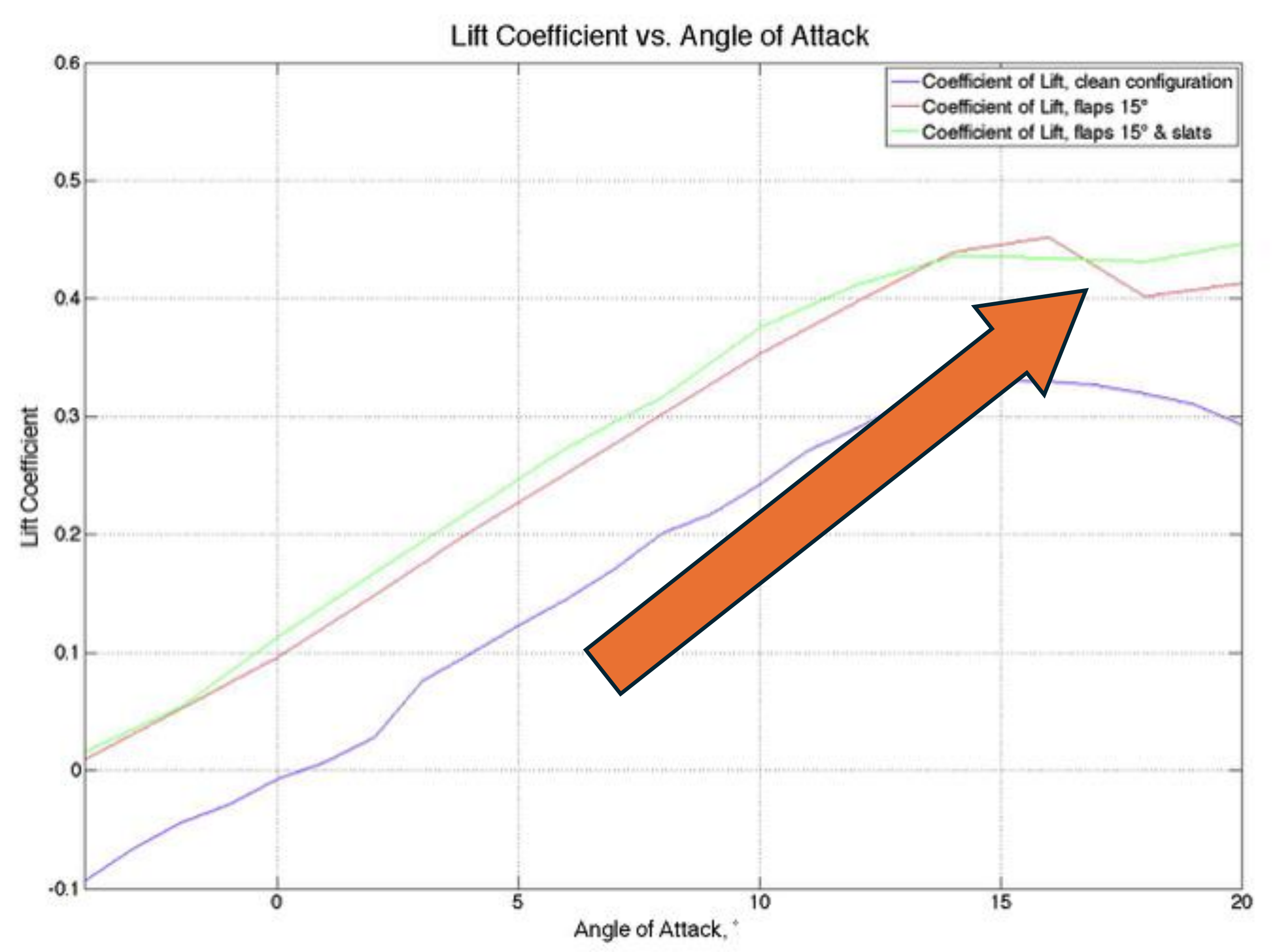
- Not to be confused with slats.
- This form of flap helps reduce the pitching moment caused by trailing edge flaps.
- Lift/Drag behavior with extension is similar to trailing edge flaps.

Slats

- Slats are leading edge devices.
- Their deployment delays stalls to higher angles of attack, as shown on the next slide.
- Some deploy automatically with flaps, other manually, and others “autonomously”, and others are fixed.

Effects of Slats

- Slats delay the stall to higher angles of attack
- The plot on the right is experimental data collected at the Florida Tech wind tunnel.
- Red line = flaps 15
- Green line = flaps 15 + slats
- Note how the green curve keeps producing lift, while the red one drops with the stall.



Types of Slats

- **Fixed slots** redirect air to the suction surface of the wing delaying wing separation.
- **Automatic slats** deploy on their own at higher angles of attack when they feel the change in pressure.
- **Powered slats** deploy by pilot input, typically paired with flaps. Most common.

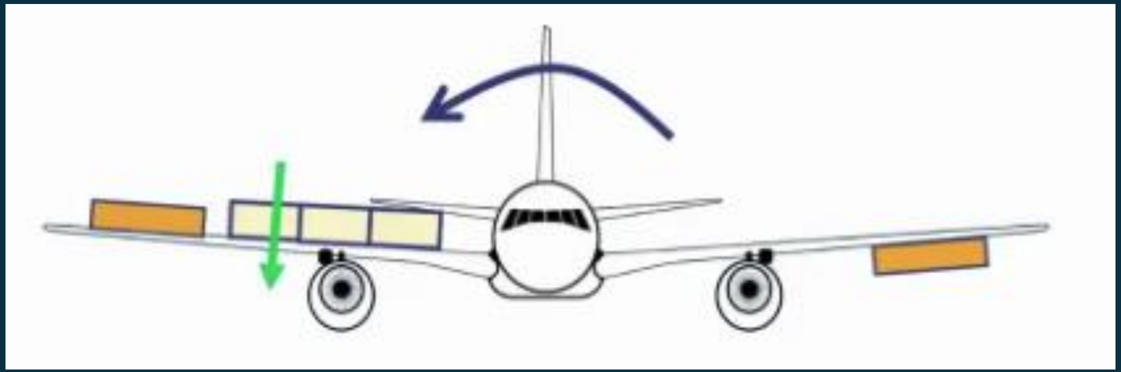
Types of Slats

- **Leading Edge Cuffs** are fixed structures that modify the camber of the airfoil permanently.
- They delay the stall but also increase the stall speed.

Cirrus SR Series

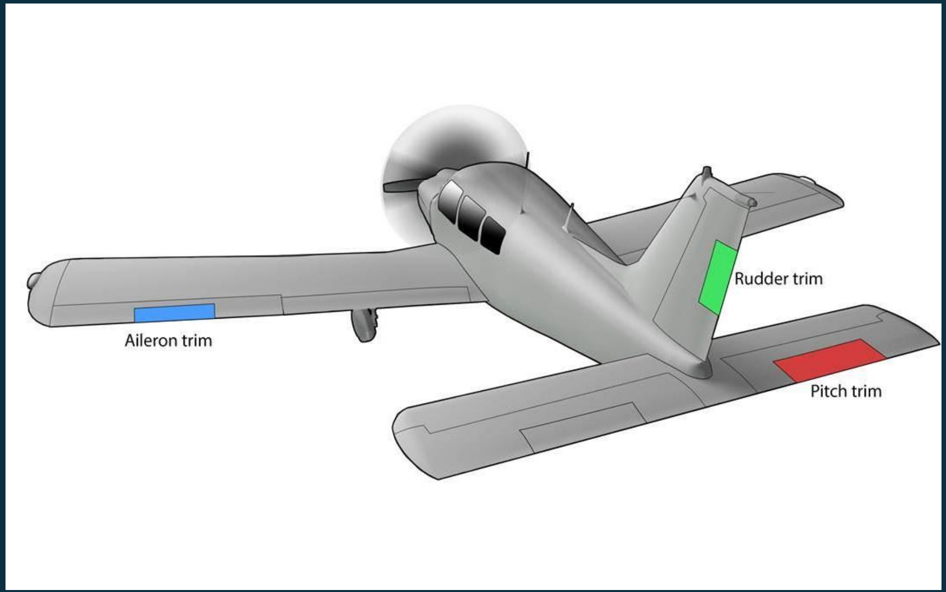
Spoilers

- Spoilers are generally deployed on touchdown to reduce landing distances by drastically increasing drag.
    - Air brakes!
    - Also referred to as “boards”
- They also help with roll control on larger jets (e.g., Boeing or Airbus airliners).



Trims

- Moving a control surface requires pilot input.
- The control surface exerts an aerodynamic load.
- That translates into a "stick force" that the pilot needs to exert onto the controls.
- Trims are control surface systems designed to alleviate those forces and help pilots control the airplane.
- Located at the trailing edge of control surfaces, like the trailing edge of the elevator.
- Note that stick force is a form of feedback, so trims don't have the goal of eliminating feedback altogether.
- **Note also that you trim the airplane for a given speed.**



Generic Trim

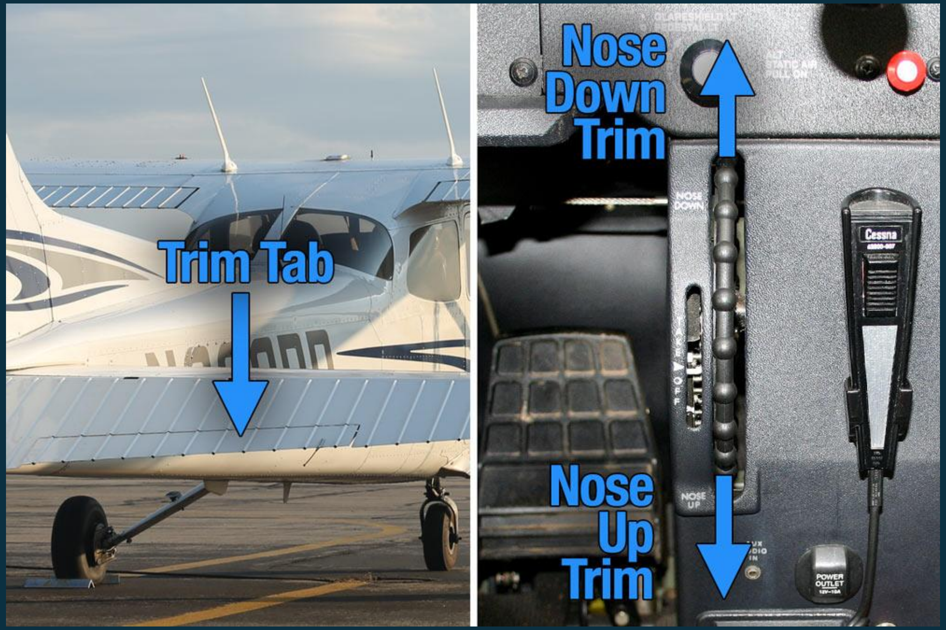
- Many large airplanes today, but also Pipers, move the entire tail with trim controls.
- Since a larger surface moves, the trim becomes more effective.
- A jack screw moves the entire surface up and down.

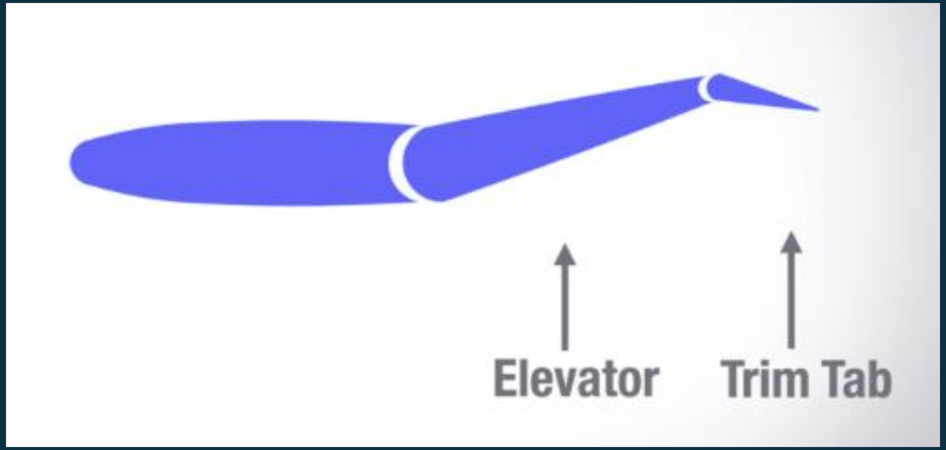
Gulfstream G700

Airbus A320 Family

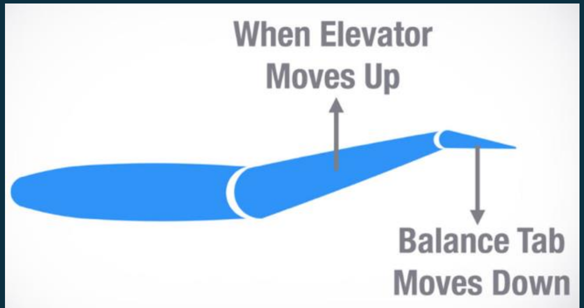
Trim Tabs

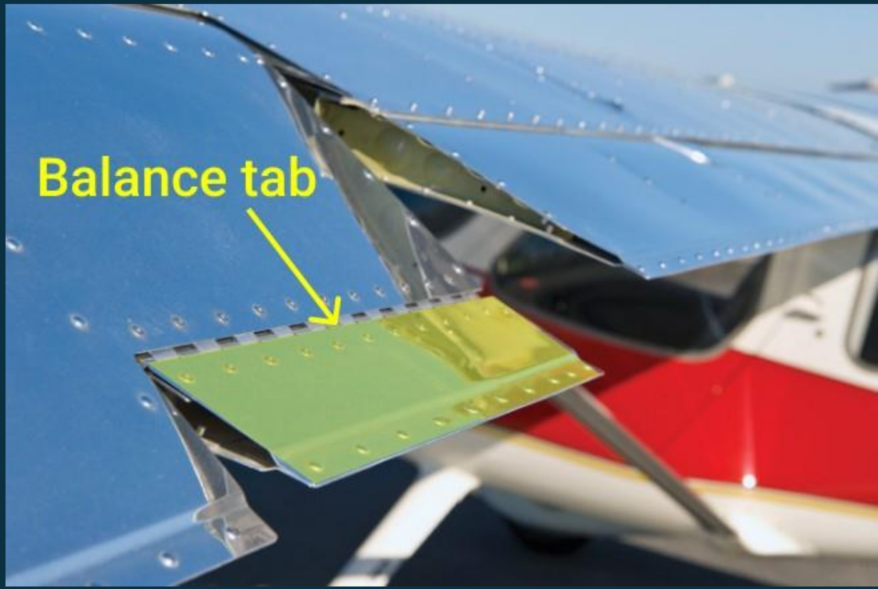
- Trim tabs are the simplest form of trim.
- They move with the control surfaces when untouched, but when the pilot moves the trim wheel, they move **opposite direction** of the elevator.
- It's a matter of balancing the aerodynamic forces.
  - When I pull the controls back, I am causing a force in one direction,
  - When I move the trim wheel, I am causing a force in the opposite direction **to cancel the stick forces**.



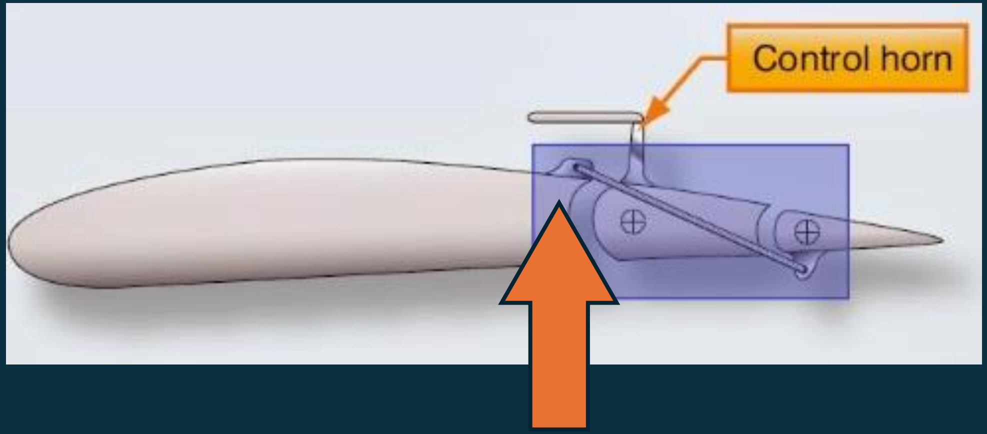


Balance Tabs





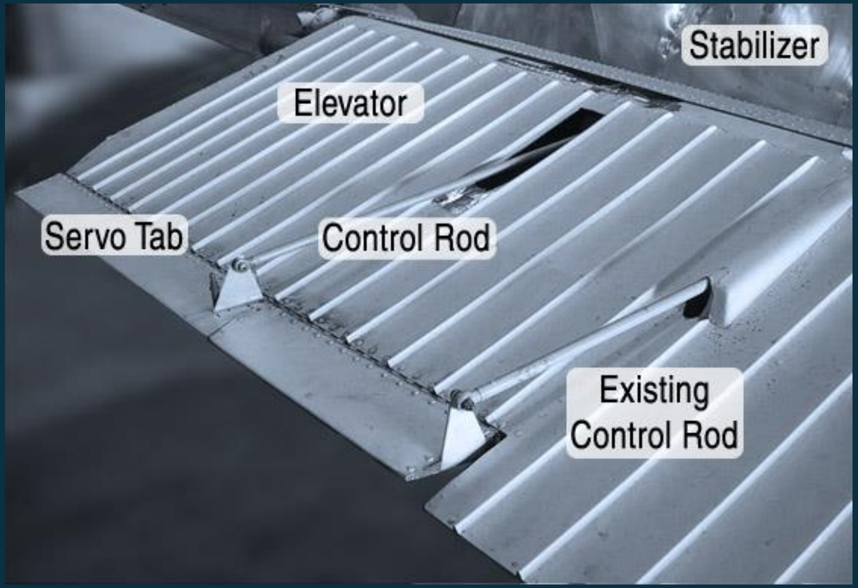
- Balance tabs are surfaces that **automatically** move opposite direction of the elevator.
  - When elevator goes up, balance tab goes down.
  - Similar to trim tabs, but movement is coupled.
- They are **coupled mechanically** with the elevator.
- Designed generically for high-speed aircraft with high control surface loads.

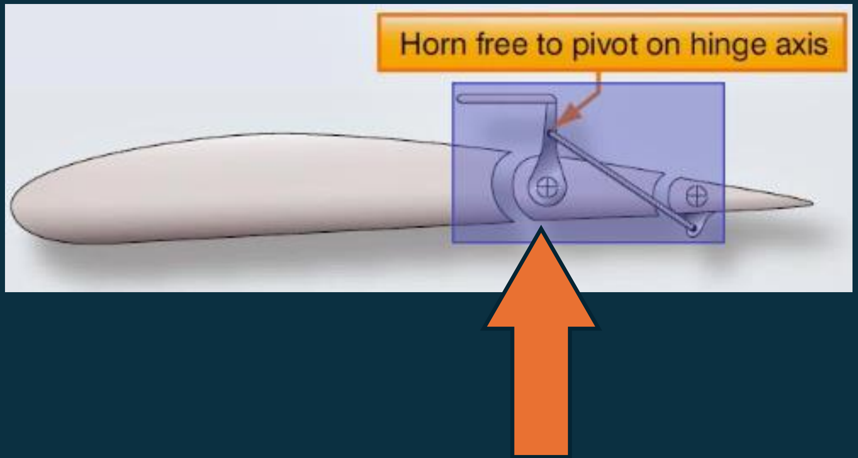


Linked to elevator

Servo Tabs

- Servo tabs are small control surfaces that move in such a way to support pilot input.
- Usually found on large aircraft
- Also referred to as Flight Tabs.





Not Linked to elevator

Anti-Servo Tabs

- Anti-servo tabs are control surfaces that automatically move in the same direction of the elevator.
- They anticipate aerodynamic load changes, aiding the pilot in precise flying.
- When pilot moves the controls back,
  - The elevator moves up
  - The anti-servo tab moves up “more” and “before” the elevator, giving the pilot a taste of what they’re about to do.

Ground Adjustable Tab

- Ground adjustable tabs are fixed metal surfaces located on trailing edges of other control surfaces.
- They are tweaked on the ground by "literally" bending metal.
- They are optimized by trial and error.

SIMPLIFIED FLIGHT CONTROLS

“What do you mean there’s no rudders?” – Pilot who has never seen an Ercoupe

SFC

- There exist aircraft that received designation as “simplified flight controls”.
- These are aircraft that do not have the traditional primary or secondary flight controls as most aircraft.
- An example is the Engineering Research Corporation “Ercoupe” which does not have rudder pedals. Thees are linked to the ailerons.
- Part 61 has many rules as to how one can be certified in them.
- Skyryse, an automation company is also building SFCs for helicopters and airplanes.

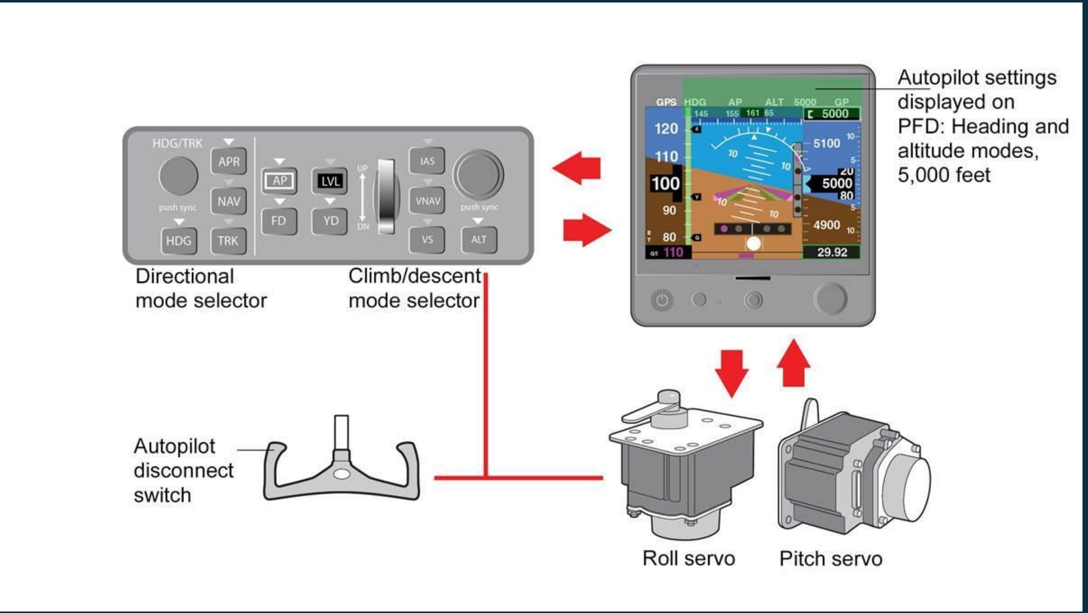
AUTOPILOT SYSTEMS

“It’s… automagical!” – Pilot about to go fly for 6 hours in a straight line

Automagical...

- Autopilots of varying complexity and sophistication are able to control multiple axes of the airplane.
- They command movement of servos that in turn move the control surfaces.
- Advanced control systems with feedback loops constantly judge the performance of the system to acquire the desired outcome.
- Check out this video on automation management.

Garmin GFC 500



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