Agenda (1/3)

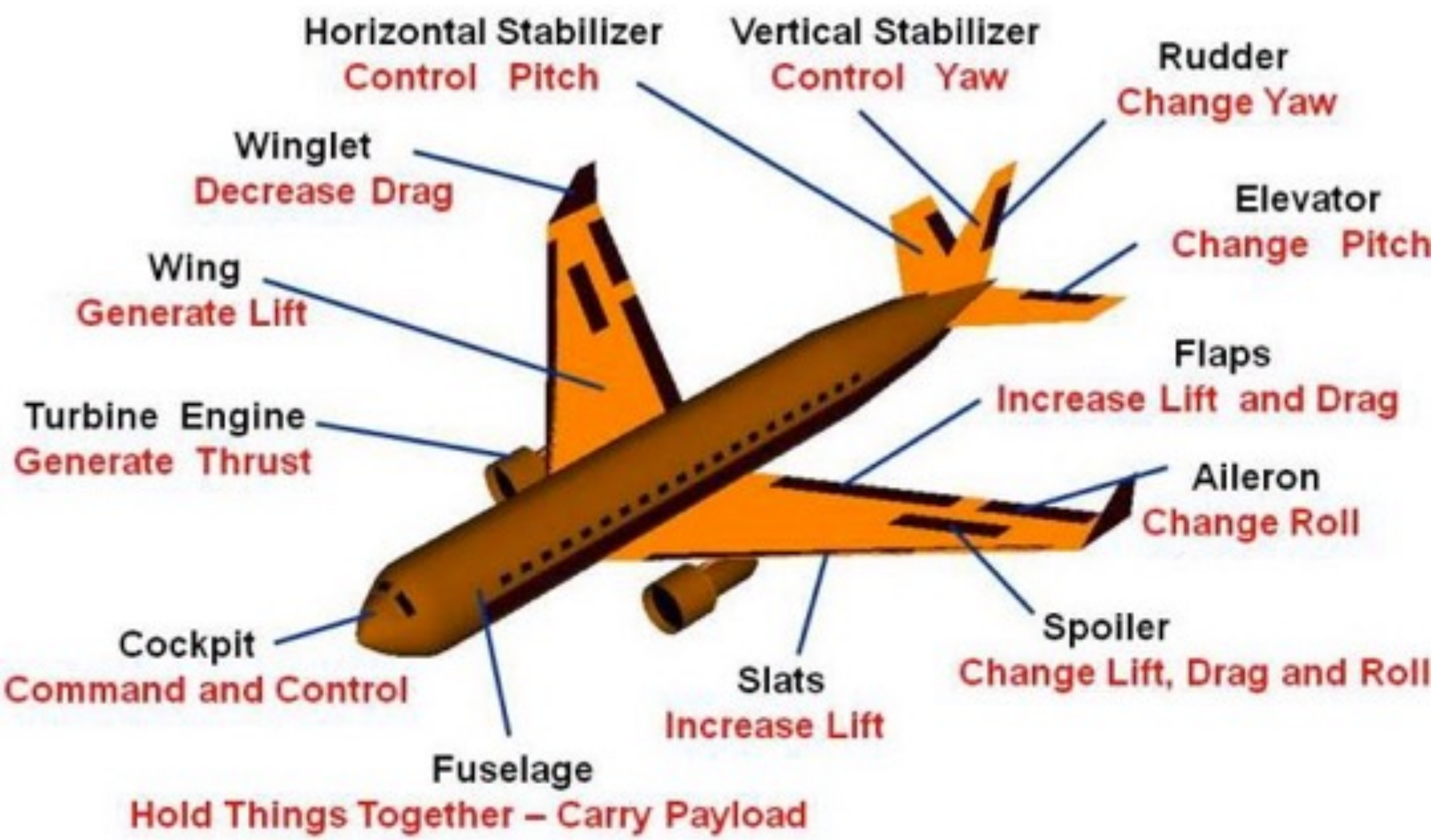
- **Module 1- Introduction (Day 1)**
  - 1-1 General Course Introduction (Day 1 Morning 1)
  - 1-2 Introduction of the Actuation session

- **Module 2 – Introduction to Aircraft Aerodynamics, stability and control (Day 1)**
  - 2-1 Aircraft Aerodynamics (Day 1 Morning 2,3,4)
  - **2-2 Aircraft Stability and Control** (Day 1 Afternoon 1,2,3,4)

- **Module 3 - A/C Aircraft configuration for flight controls and high lift (Day 2)**
  - 3-1 Arrangement of flight control surfaces and high lift devices (Day 2 Morning 1)
  - 3-2 Cockpit Controls (Day 2 Morning 2)

Aircraft Stability and control, Introduction

Aircraft Stability and control,Introduction
Airplane Parts and function



Stability of an Airplane

Question ?

An airplane in flight is constantly subjected to forces that disturb it from its normal flight path. (Climb, cruise, decend) Rising columns of hot air, down drafts gusty winds, etc., make the air bumpy and the airplane is thrown off its course. Its nose or tail drops or one wing dips. How does the airplane reacts to such a disturbance from its flight attitude?

It depends on its stability characteristics.

About stability

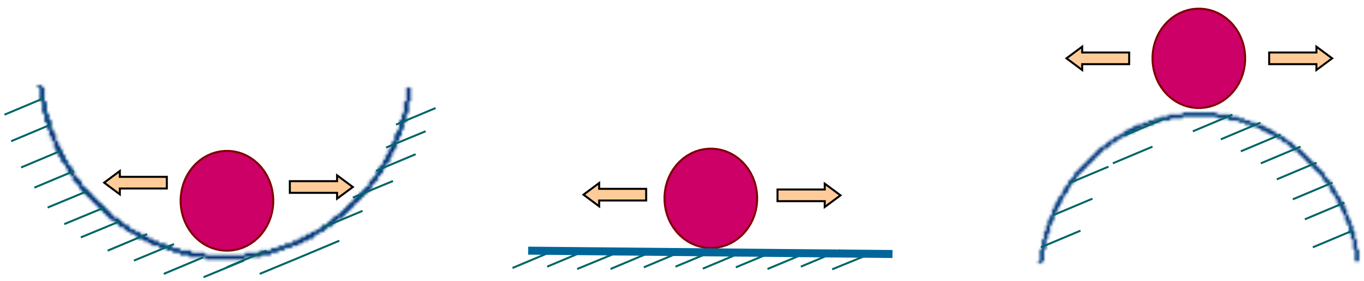
- Stability is the tendency of an airplane in flight to remain in straight, level, upright flight and to return to this attitude, if displaced, without corrective action by the pilot.
- Static stability is the initial tendency of an airplane, when disturbed, to return to the original position.
- Dynamic stability is the overall tendency of an airplane to return over time to its original position, following a series of damped out oscillations.

Static stability

Static Stability describes the initial response of the system when disturbed. If it moves back toward equilibrium, then the system is said to have **positive static stability**.

- **positive,** meaning the airplane will develop forces or moments which tend to restore it to its original position;
- **neutral,** meaning the restoring forces are absent and the airplane will neither return from its disturbed position, nor move further away;
- **negative,** meaning it will develop forces or moments which tend to move it further away. Negative stability is, in other words, the condition of instability. (static instability)

Static stability

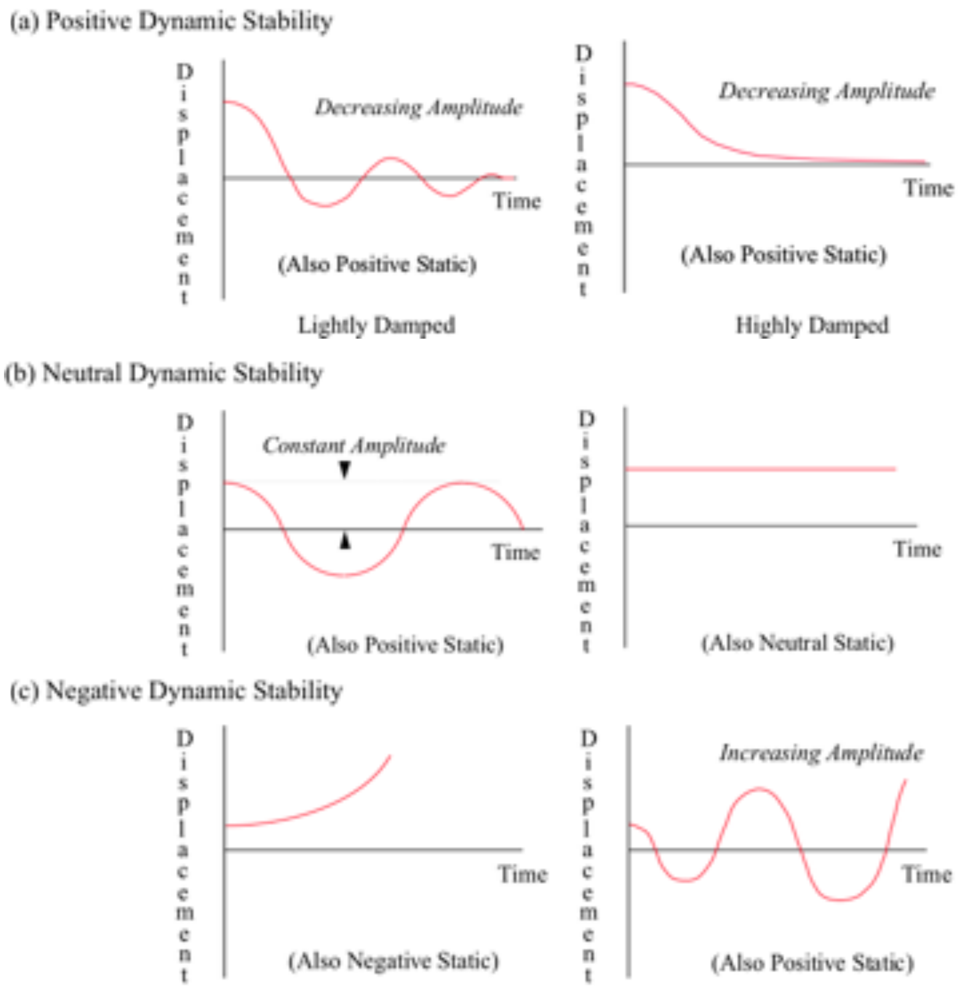


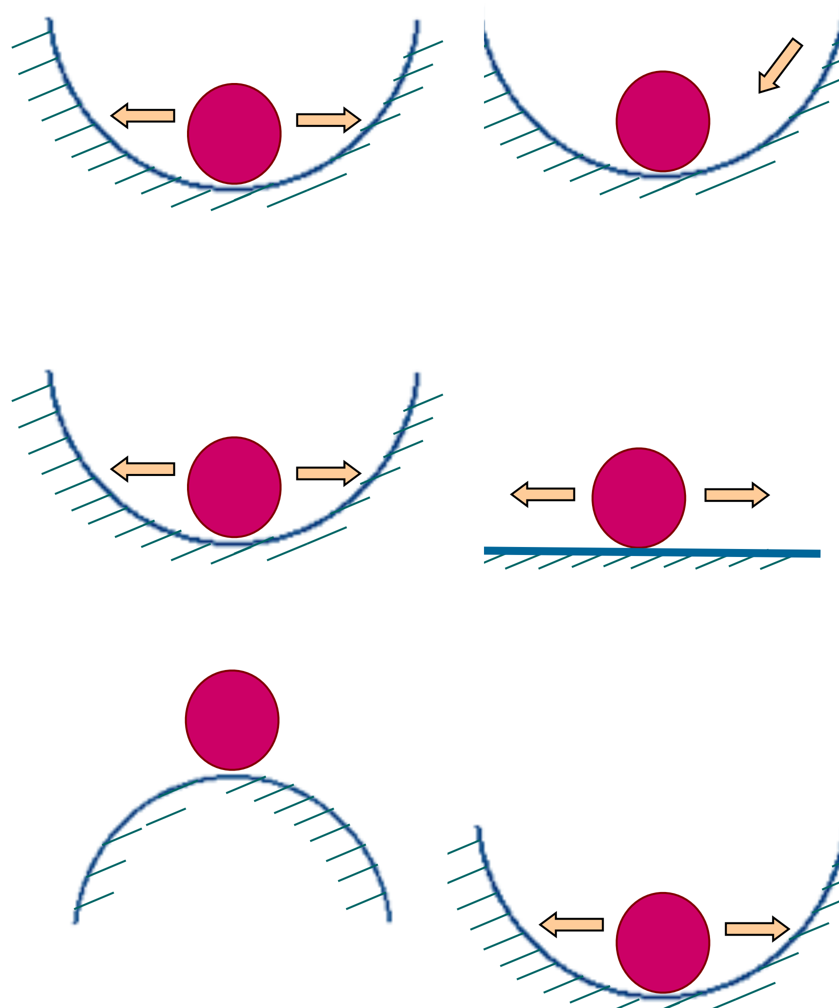
positive neutral negative

Dynamic Stability

- Dynamic stability refers to the response of the system over time.
- Positive dynamic stability—over time, the motion of the displaced object decreases in amplitude and the object displaced returns toward the equilibrium state.
- Neutral dynamic stability—once displaced, the displaced object neither decreases nor increases in amplitude.
- Negative dynamic stability—over time, the motion of the displaced object increases and becomes more divergent.

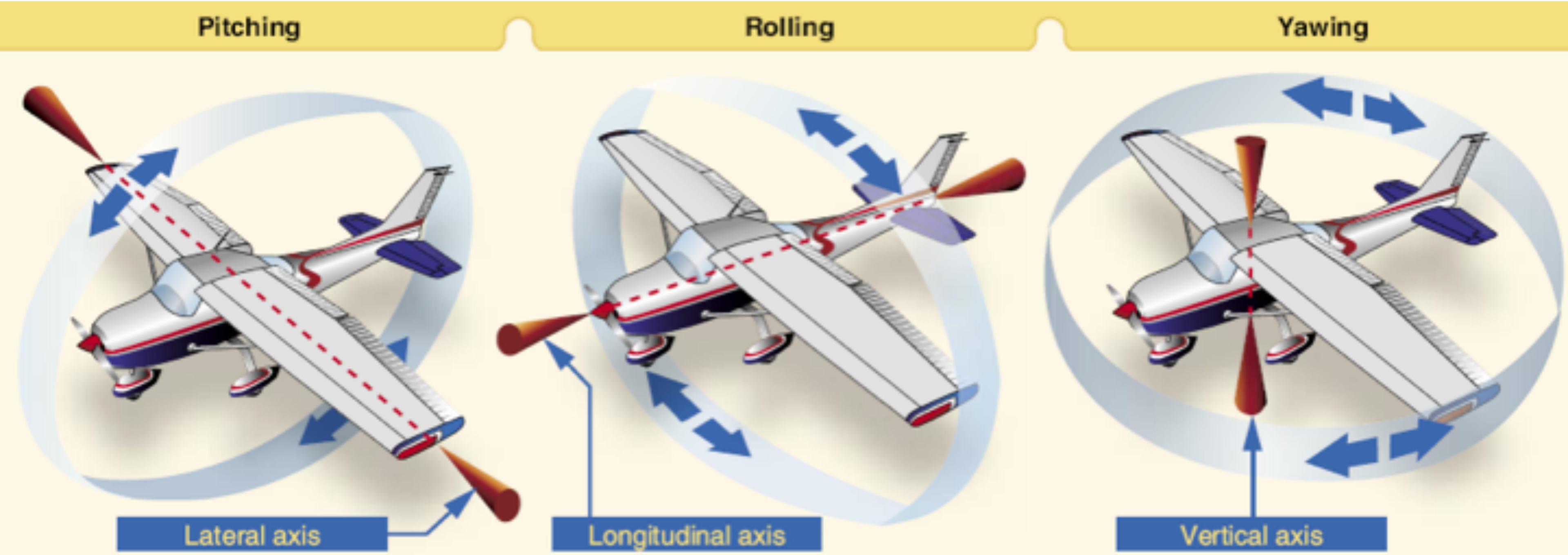
Dynamic stability





- **Stability in an aircraft affects two areas significantly**:
  - Maneuverability—the quality of an aircraft that permits it to be maneuvered easily and to withstand the stresses imposed by maneuvers.
  - Controllability—the capability of an aircraft to respond to the pilot's control, especially with regard to flightpath and attitude. It is the quality of the aircraft's response to the pilot's control application when maneuvering the aircraft, regardless of its stability characteristics.

Axes of an Aircraft



The disturbance has affected the airplane may be

- **pitching**
- **rolling**
- **yawing**

So stability can be classified

- **Longitudinal**
- **lateral**
- **directional**

Aircraft stability

- Longitudinal stability is pitch stability, or stability around the lateral axis of the airplane. (y axis)
- Lateral stability is stability around the longitudinal axis, or roll stability. (x axis)
- Directional stability is stability around the vertical or normal axis. (z axis)
- Disturbance source: gust, thrust changes,(one engine stop), configuration changes, control surface deflection, etc

LONGITUDINAL STABILITY

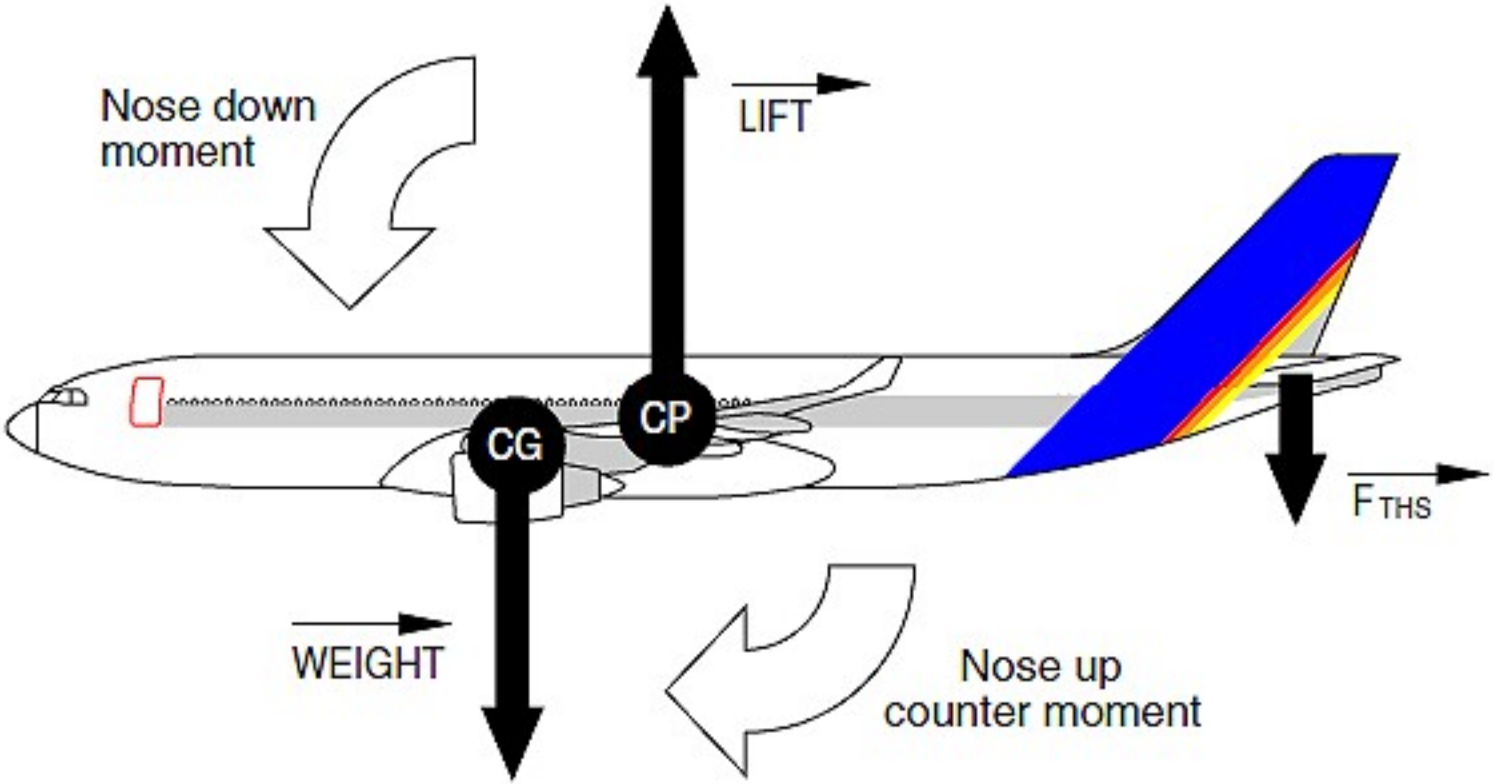
- To obtain longitudinal stability, airplanes are designed to be nose heavy when correctly loaded. The center of gravity is ahead of the center of pressure.
- Two principal factors influence longitudinal stability: (1) size and position of the horizontal stabilizer, and (2) position of the center of gravity.

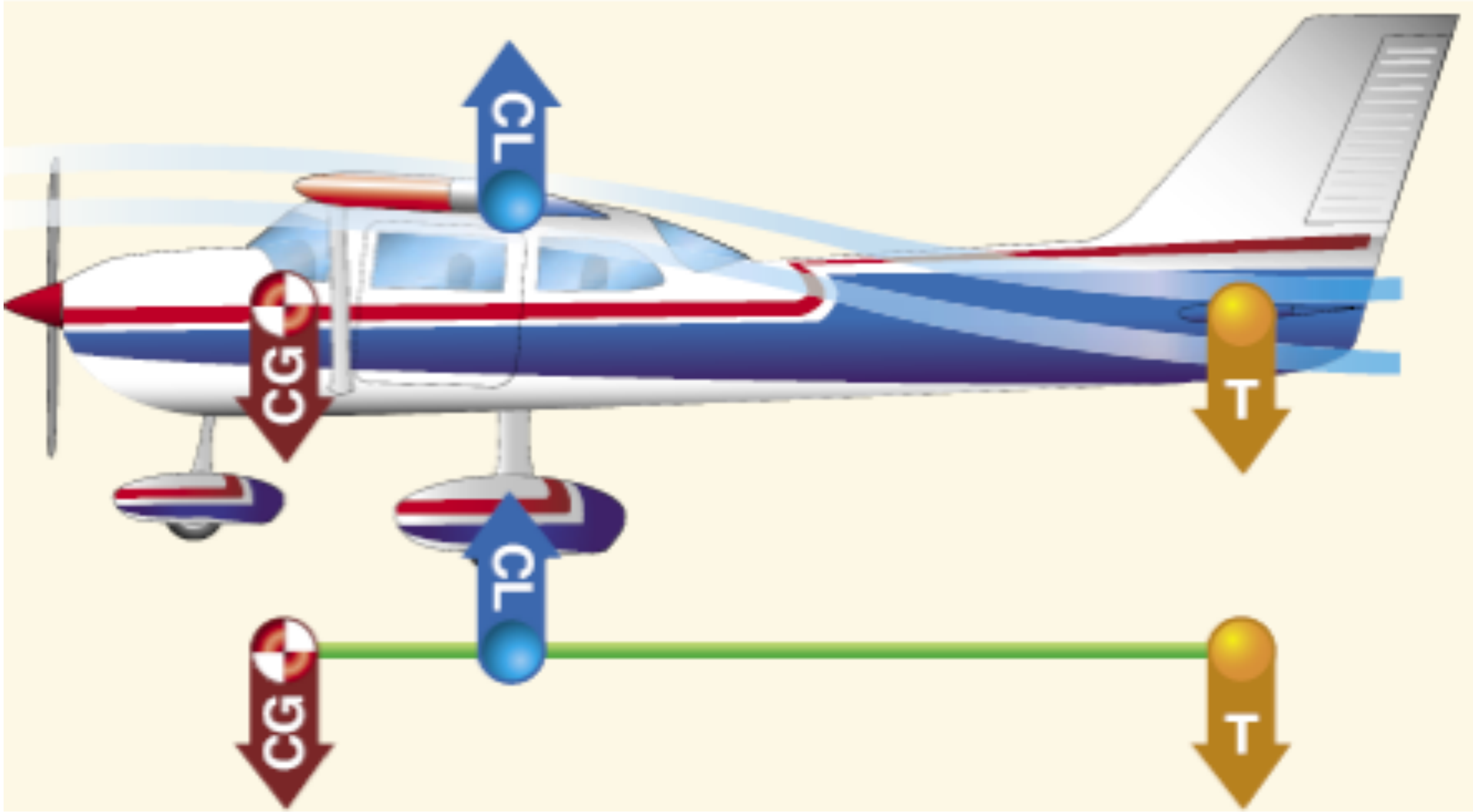
The Horizontal Stabilizer

The tail plane, or horizontal stabilizer, is placed on the tail end of a lever arm (the fuselage) to provide longitudinal stability. Compared to the wing size, it is small (6 to 8%). However, being situated at the end of the aircraft fuselage, it has a leverage. When the angle of attack on the wings is increased by a disturbance, the center of pressure moves forward, tending to turn the nose of the airplane up and the tail down. The tailplane, moving down, meets the air at a greater angle of attack, obtains more lift and tends to restore the balance.

Center of Gravity

The center of gravity is very important in achieving longitudinal stability. If the airplane is loaded with the center of gravity too far aft, the airplane may assume a nose up rather than a nose down attitude. The inherent stability will be lacking and, even though down elevator may correct the situation, control of the airplane in the longitudinal plane will be difficult and perhaps, in extreme cases, impossible.


Nose down
moment
$\overrightarrow{\text{LIFT}}$
CP
CG
$\overrightarrow{F_{THS}}$
$\overrightarrow{\text{WEIGHT}}$
Nose up
counter moment


CL
CG
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CG
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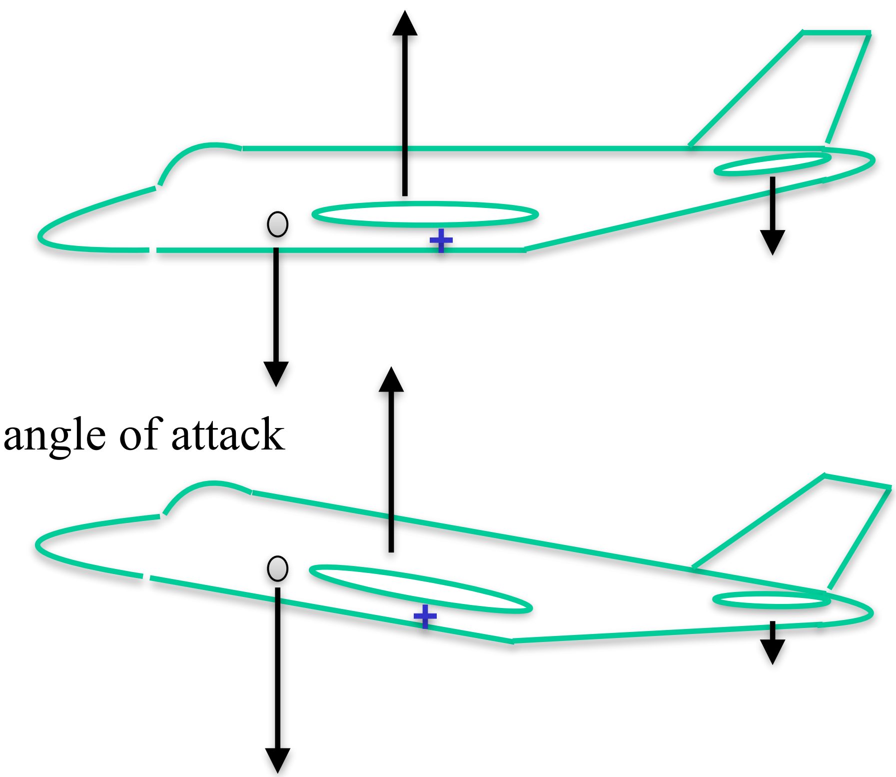
Longitudinal stability, Stable CG position

Straight and level flight

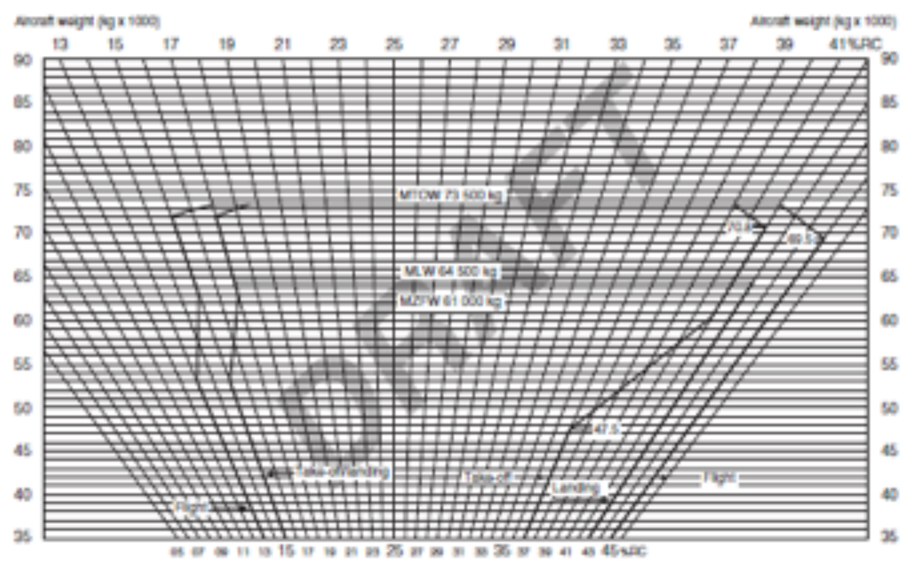
α

Perturbed with increased angle of attack



CG Control

- Aircraft CG can vary during the operation of the aircraft
- Main influencing factors are the Payload and the Fuel
- The center of gravity must be maintained within the allowable range for the operational weight of the aircraft.
- For each individual aircraft type specific weight and Balance diagram indicate the allowable limits



A320-232 CG limits IAE engines - IAE V2527-A5

CG Control

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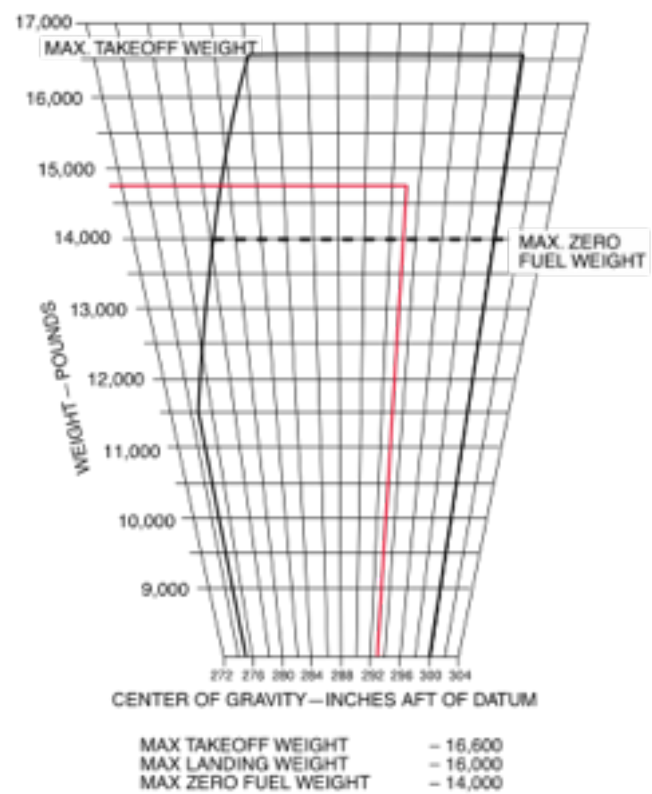
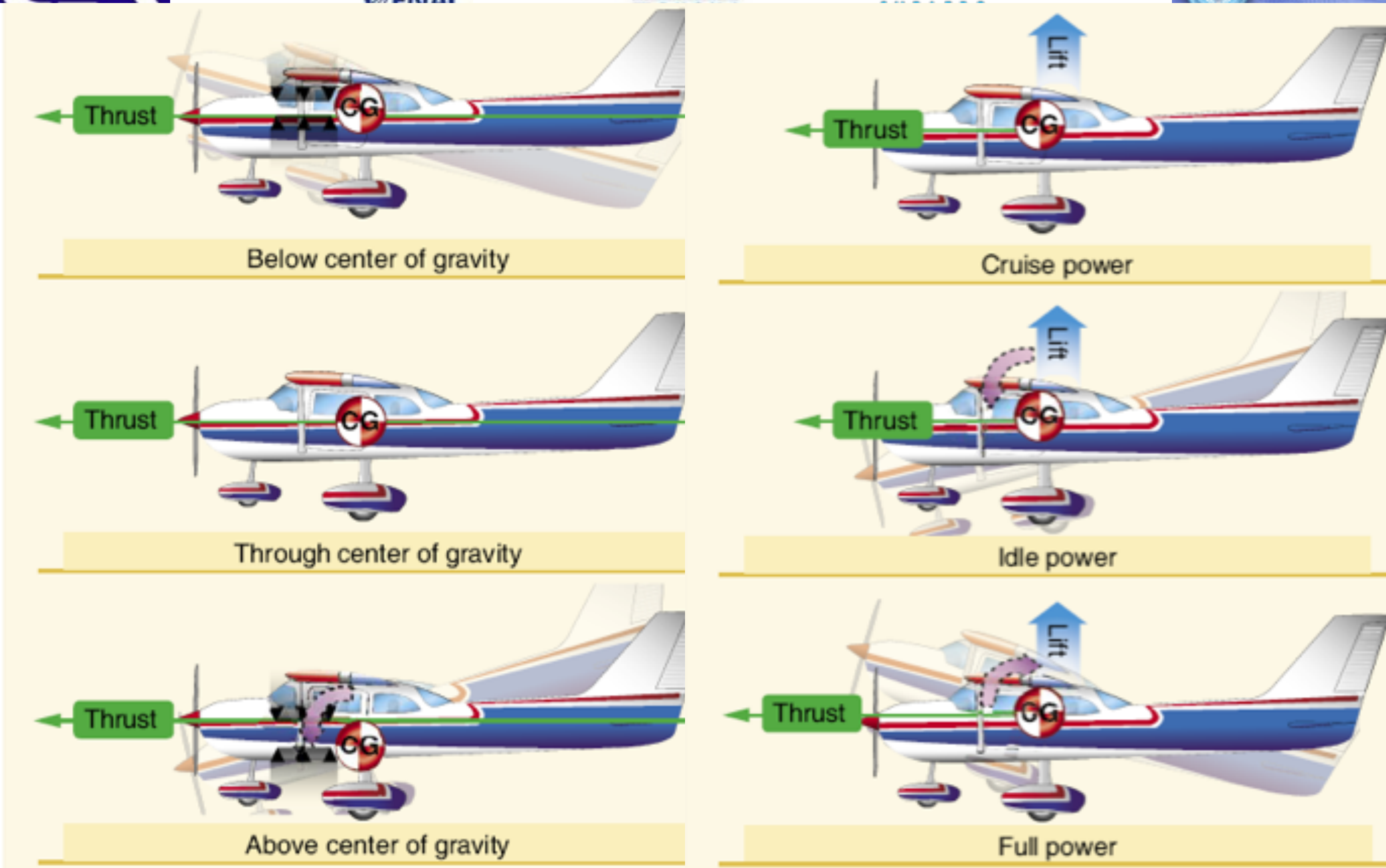
WEIGHT AND BALANCE DIAGRAM



THALES AIRBUS GROUP SAFRAN


Thrust
CG
Below center of gravity
Lift
Thrust
CG
Cruise power
Thrust
CG
Through center of gravity
Lift
Thrust
CG
Idle power
Thrust
CG
Above center of gravity
Lift
Thrust
CG
Full power

Conclusion

- ✈ With CG forward of the CP and with an aerodynamic tail-down force, the aircraft is considered stable, after disturbance it returns to a safe flying attitude.

LATERAL STABILITY

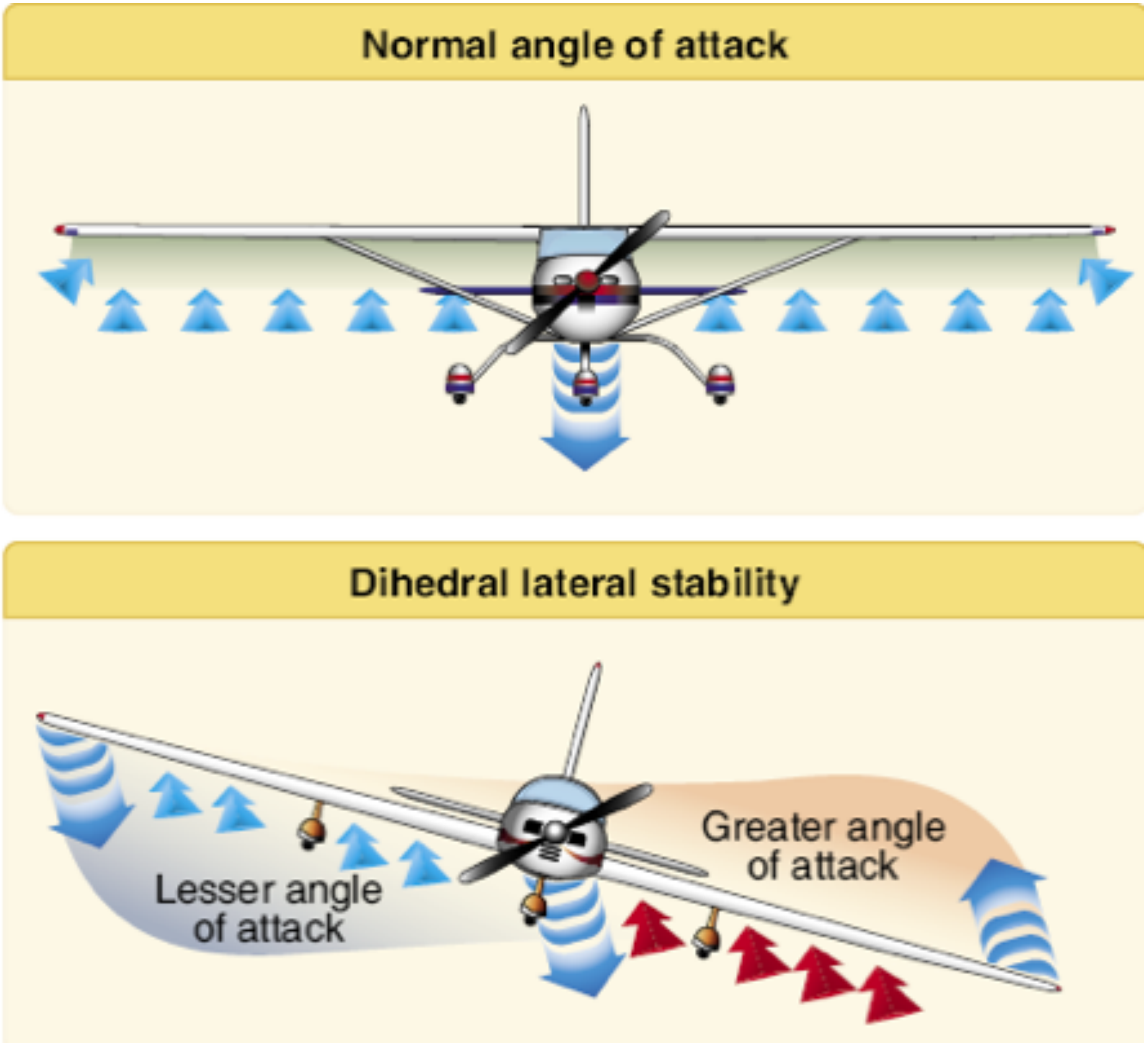
- Lateral stability is stability around the longitudinal axis, or roll stability.
- Lateral stability is achieved through
  - (1) dihedral
  - (2) sweepback
  - (3) keel effect
  - (4) proper distribution of weight.

Dihedral

The dihedral angle is the angle that each wing makes with the horizontal.

The purpose of dihedral is to improve lateral stability. If a disturbance causes one wing to drop, the unbalanced force produces a sideslip in the direction of the downgoing wing. This will, in effect, cause a flow of air in the opposite direction to the slip. This flow of air will strike the lower wing at a greater angle of attack than it strikes the upper wing. The lower wing will thus receive more lift and the airplane will roll back into its proper position.

Dihedral for lateral stability



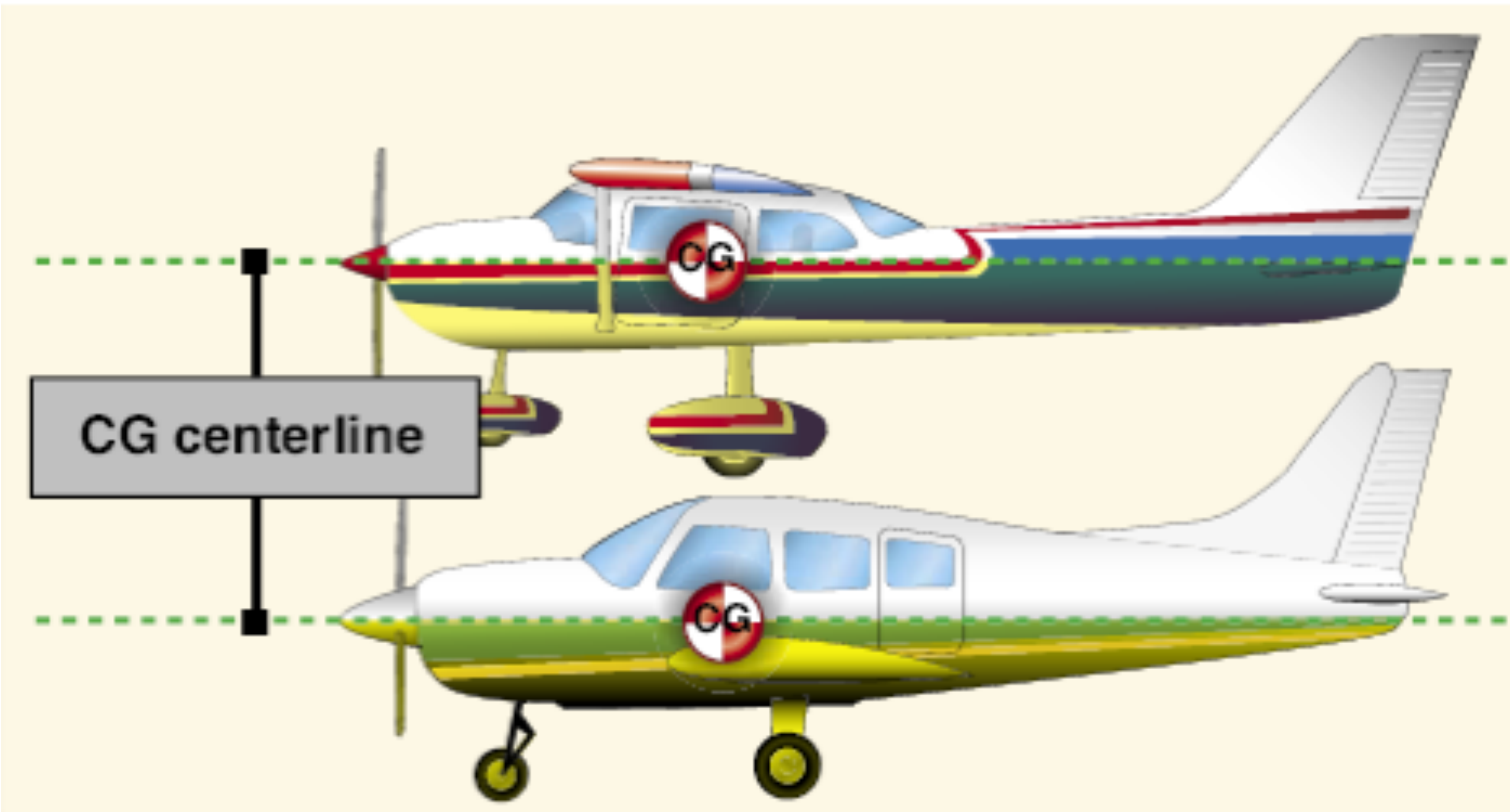
Sweepback

A sweptback wing is one in which the leading edge slopes backward. When a disturbance causes an airplane with sweepback to slip or drop a wing, the low wing presents its leading edge at an angle that is perpendicular to the relative airflow. As a result, the low wing acquires more lift, rises and the airplane is restored to its original flight attitude.

Keel Effect

Most high wing airplanes are laterally stable simply because the wings are attached in a high position on the fuselage and because the weight is therefore low. When the airplane is disturbed and one wing dips, the weight acts as a pendulum returning the airplane to its original attitude.

Keel area for lateral stability



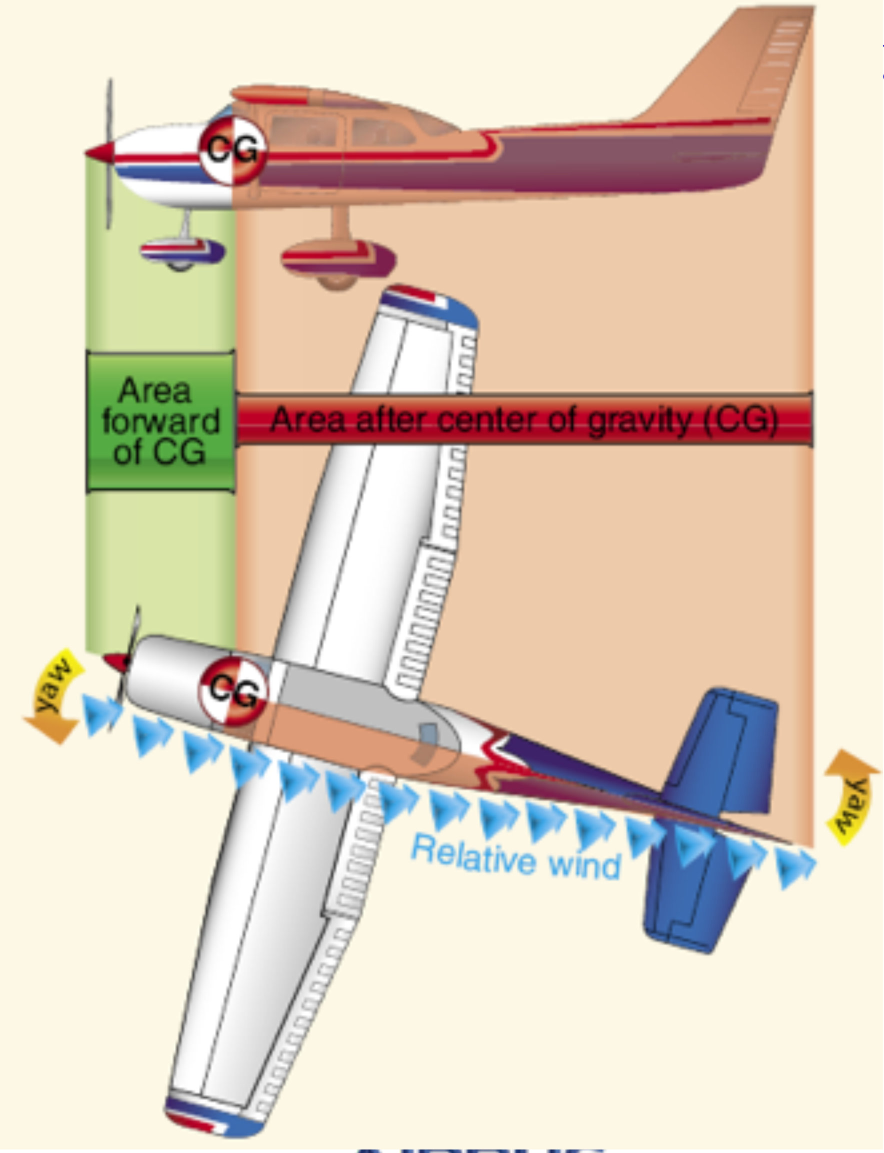
DIRECTIONAL STABILITY

The most important feature that affects directional stability is the vertical tail surface, that is, the fin and rudder. Keel effect and sweepback also contribute to directional stability to some degree.

The Fin

An airplane has the tendency always to fly head-on into the relative airflow. This tendency which might be described as weather vaning is directly attributable to the vertical tail fin and to some extent also the vertical side areas of the fuselage. If the airplane yaws away from its course, the airflow strikes the vertical tail surface from the side and forces it back to its original line of flight. In order for the tail surfaces to function properly in this weather vaning capacity, the side area of the airplane aft of the center of gravity must be greater than the side area of the airplane forward of the C.G. If it were otherwise, the airplane would tend to rotate about its vertical axis.

y


CG
Area forward of CG
Area after center of gravity (CG)
CG
yaw
Relative wind
yaw

Sweepback

Sweepback also contributes to directional stability. When turbulence or rudder application causes the airplane to yaw to one side, the right wing presents a longer leading edge perpendicular to the relative airflow. The airspeed of the right wing increases and it acquires more drag than the left wing. The additional drag on the right wing pulls it back, yawing the airplane back to its original path.

Why use sweepback wing?

Two reasons:

- Increase the critical Mach number
- Contributes to directional stability and Lateral stability

Aerodynamic Center

- Aerodynamic center F is the REFERENCE point for Aerodynamic calculations.
- Aerodynamic center Position is constant. For subsonic flight, its position is 25% of chord.
- Aerodynamic center Pitching moment is constant with angle of attack.(found both experimentally and theoretically)
- Lift force application point depend on Angle of Attack.

$$\boxed{M_F = M_0 = \frac{1}{2}\rho_0 V_0^{\,2} S_{ref}\, l C_{m_0}}$$

Calculation of MAC

<u>**The Equations**</u>

C = (S(A+2B)) / (3(A+B))

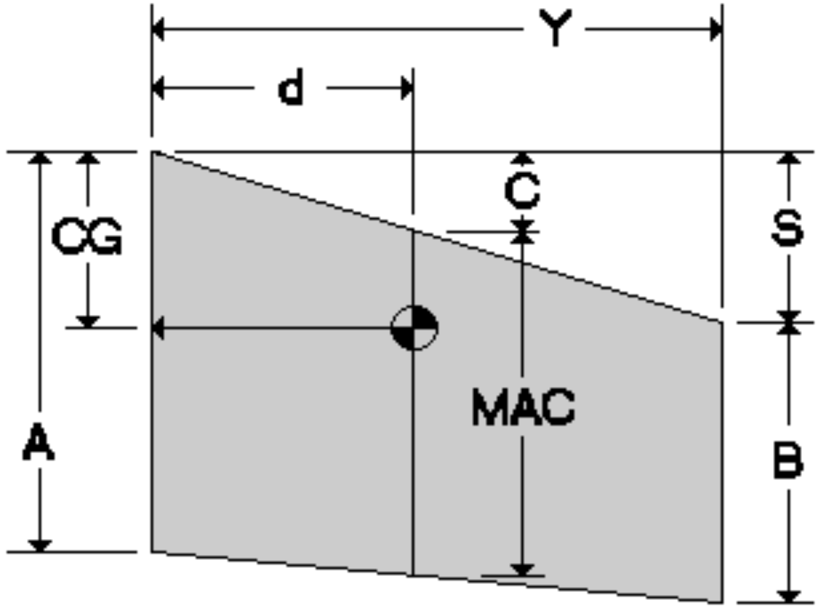
MAC = A-(2(A-B)(0.5A+B) / (3(A+B)))

d = (2Y(0.5A+B)) / (3(A+B))

CG = %MAC B.P.*(MAC) + C

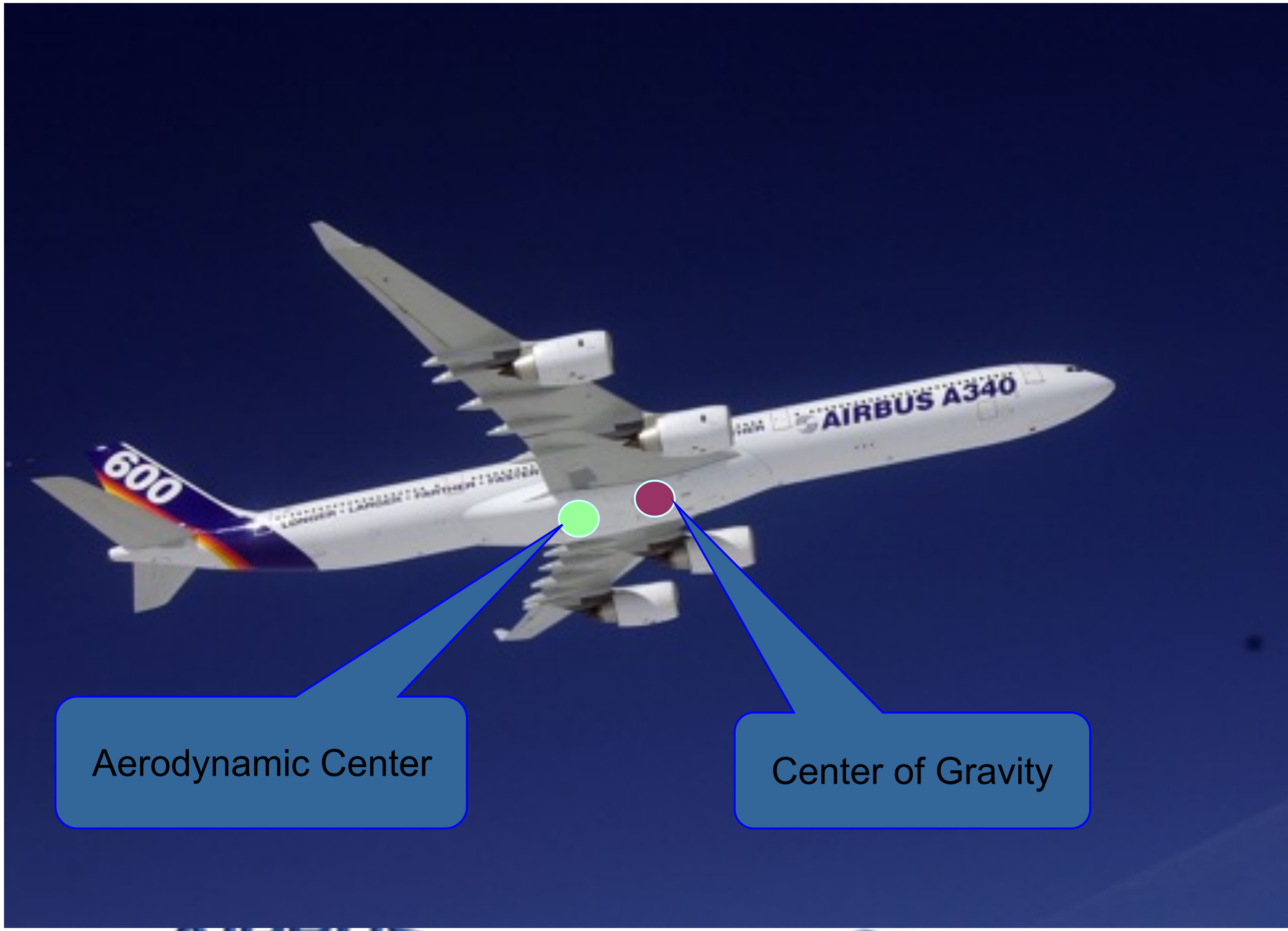
%MAC B.P. = ((CG-C) / MAC)*100

B.P. = Balance point



Position of Aerodynamic Center

To obtain longitudinal stability, the center of gravity must be ahead of the Aerodynamic Center



Directional Control ⇨ ROLL

Ailerons

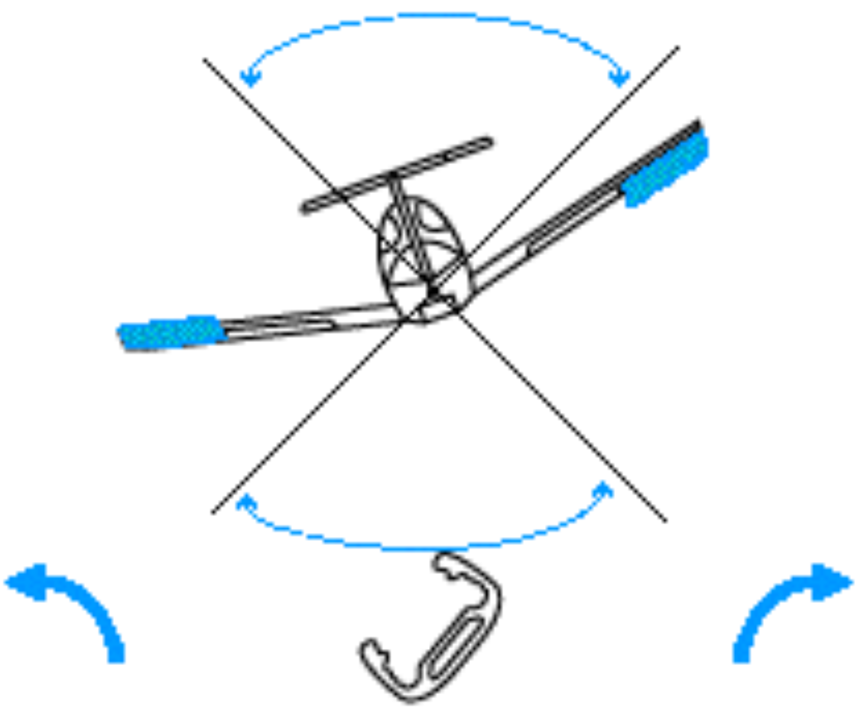
- The stick is connected by means of wires or hydraulics to the wings' ailerons. By turning the stick, the pilot can change the positions of the ailerons.
- When the control wheel (side stick) is turned to the right, the right aileron goes up and the left aileron goes down, rolling the airplane to the right.
- When the control wheel is turned to the left, the right aileron goes down and the left aileron goes up, rolling the airplane to the left.

Directional Control ROLL

Directional Control - AILERONS

ROLL

Ailerons rotate airplane around longitudinal axis



Directional Control → YAW

Rudder

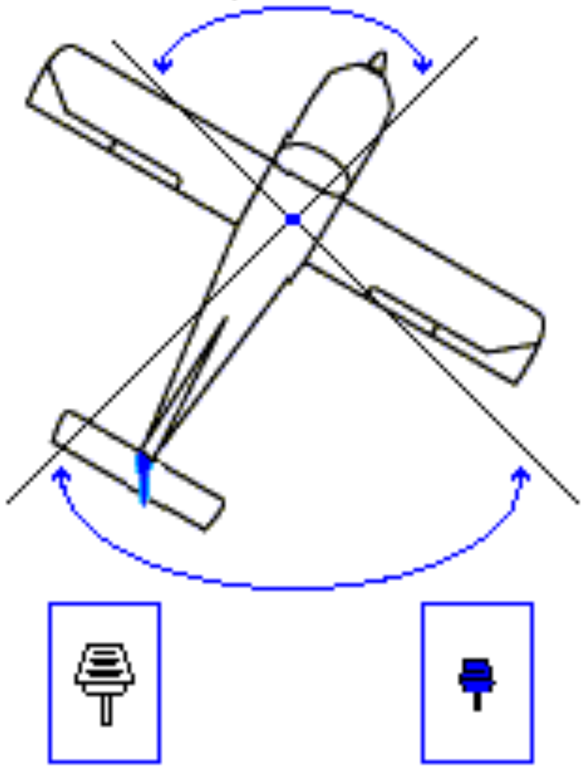
- The foot pedals are connected by means of wires or hydraulics to the rudder of the tail section. The rudder is the vertical part of the tail that can move from side to side.
- When the foot pressure on the left rudder pedal moves the rudder to the left, causing the nose of the airplane to move to the left.
- When the foot pressure on the right rudder pedal moves the rudder to the right, causing the nose of the airplane to move to the right.

Directional Control — YAW

Directional Control - RUDDER

YAW

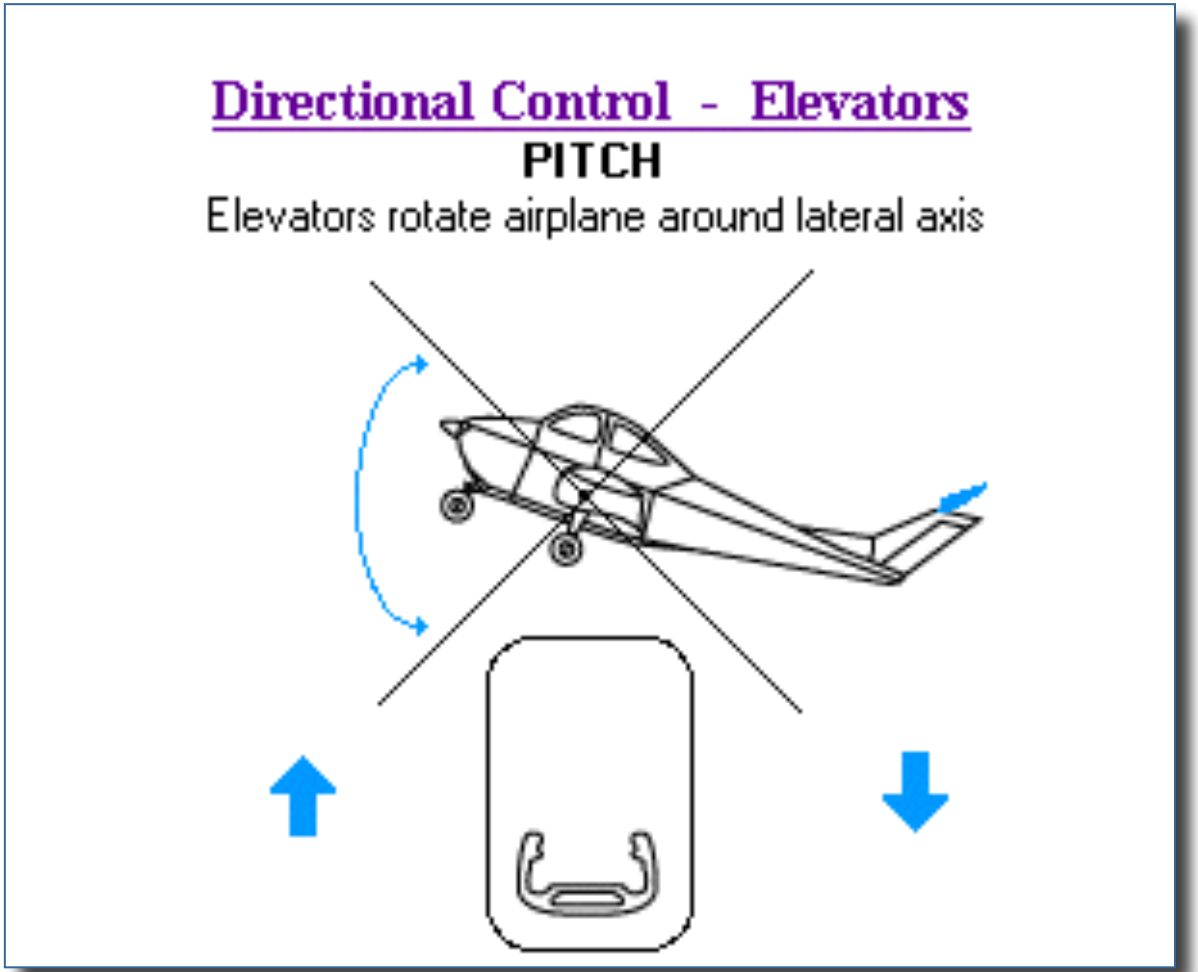
Rudder rotates airplane around vertical axis.



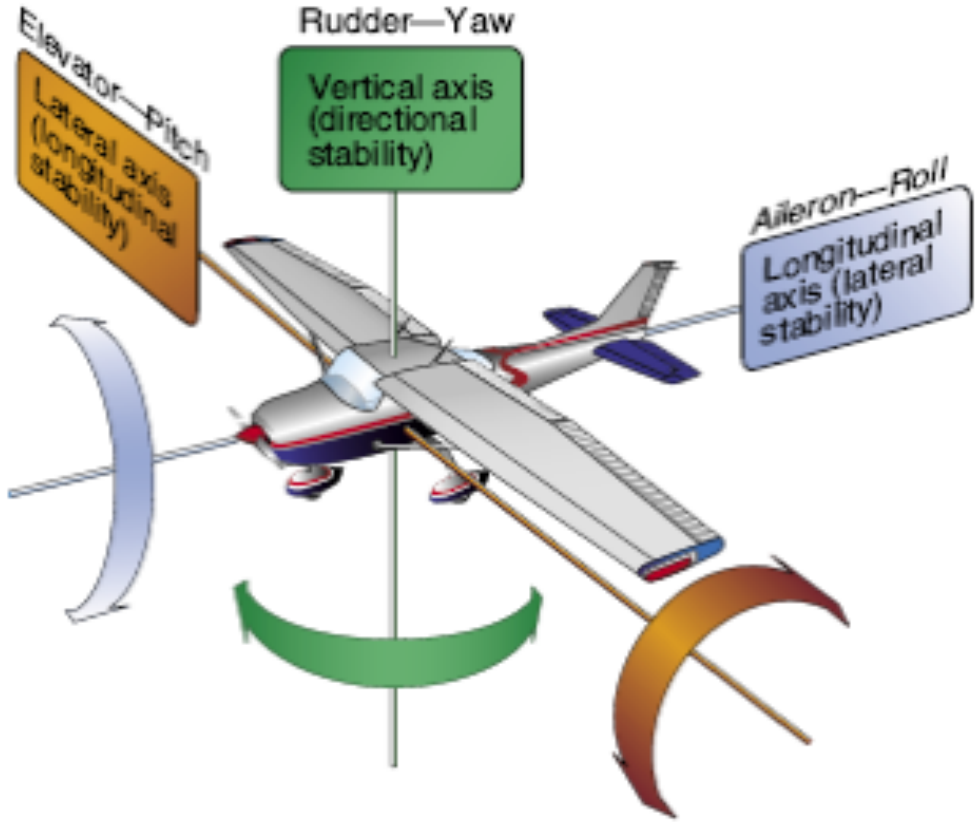
Directional Control ⇒ PITCH

- Elevators
- The stick (control colum) is connected by means of wires or hydraulics to the tail section's elevators. By moving the stick, the pilot can change the position of the elevators.
- When the control column is pushed in, the elevators move down, pitching the tail of the airplane up and the nose down, rolling the airplane down.
- When pulling the control column back makes the elevators move up, pitching the tail of the airplane down and the nose up, rolling the airplane upwards.

Directional Control ⇨ PITCH



GEA Ti



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

Wing loading

- Wing loading is an important parameter.
- Slow airplanes have low wing loadings.
- Transonic and supersonic airplanes have higher wing loadings.

Light single engine piston airplane
100 kg/m2
120 kt

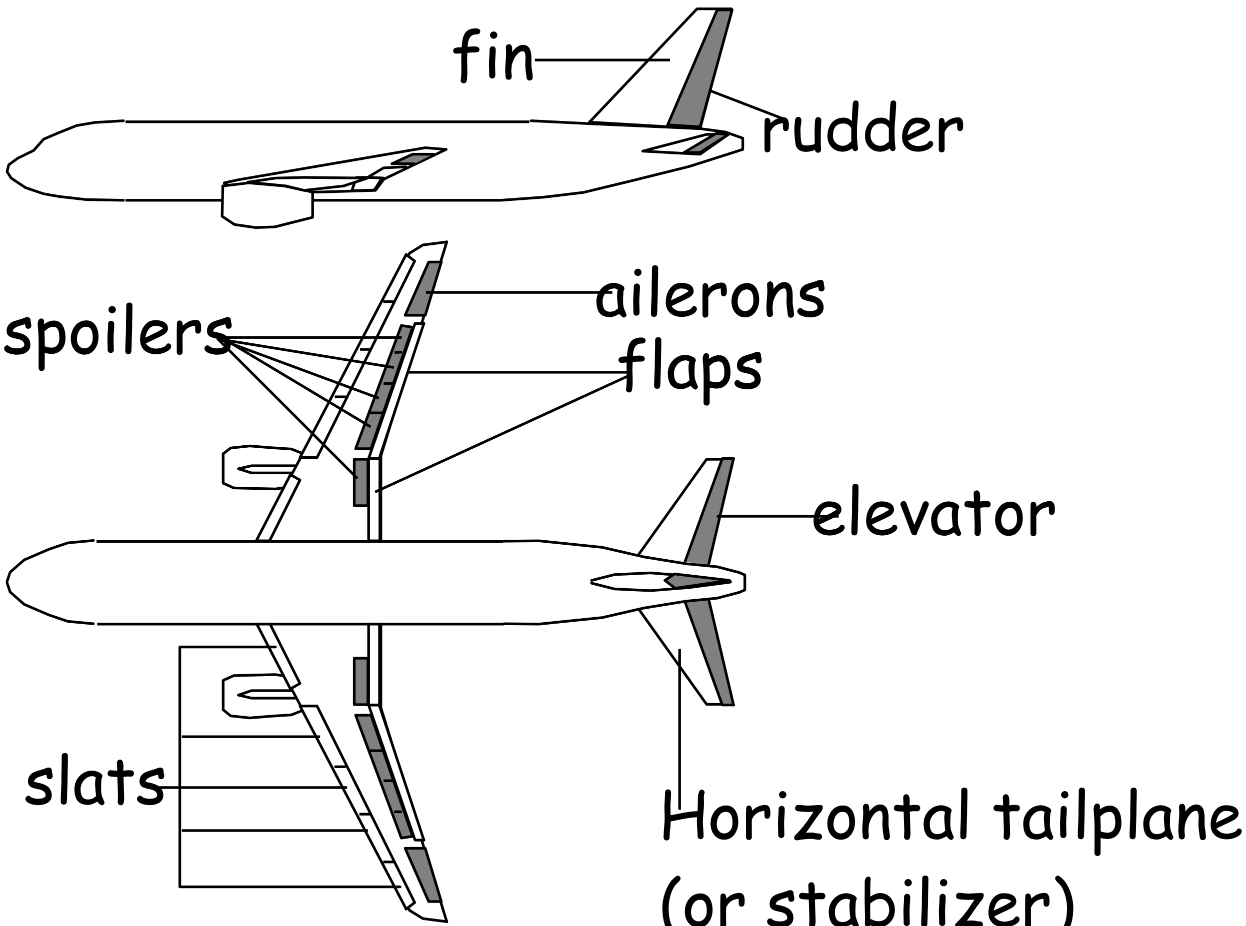
Commercial jet
700 kg/m^2
Mach 0.8

End of Session

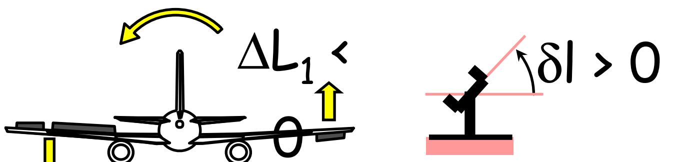
- End of session, thank you !
- Questions?

Flight controls

Definitions

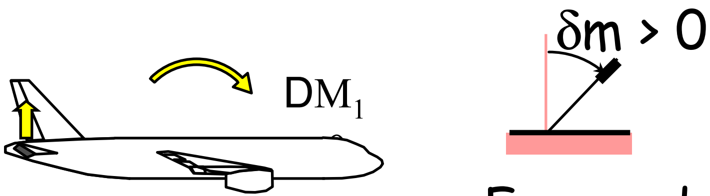


Definitions (2)



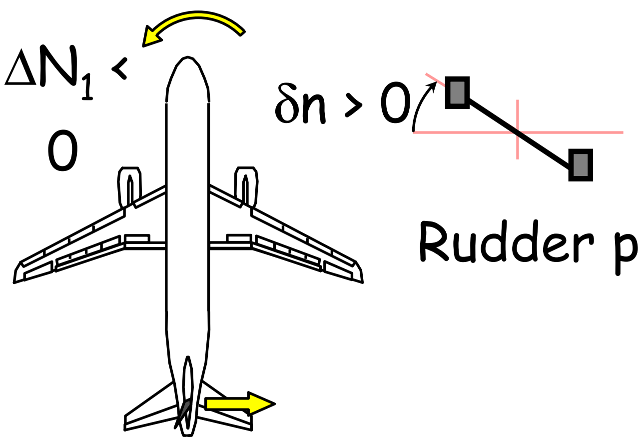
Roll

Left stick (or control wheel)



Pitch

Forward stick (or control wheel)

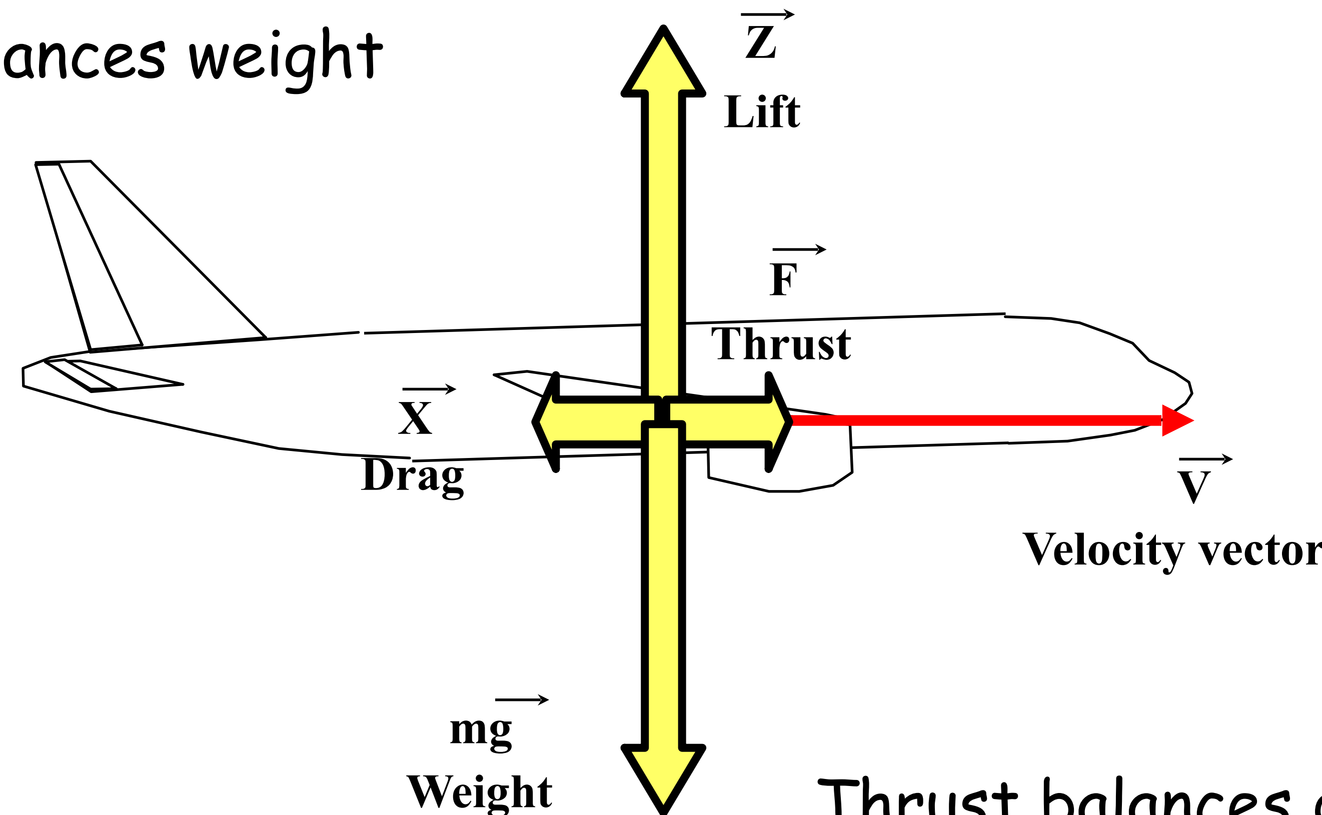


Yaw

Rudder pedals to the left

Basic Flight Mechanics Equitation

Lift balances weight



Thrust balances drag

An airplane has :

wings to generate lift,

engines to balance drag.