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Aircraft Stability and Control

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Table of Contents

Introduction:

Aircraft flies in the air and it's subjected to different forces in different directions, and its aerodynamic structure is designed carefully and precisely to let the aircraft maintain its trimmed position with minimum efforts from the pilot, so he can focus on other tasks such as navigation, monitoring, changing altitude when required, etc.

Aircraft structures are also provided with aerodynamic movable surfaces called flight controls which respond to the aircraft computer or the pilot inputs to move the aircraft and control it around its axes of motion, So that we can understand the stability well, we have to know the aircraft's axis of motion.

1. Aircraft Axis of Motion:

1.1 Longitudinal axis: it's a virtual line running from the aircraft nose to the aircraft tail around which the aircraft roll.

1.2 Lateral axis: it's a virtual line run from wing tip to wing tip around which the aircraft pitches.

1.3 Vertical axis: it's a virtual line run vertically through the center of the aircraft around which the aircraft yaws.

The three-axis intersect the aircraft's center of gravity, the point over which the aircraft balance.

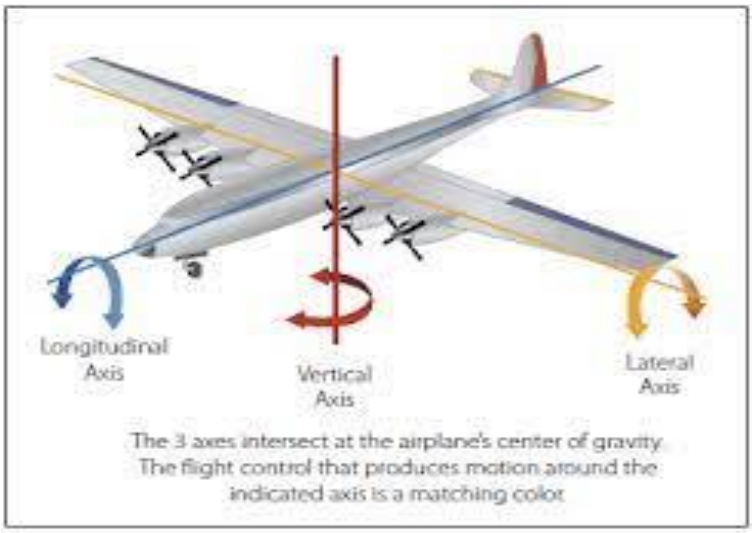


Figure 1. axes of an aircraft flight-mechanic.com

Stability can be defined as the ability of an aircraft to return to its original position when disturbances occur at straight and level flight.

The stability and maneuverability of an aircraft are vice versa, as we mentioned above

Very stable aircraft will resist changes in their attitude and therefore, will be difficult to maneuver such as commercial airplanes, on the contrary, Military aircraft like jet fighters, where the high maneuverability is one of the requirements, have lower levels of stability than civil airplanes and "can even be unflyable without the help of computer controlled fly-by-wire systems" stated (Catlir 2015).

so, stability is a desirable feature but it depends on aircraft type and mission.

Figure 2. static and dynamic aircraft stability. Boldmethod.com

2. Stability:

They are two general types of stability ***static*** and ***dynamic,***

Static stability is divided into three types ;

Positive static stability, neutral static stability, and negative static stability

Also, dynamic stability is divided into three types :

Positive dynamic stability, neutral dynamic stability, and negative dynamic stability

the below hierarchy in figure 3 illustrates the types of stability and subtypes.

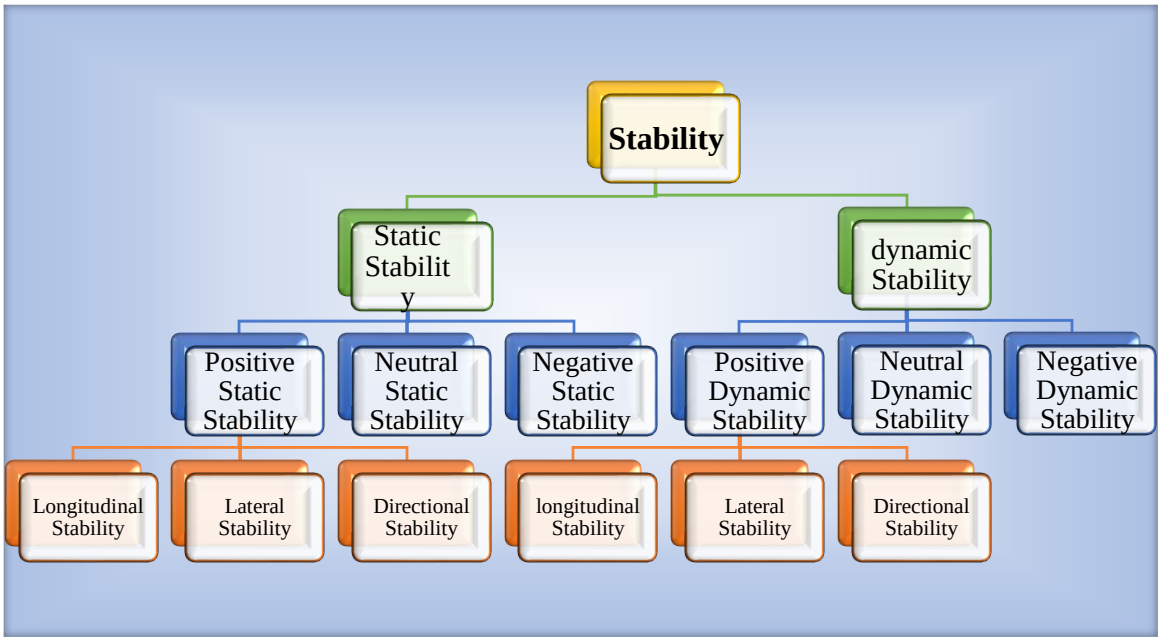


FIGURE 3. TYPES OF STABILITY DESIGNED BY AMER AL YAZJIN

2.1 Static stability

Static stability is the ability of an aircraft to return to its original poison when it's disturbed and there are three types of static stability :

2.1.1 Positive Static Stability: Positive static stability is entirely aircraft design matter, so aircraft designed to return to its original position after disturbance around any of its three axes of motion *Longitudinal, Lateral and vertical.*

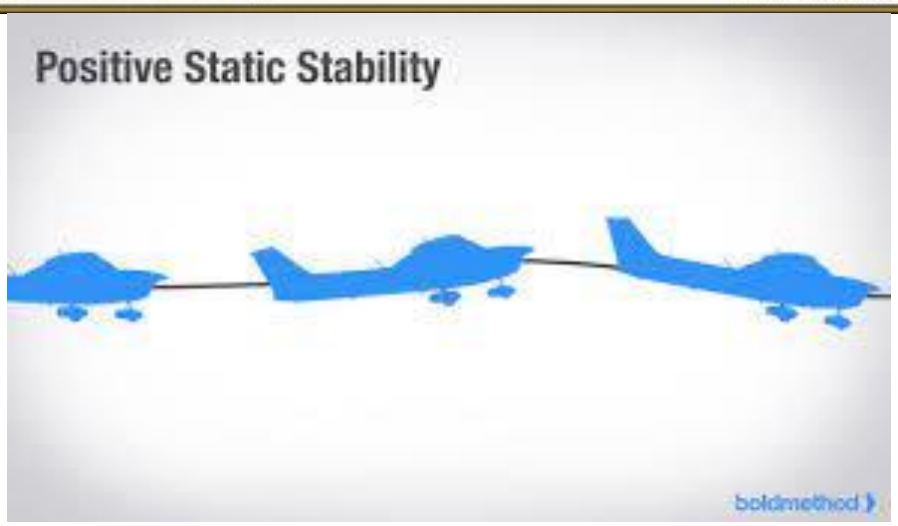


Figure 4. Positive static stability. boldmethod.com

2.1.1.1 Longitudinal Static Stability :

It's aircraft stability after disturbed in pitch (nose up or down)

around the lateral axis.

-so if disturbance makes the aircraft nose up since the design of the wing airfoil let the center of pressure (lift axis) behind the center of gravity these two opposite forces return the aircraft to its original position.

- if disturbance makes the aircraft nose down the horizontal stabilizer will create adown force on the aircraft tail which raises the nose and returns the aircraft to its original position.

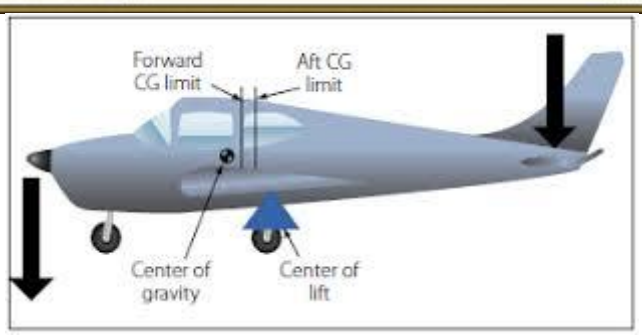


Figure 5. longitudinal static stability flight mechanic.com

2.1.1.2 Lateral Static Stability

its aircraft stability after disturbing force makes the aircraft

Roll around its longitudinal axis.

-if disturbance makes the aircraft roll left or right so one wing will drop down increasing the angle of attack and creating more lift, and the other wing will raise decreasing the angle of attack, creating less lift this creating a roll opposite to the disturbance roll that returns the aircraft to its original position also this improved by the vertical stabilizer.

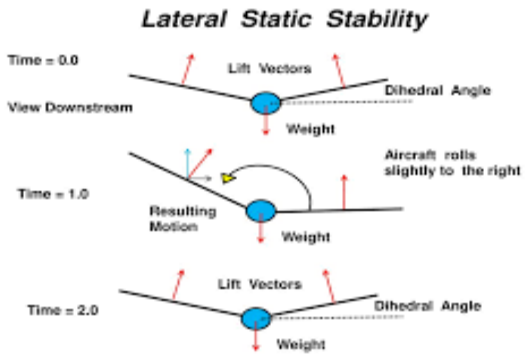


Figure 6. Lateral Static Stability slideplayer.com

2.1.1.3 Directional Static Stability:

is aircraft stability around the vertical axis when a disturbance force rotates the aircraft's nose right or left.

-when the wind rotates the aircraft's nose for example to left, the nose will yaw in the same direction of the wind and the vertical stabilizer will yaw in the opposite the direction of the wind creating drag to the vertical stabilizer which returns the aircraft to its original direction.

Figure 7. Lateral Static Stability. print screen from youtube video.

2.1.2 Neutral Static Stability: the aircraft tends to stay on its new poison when it's disturbed.

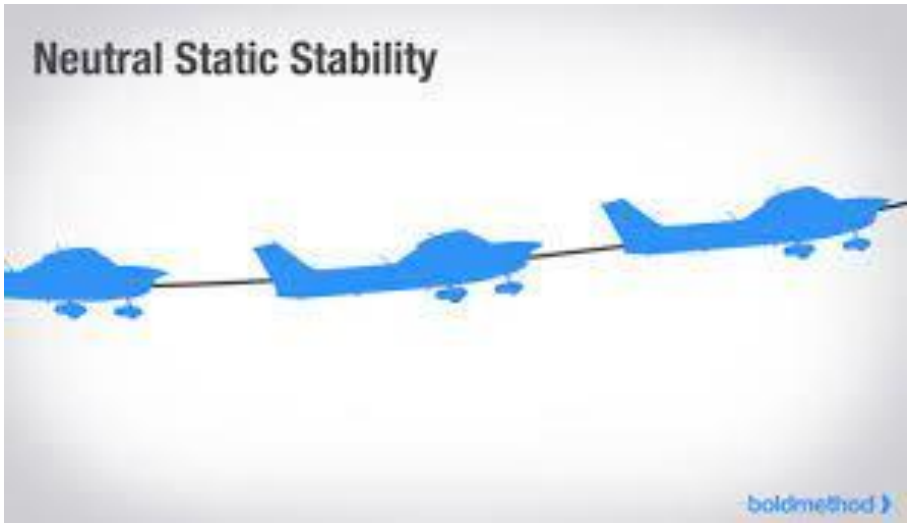


Figure 8. Neutral Static Stability boldmethod.com

2.1.3 Negative Static Stability: the aircraft continue moving away from its original poison when it's disturbed.

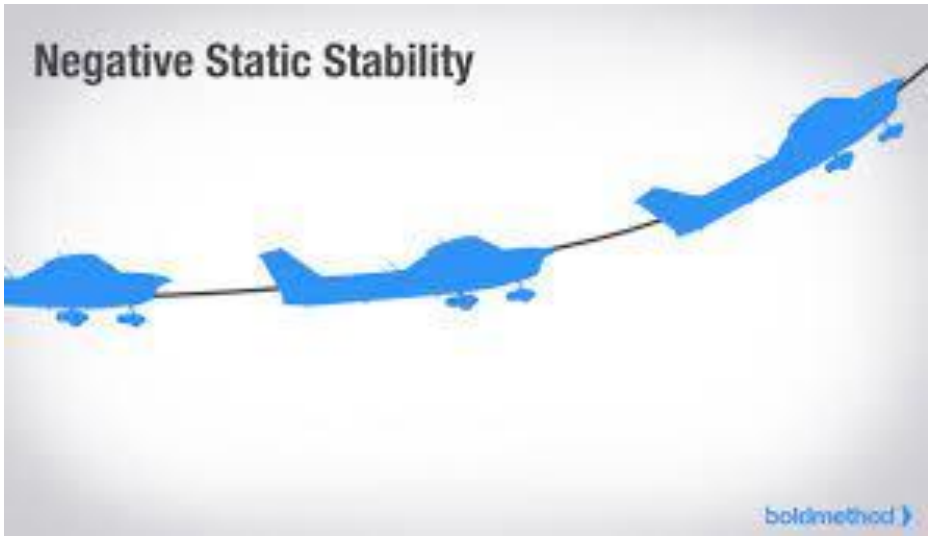


Figure 9. Negative Static Stability boldmethod.com

2.2 Dynamic Stability

Dynamic stability is how an airplane reacts over time to a disturbance and there are three types of dynamic stability

2.2.1 Positive Dynamic Stability: Aircraft have oscillations that reduced gradually over time.

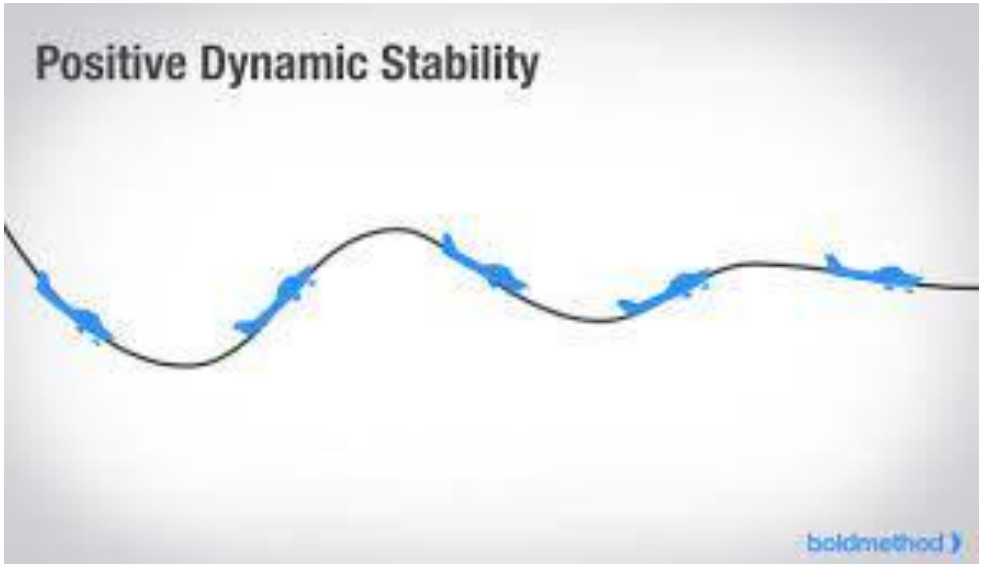


Figure 10. Positive Dynamic Stability. Boldmethod.com

5.2.2 Neutral Dynamic Stability: "Aircraft with neutral dynamic stability have oscillations that never dampen out." stated (Catlir 2015).

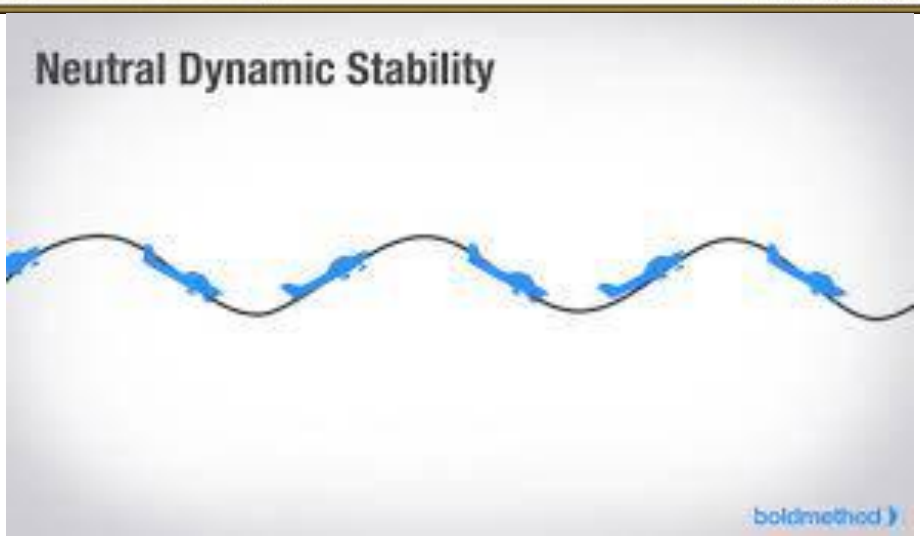


Figure 11. Natural Dynamic Stability. Boldmethod.com

2.2.3 Negative Dynamic Stability: Aircraft with negative dynamic stability have Fluctuating deteriorates over time.

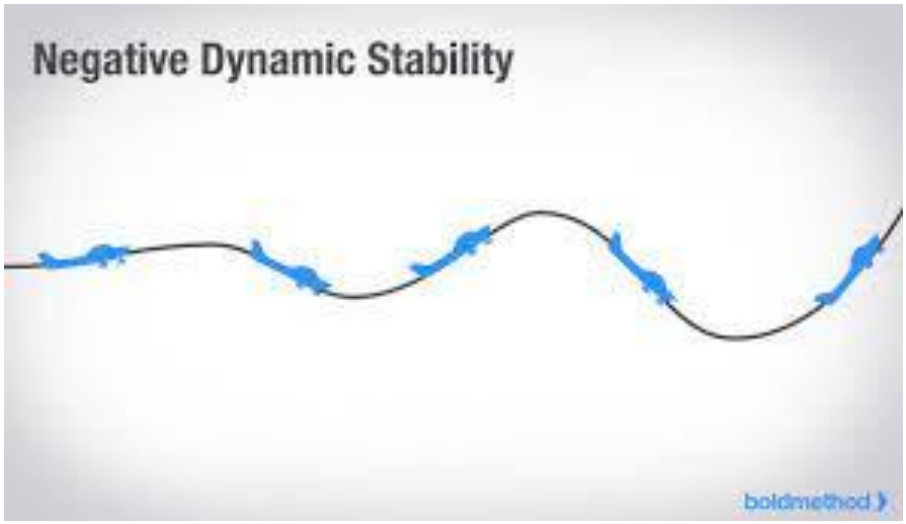


Figure 12. Negative Dynamic Stability. Boldmethod.com

Through studying the types of stability we can find that the aircraft with good stability should have positive static stability and positive dynamic stability,

3. Control it's the moments and forces generated by the pilot's inputs to flight controls to move the aircraft to a new desired state of flight.

At cruising the aircraft flying straight and level where the forces acting on it in equilibrium, the pilot can control the aircraft to change the state of flight such as changing altitude, route, landing, etc. by producing inputs to the aircraft flight controls so aircraft can move around its axes according to the received signal.

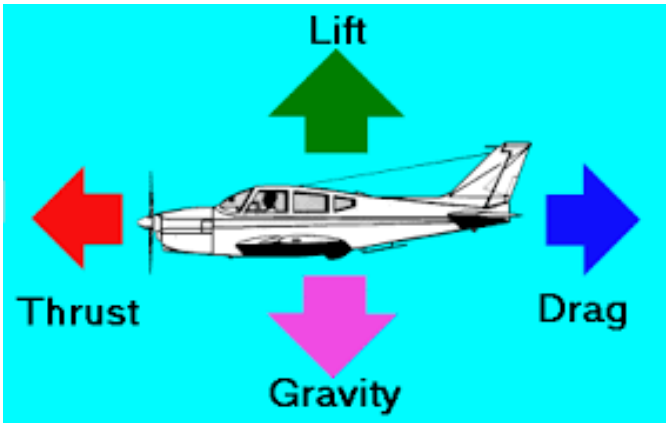
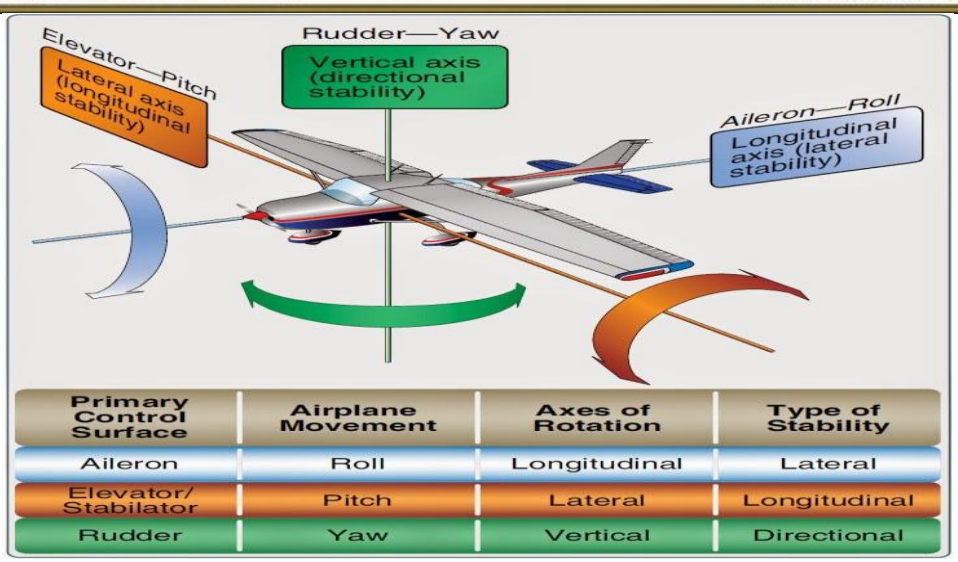


Figure 13. Forces Acting on Aircraft aviation- histoty.com

3.1 Flight control:

The movable surfaces of the aircraft structure, mainly attached to the wings and stabilizers Used to direct and control the aircraft around its axis of motion from takeoff to landing.

Flight controls are divided into two groups primary flight control, and secondary or auxiliary flight control, the below figure summarises the aircraft axes, primary control surfaces, aircraft movement, and type of stability.



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 14. Flight control surfaces move the aircraft around the three axes of flight.

aircraftsystemstech.com

3.1.1 Primary Flight Control:

Ailerons are hinged to the wings trailing edge and move opposite to each other to rotate the aircraft around its longitudinal axis.

Elevators are hinged to the horizontal stabilizer trailing edge and move together to pitch the aircraft's nose up or down around its lateral axis.

The rudder is hinged to a vertical stabilizer when it moves it's the aircraft rotates around its vertical axis (yaw)

3.1.2 Secondary Flight Control Surfaces:

Flaps are common on most aircraft located at the wing trailing edge near the fuselage, leading-edge flaps are also common on aircraft, the flaps are extended and lowered to increase wing surface area and camber area which increases the lift at lower speed allows

aircraft at slow speed also reduces the amount of runway required for landing and takeoff.

Slat is a leading-edge device that increases the camber of the wing which increases lift, it can extend independently of the flaps also when it is fully extended it leaves a slot between its trailing edge and wing leading edge which maintains uniform airflow over the wing to allow aircraft to fly at a high angle of attached slow speed with a reduced stall speed.

Spoilers and Speed Brakes its device is located at the top surface of the wing in heavy aircraft's flush with the wing surface when activated it rises in the airflow and disturbs limner flow to reduce lift. At low speed, the spoilers work with the aileron to help in lateral movement and stability of the aircraft in the wing when the aileron rises the spoiler also rises to help in reducing lift, the In another wing, the aileron will move down to increase lift so the spoiler at this wing remains stowed. At high speed, the ailerons become more efficient so spoilers will not work with them. Spoilers when deployed together at both wings ats act as speed brakes by creating drag and reducing lift. when the aircraft touches down on the runway Spoilers are deployed to kill the lift at the wings so the weight of the aircraft makes good contact between wheels and ground so wheel brakes work efficiently.

Also, you can find dedicated speed brakes panels over the wings to reduce aircraft speed.

Tab devices found on trailing of primary flight control its function to help in moving the primary flight control surface especially at high speeds when its hard to move these surfaces and hold in their deflection positions and there are four types of tap:

Trim tabs use independent linkage set by the pilot to balance the aircraft in flight allowing hands-off.

Balance tabs connected to flight control surfaces linkage moves with control surfaces to the force required to move it.

Servo tabs aerodynamically position control surfaces that require too much force to move manually.

Anti-balance or ant-servo tabs increase the force needed by the pilot to change flight control position. De- sensitizes flight controls.

Spring tabs Enable moving control surface when forces are high. Inactive during slow flight.

Conclusion

The aircraft has three axes of motion it can move around to change its position of flight, this change of position could be pilot inputs to aircraft flight controls or disturbances from the air or air turbulences, etc.

There are two main types of aircraft stability static stability and dynamic stability the static stability is the initial response of aircraft to disturbance whereas dynamic stability is the response over time to disturbances and a very stable aircraft should have positive static stability and positive dynamic stability.

A very stable aircraft like passengers aircraft tends to return to its trimmed Original flight position after disturbances around any of its axes, this is due to a desirable feature (positive static stability) created through the design of aircraft. whereas the high maneuverability aircraft like jet fighters are less stable.

Control of aircraft is achieved by inputs from the pilot to aircraft flight controls to change its altitude in ascending or descending, also changing direction, so the aircraft will respond according to flight control movement, finally, stability is an aircraft design matter to maintain straight and level flight and aircraft control its inputs from the pilot or autopilot to aircraft flight control(movable surfaces) to change from straight and level flight to any other desired position.

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