Chapter 3

Aerodynamics and Aircraft Control

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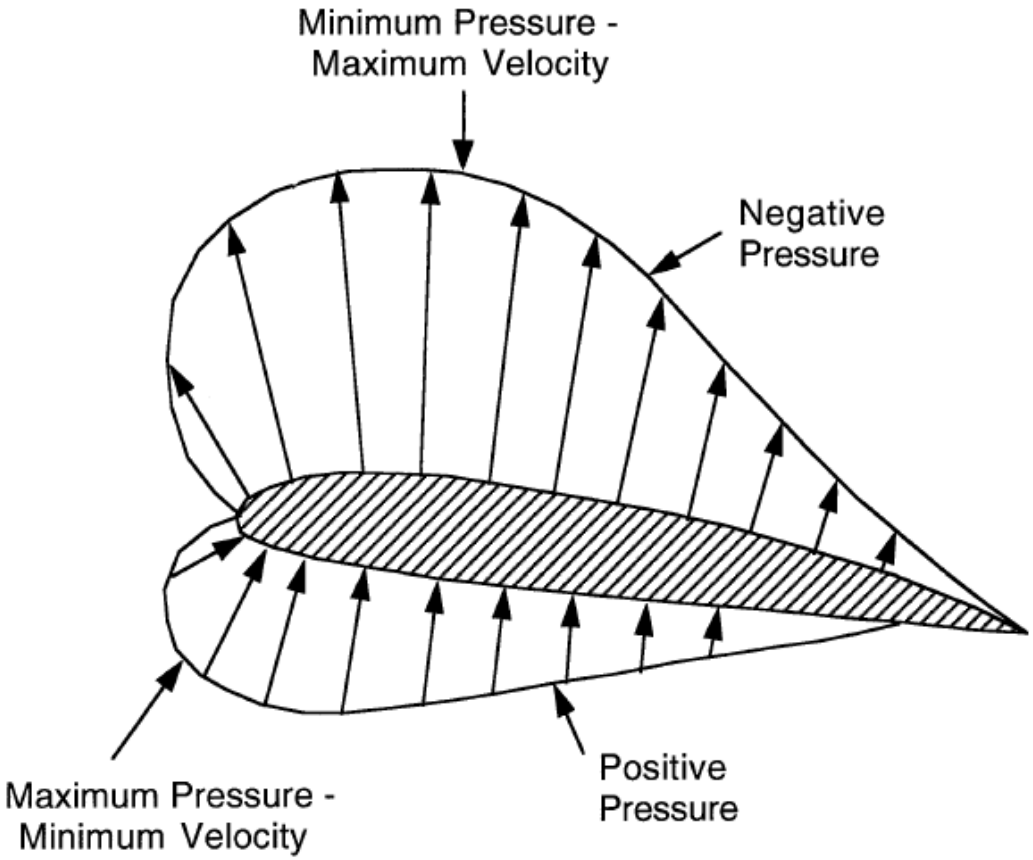
1. Basic Aerodynamics

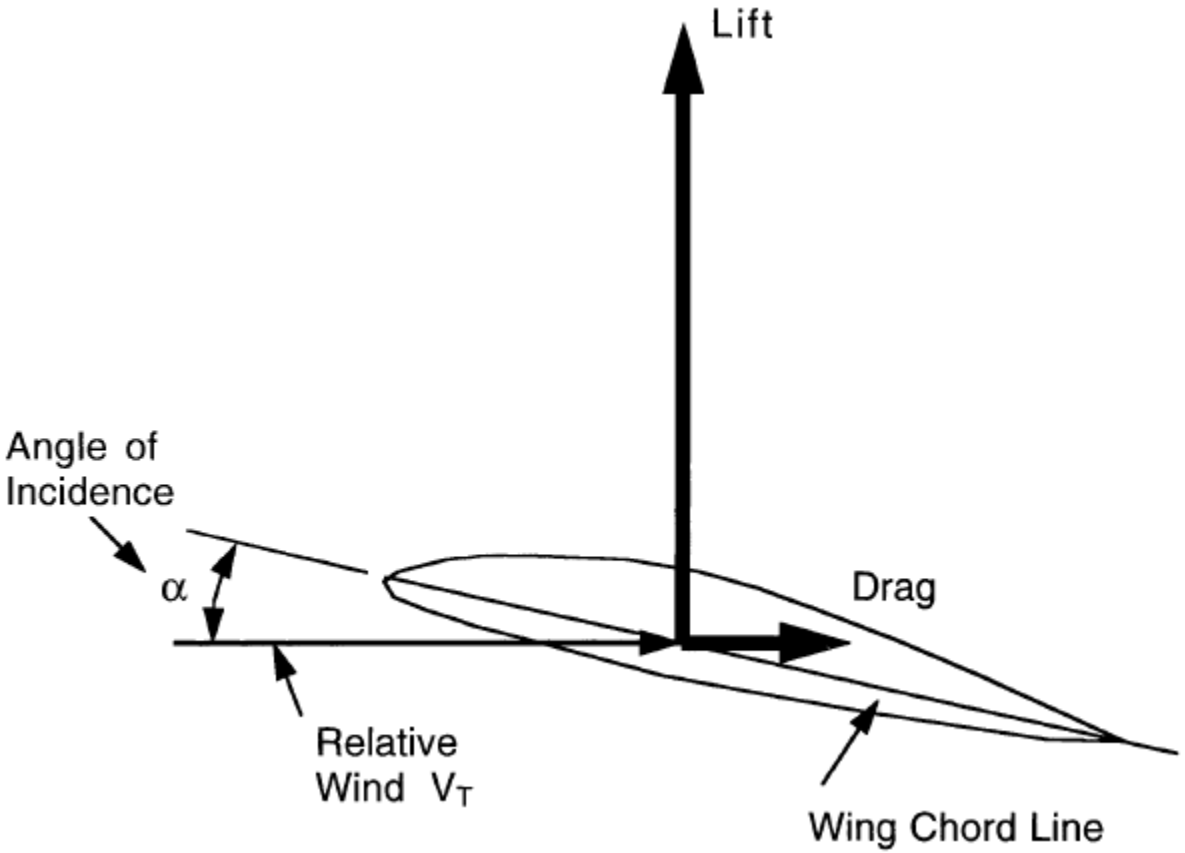
- Lift and Drag.
- Angle of Incidence/Angle of Attack
- Flight Path Angle
- Lift and Drag Coefficients
- Pitching Moment and Aerodynamic Centre

1. Basic Aerodynamics



Pressure distribution over an airfoil.

1. Basic Aerodynamics



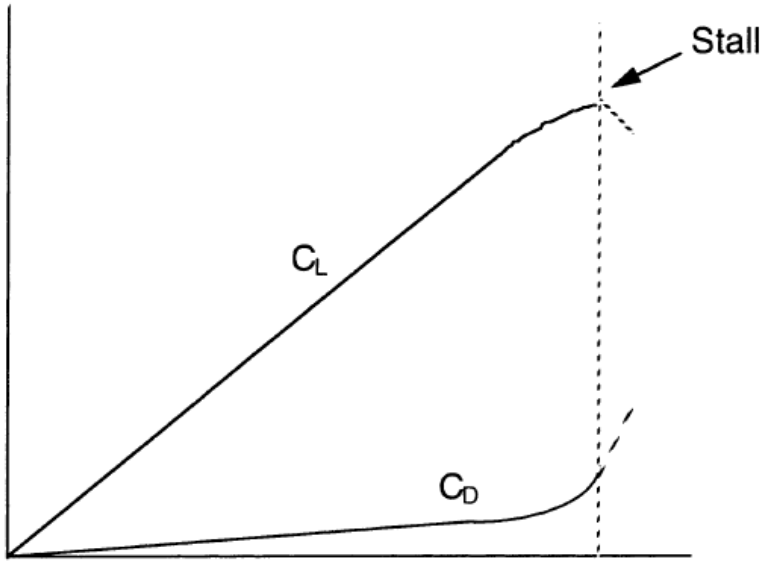
Angle of incidence (UK)/**Angle of attack (USA)**

1. Basic Aerodynamics

Drag Coefficient $C_L = \dfrac{L_W}{\frac{1}{2}\rho V_T^2 S}$

Lift Coefficient $C_D = \dfrac{D_W}{\frac{1}{2}\rho V_T^2 S}$

Drag Equation $C_D = C_{DO} + kC_L{}^2$



C_L and C_D versus α

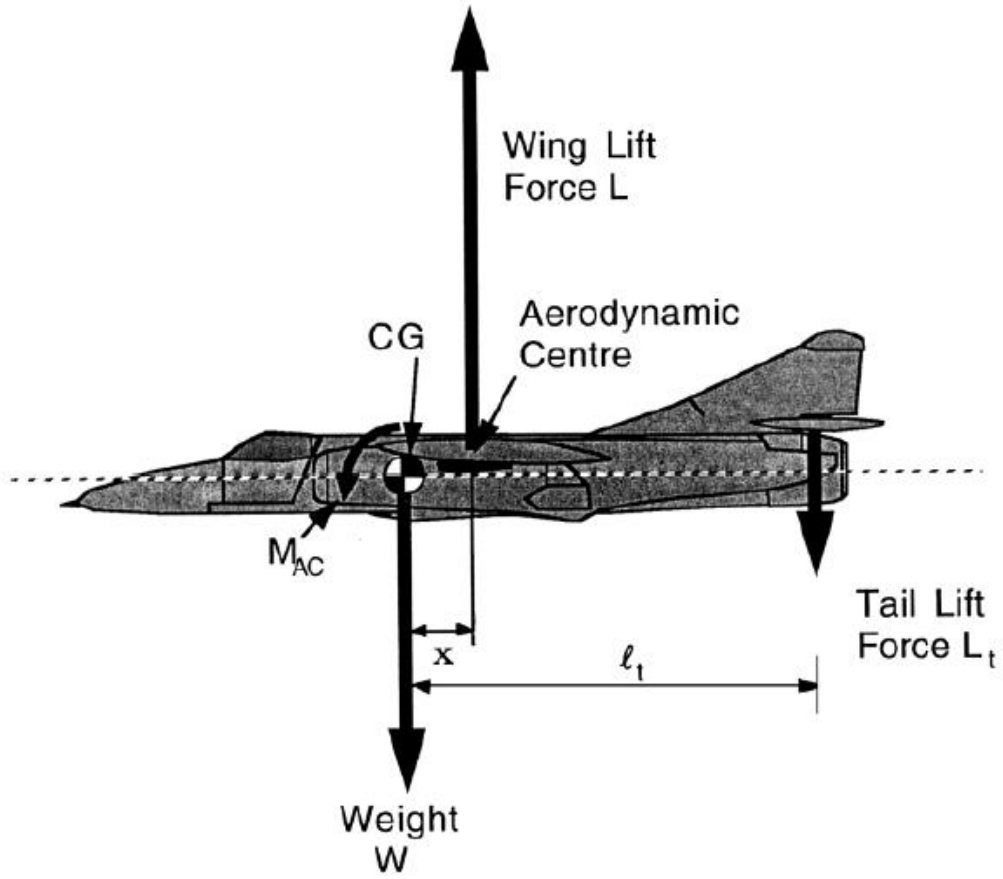
1. Basic Aerodynamics

- The **centre of pressure** is the point where the resultant lift and drag forces act and is the point where the moment of all the forces summed over the complete wing surface is zero.
- There will thus be a **pitching moment** exerted at any other point not at the centre of pressure.
- The centre of pressure varies with angle of incidence and for these reasons aerodynamic centre is used as the reference point for defining the pitching moment acting on the wing.
- The **aerodynamic centre** of the wing is defined as the point about which the pitching moment does not change with angle of attack (providing the velocity is constant).
- All airfoils (except symmetrical ones) even at zero lift tend to pitch and experience a pitching moment or couple.

1. Basic Aerodynamics

- The aerodynamic centre is generally around **the quarter chord point of the wing** (measured from the leading edge).
- At supersonic speeds it tends to move aft to the half chord point.
- The tailplane (H. stabilizers) makes a major contribution to longitudinal stability and provides the necessary downward lift force to balance or trim the aircraft for straight and level flight.
- The moment about the CG due to the tailplane lift balances the nose down pitching moment due to the wing lift and the inherent wing pitching moment or couple.

1. Basic Aerodynamics

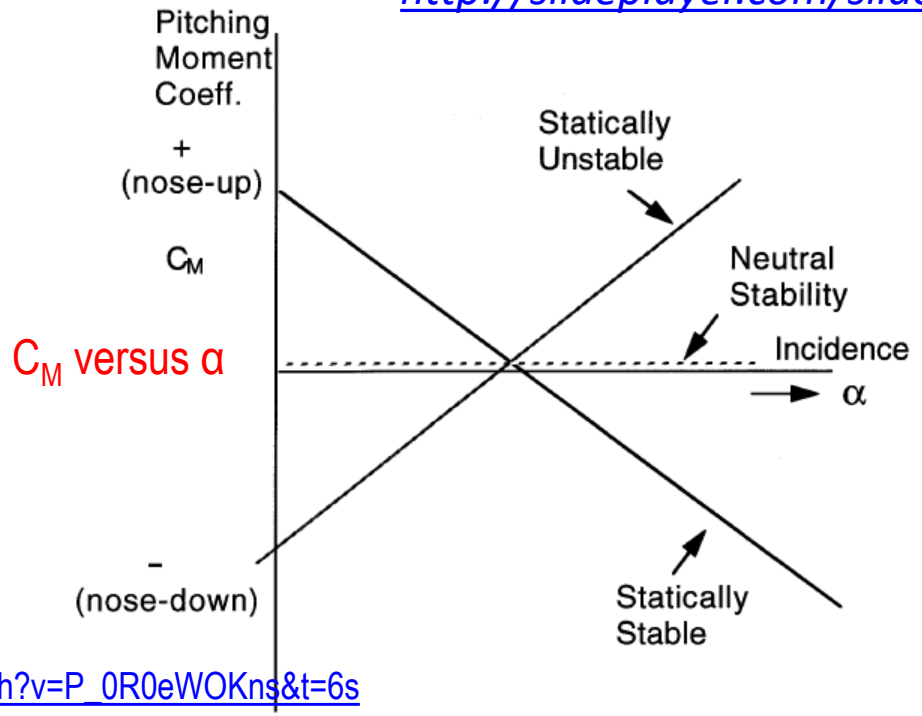


Tailplane contribution

2. Aircraft Stability

- An aircraft is said to be stable if it tends to return to its original position after being subjected to a disturbance without any control action by the pilot.
- For static longitudinal stability, the total pitching moment about the CG should be zero at a *trim angle of incidence*.

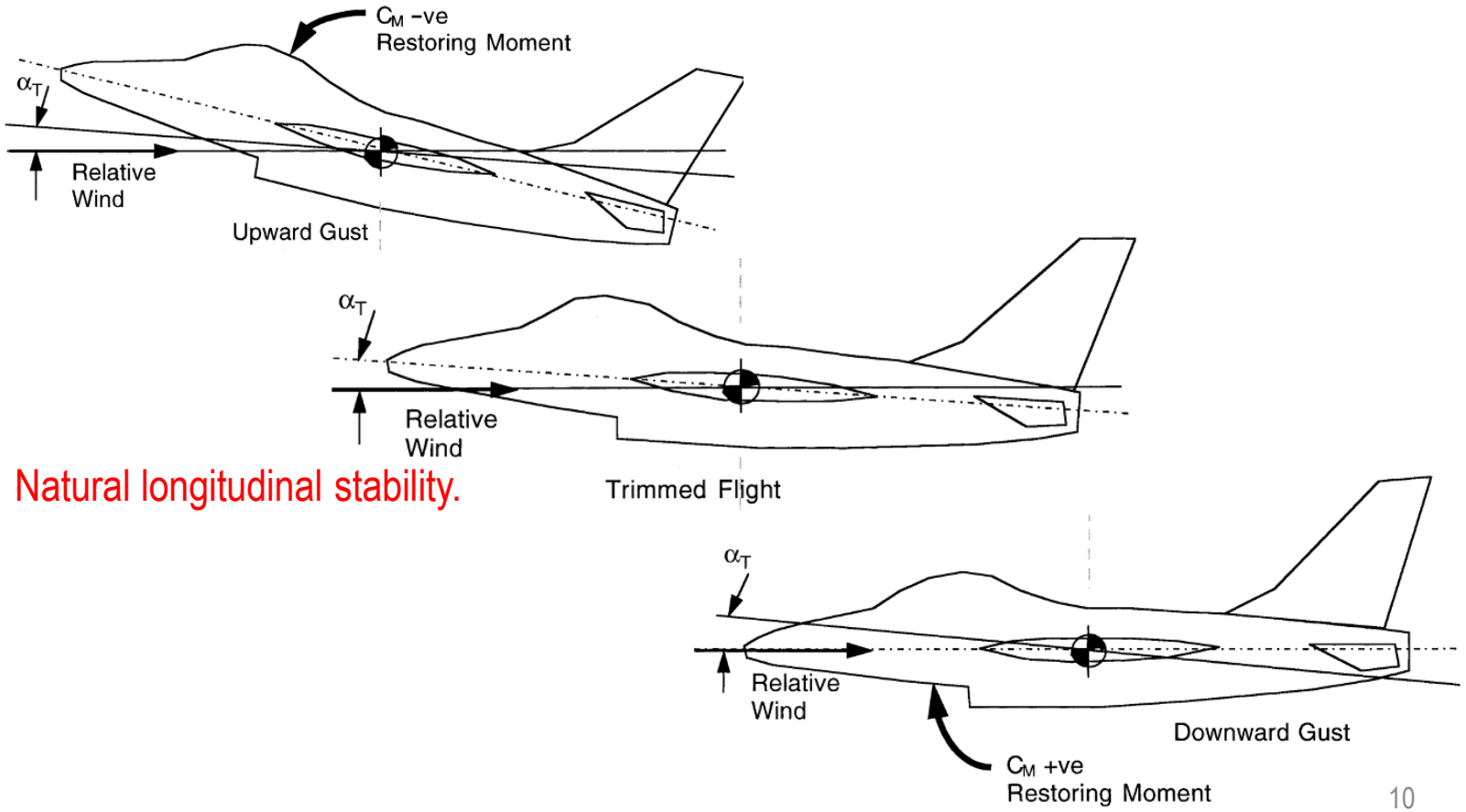
http://slideplayer.com/slide/5252043/



https://www.youtube.com/watch?v=P_0R0eWOKns&t=6s

2. Aircraft Stability

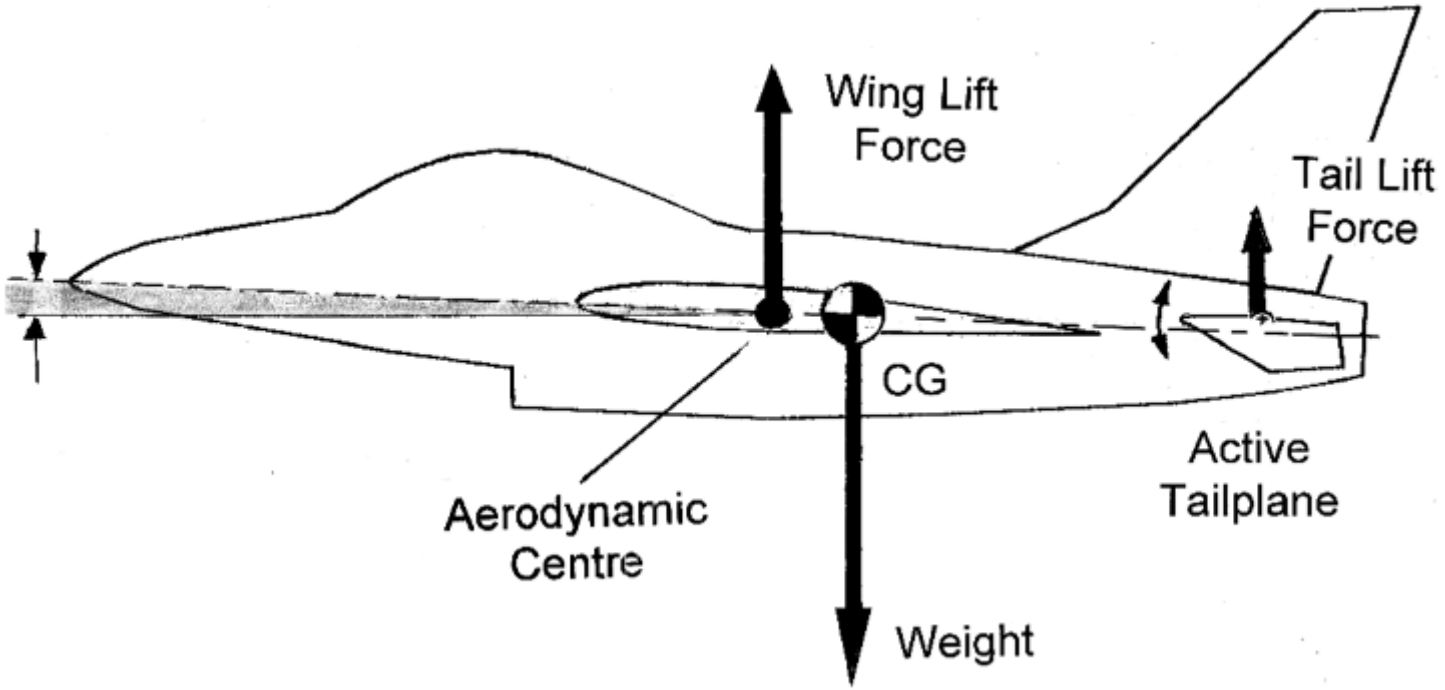
Aerodynamically Unstable Aircraft



Natural longitudinal stability.

2. Aircraft Stability

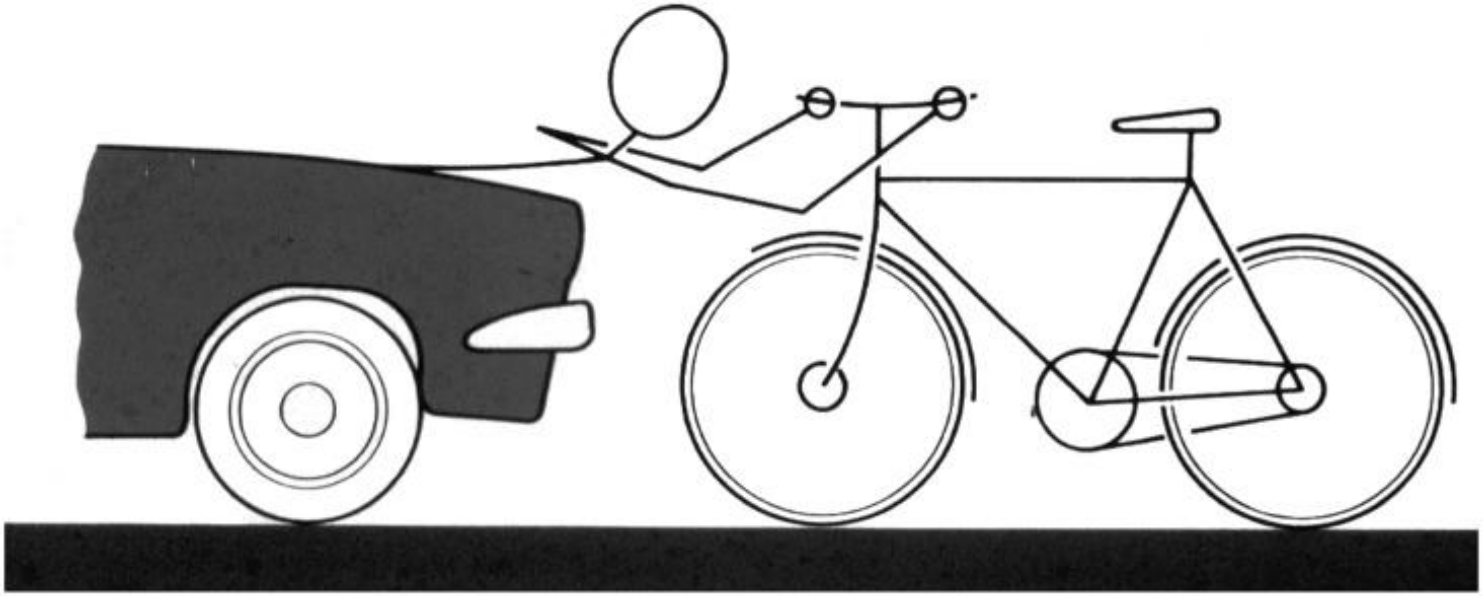
Aerodynamically Unstable Aircraft



Aerodynamically unstable aircraft.

2. Aircraft Stability

Aerodynamically Unstable Aircraft



Analogy of controlling an aerodynamically unstable aircraft.

2. Aircraft Stability

Aerodynamically Unstable Aircraft

- The pilot's speed of response to correct the tendency to divergence of an unstable aircraft is much too slow and the tailplane must be controlled automatically.
- The time for the divergence to double its amplitude following a disturbance can be of the order of 0.25 seconds or less on a modern high agility fighter which is aerodynamically unstable.
- **Higher performance and increased agility can be obtained with an aerodynamically unstable aircraft and relying totally on an automatic stability system.**
- The technology to implement such an automatic stability system with a maneuver command flight control system is now sufficiently mature to meet the very exacting safety and integrity requirements and system availability.

2. Aircraft Stability

Aerodynamically Unstable Aircraft

- The technology to implement such an automatic stability system with a maneuver command flight control system is now sufficiently mature to meet the very exacting safety and integrity requirements and system availability.
- Such a system, known as a 'Fly-by-Wire' flight control system because of its total dependence on electrical signal transmission and electronic computing, is the topic of discussion in the next chapter of our class.

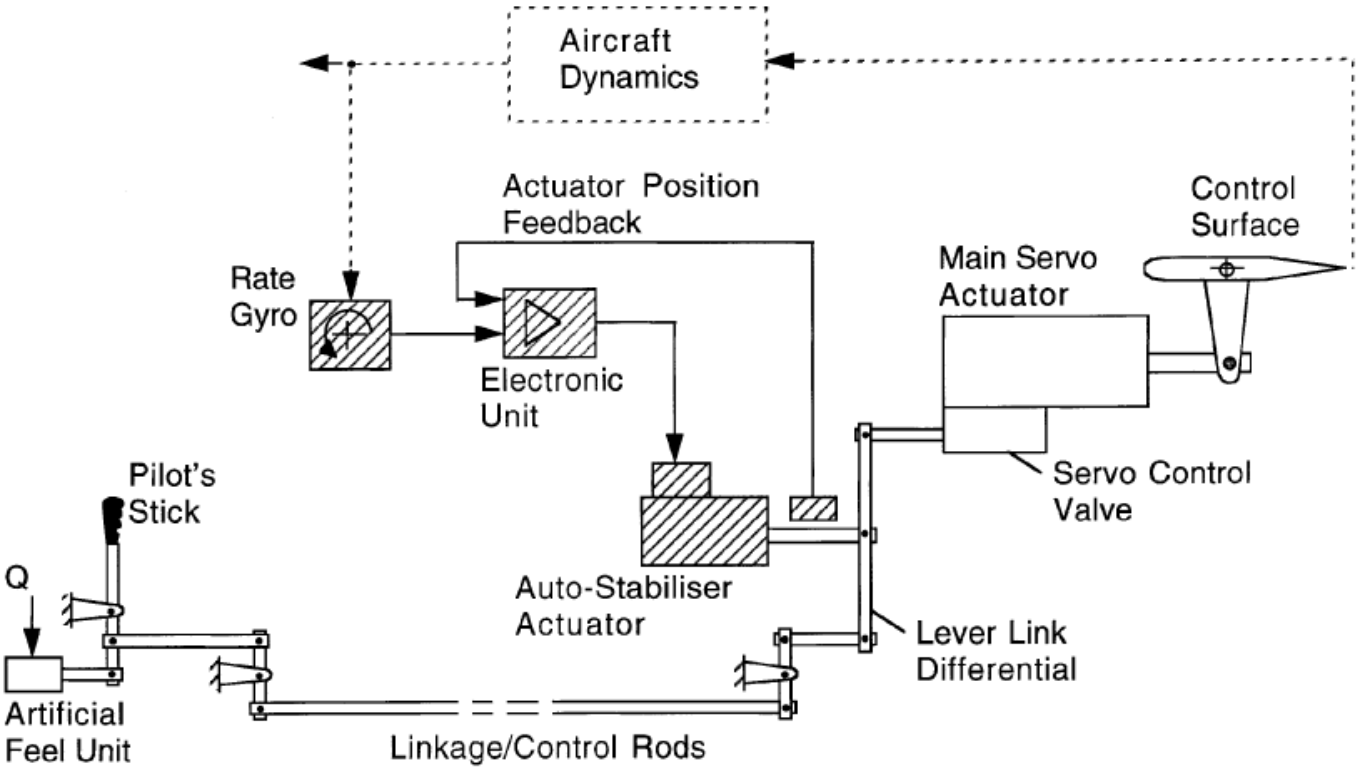
3. Stability Augmentation

- The possible need for improved damping and stability about all the three aircraft axes can be achieved by an **auto-stabilization system**, or, as it is sometimes referred to, a stability augmentation system.
- Yaw stability augmentation systems are required in most jet aircraft to suppress the lightly damped short period yawing motion and the accompanying oscillatory roll motion due to yaw/roll cross-coupling known as **Dutch roll** motion which can occur over parts of the flight envelope.
- In the case of military aircraft, the yaw damper system may be essential to give a steady weapon aiming platform as the pilot is generally unable to control the short period yawing motion and can in fact get out of phase and make the situation worse.

https://www.youtube.com/watch?v=Zmjam1evDD4

3. Stability Augmentation

- A yaw damper system is an essential system in most civil jet aircraft as the undamped short period motion could cause considerable passenger discomfort.



Example of a stability augmentation system.