UNIVERSITY OF Southampton

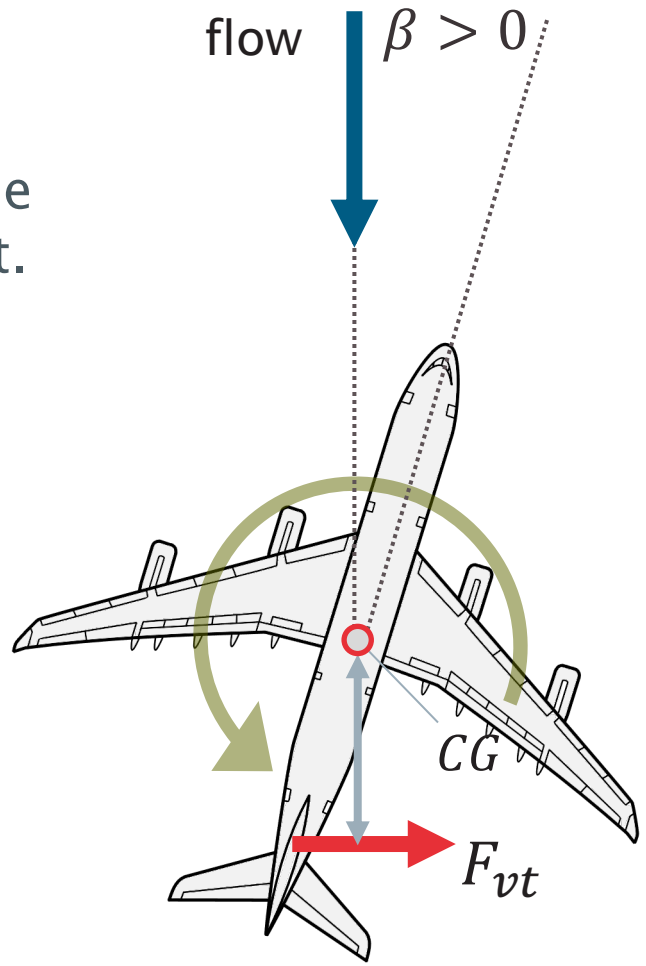
SESA2025 Mechanics of Flight Lateral/Directional Stability

Lecture 2.4

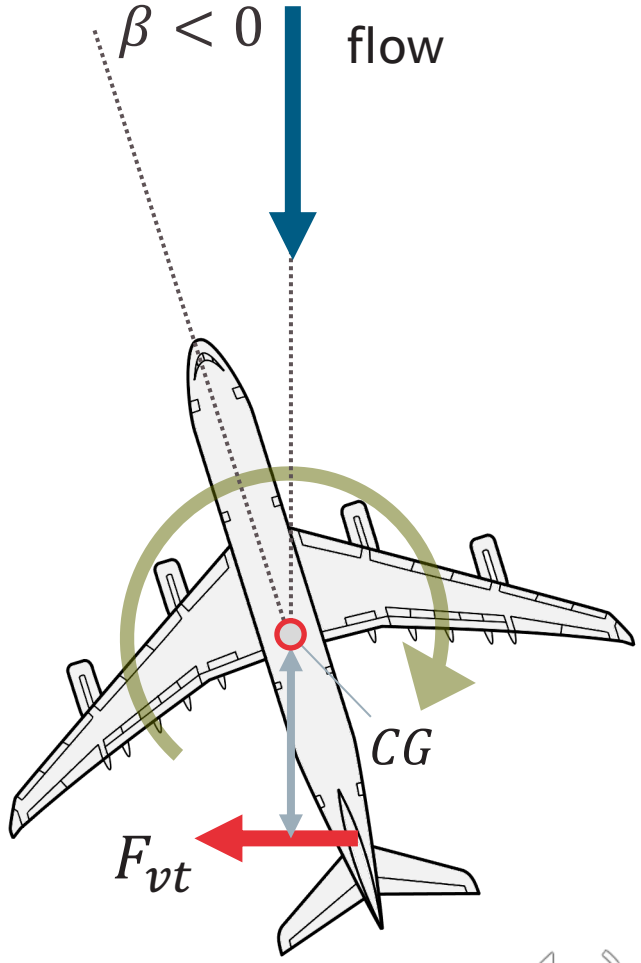
Vertical Fin, Fuselage & Directional Stability

Effect of yaw/sideslip on vertical fin

- **Directional stability:** when yawed, the vertical tail plane creates a restoring moment.



yaw to the right

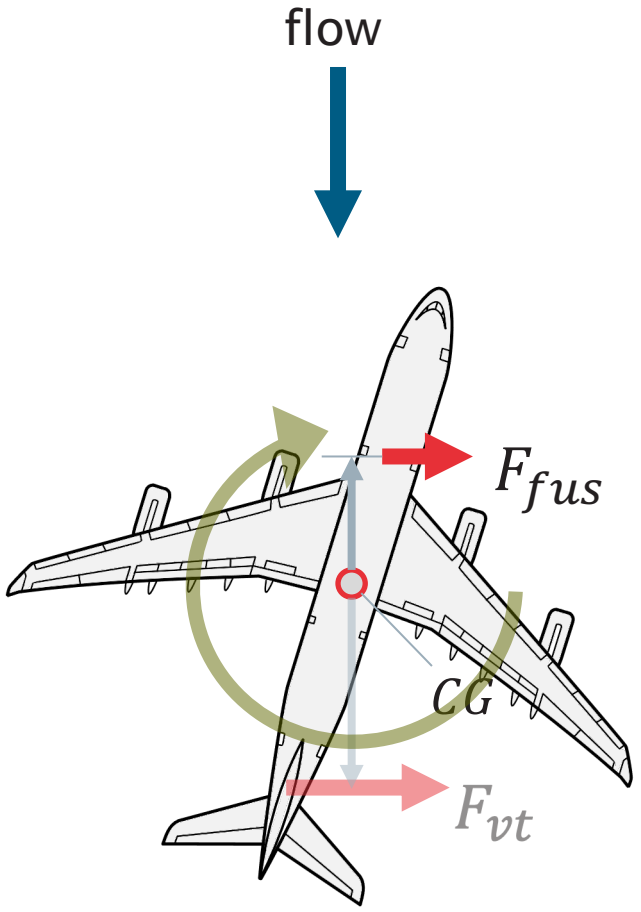


yaw to the left

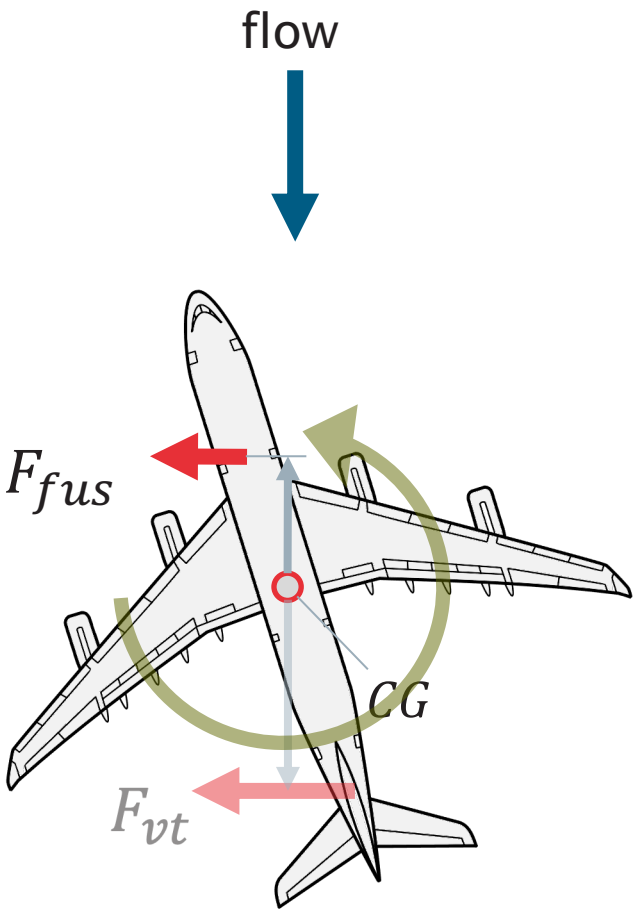
Vertical Fin, Fuselage & Directional Stability

Effect of yaw/sideslip on vertical fin

- **Directional stability:** when yawed, the vertical tail plane creates a restoring moment.
- However, the fuselage is a destabilising contribution and retards the return to the original (directional) trim condition.



yaw to the right



yaw to the left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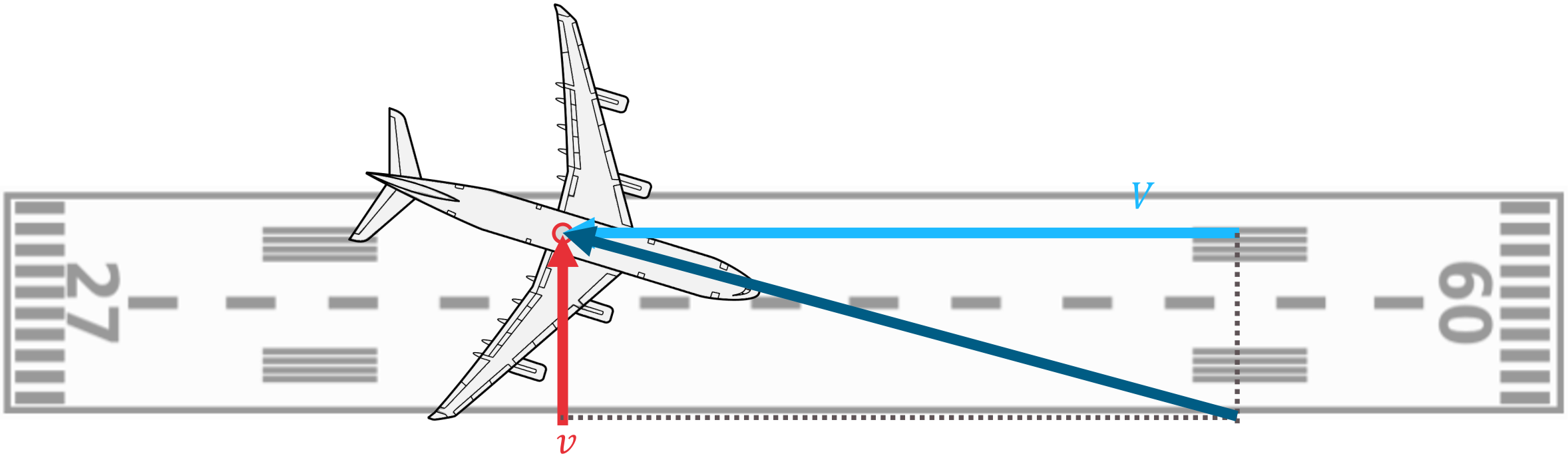
Vertical Fin, Fuselage & Directional Stability

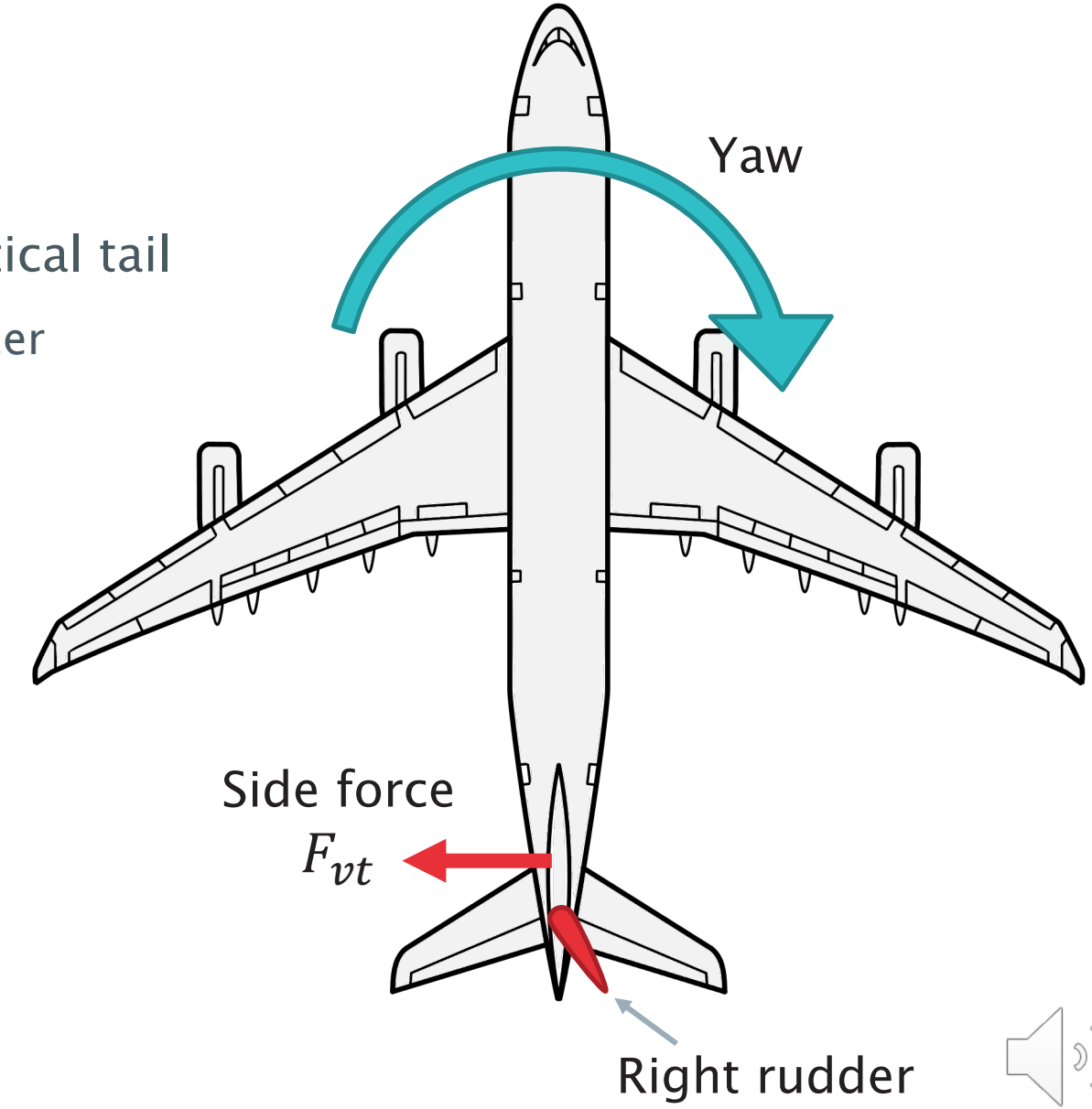
Landing/taking-off with side winds



Directional Control

Effect of rudder

- The rudder alters the camber of the vertical tail
  - Analogous to elevator/horizontal stabilizer



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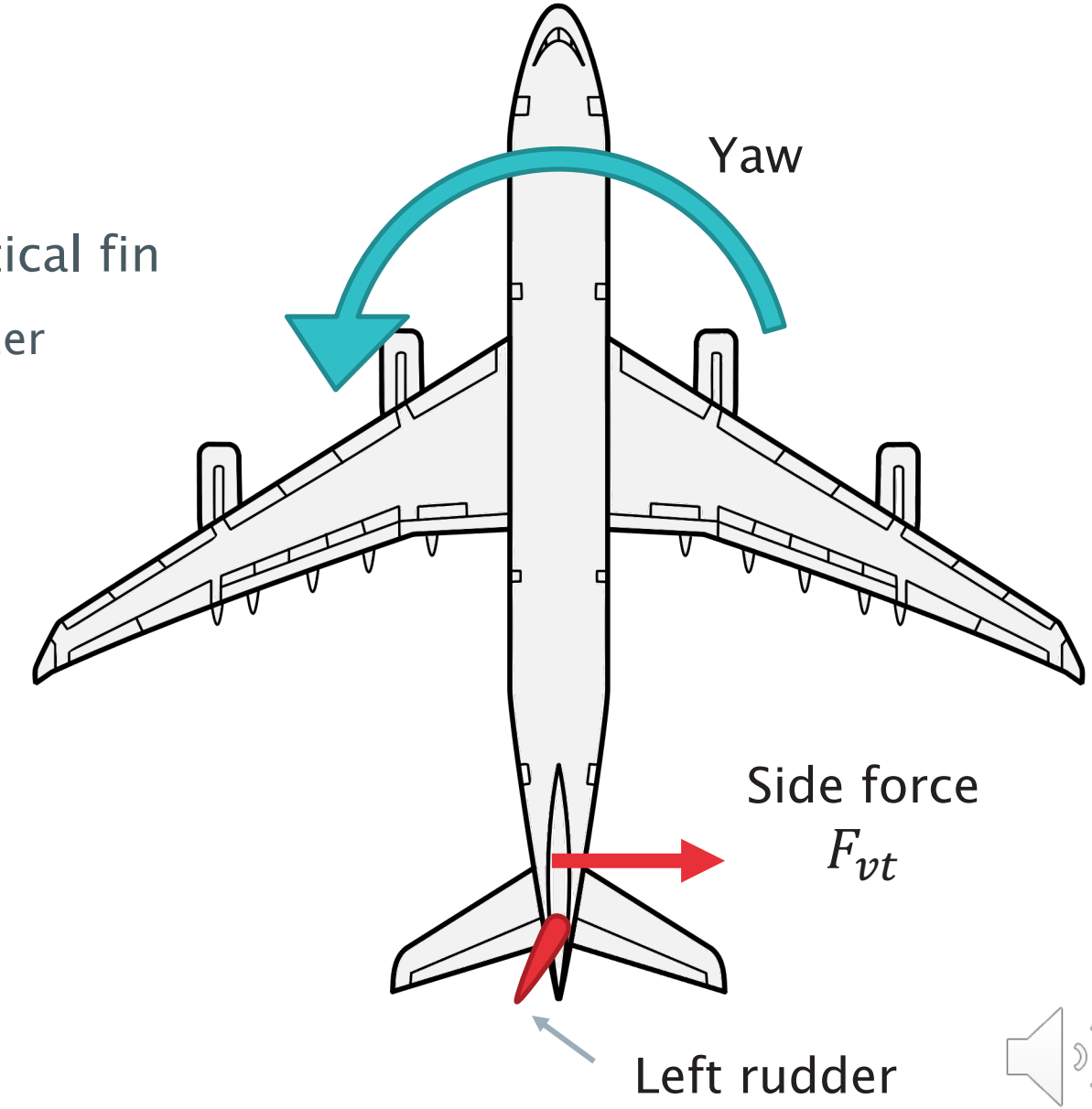
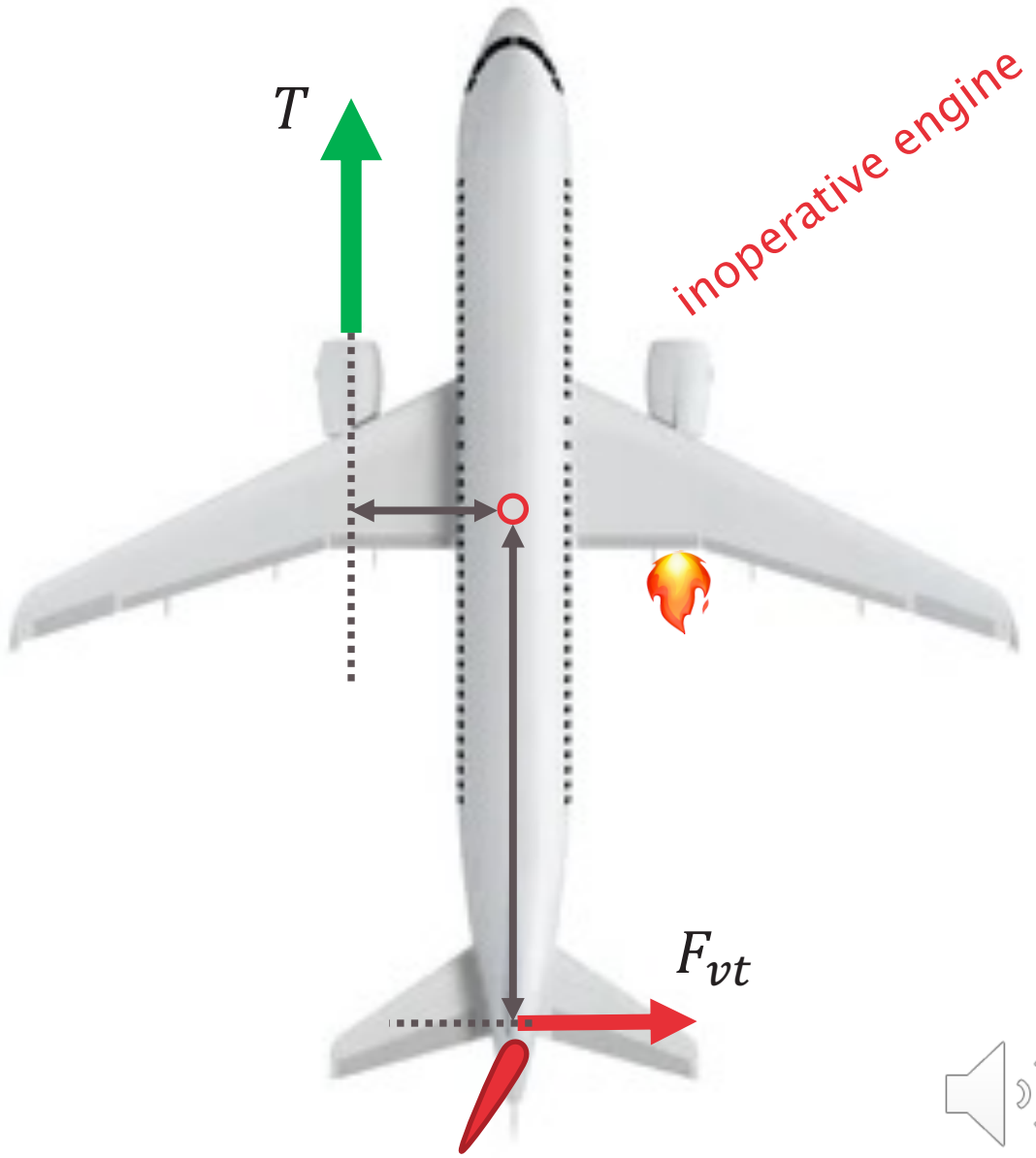


Sizing the vertical fin

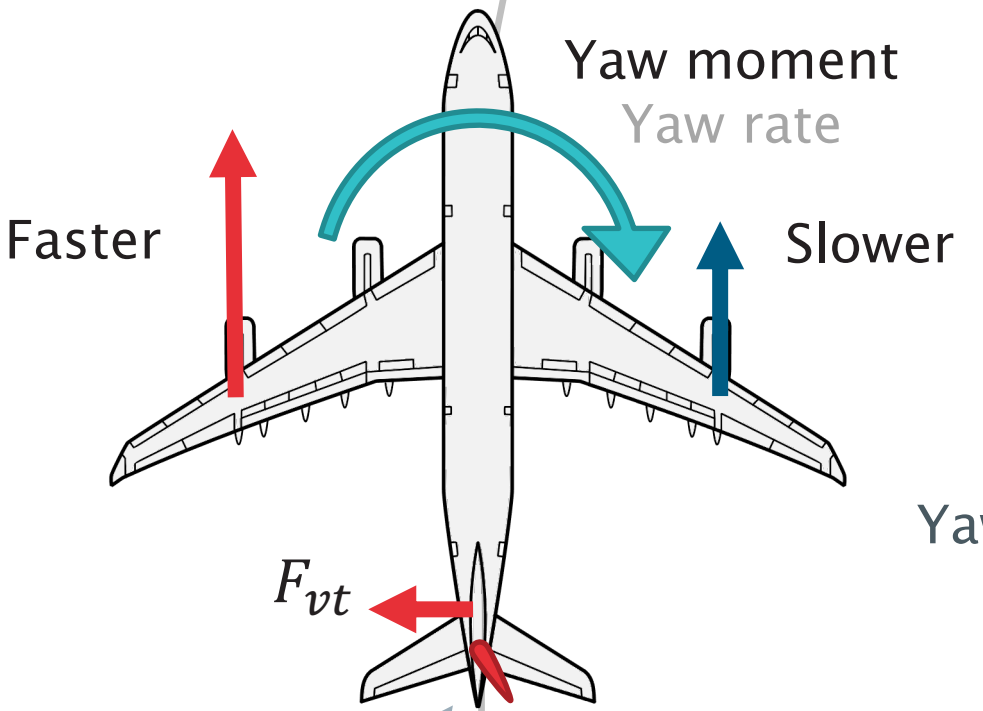
Effect of rudder

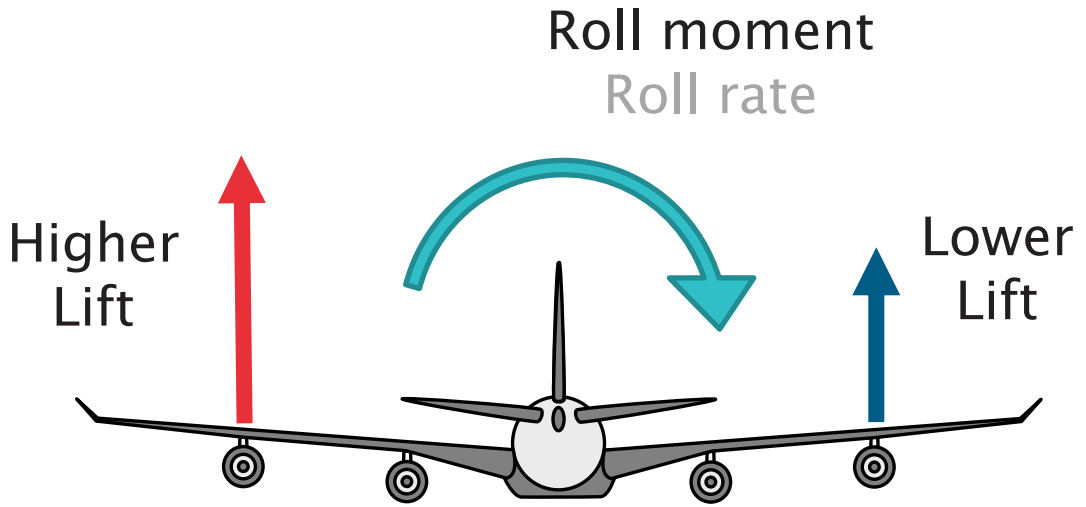
- Vertical fin:
  - Directional stability
  - Flying quality (Dutch Roll dynamic mode)
- Rudder:
  - Sufficient control at take-off and landing
  - Asymmetric engine failure



Yaw-to-Roll Coupling Effect

Curved flight path influence





Yawing in clockwise direction:

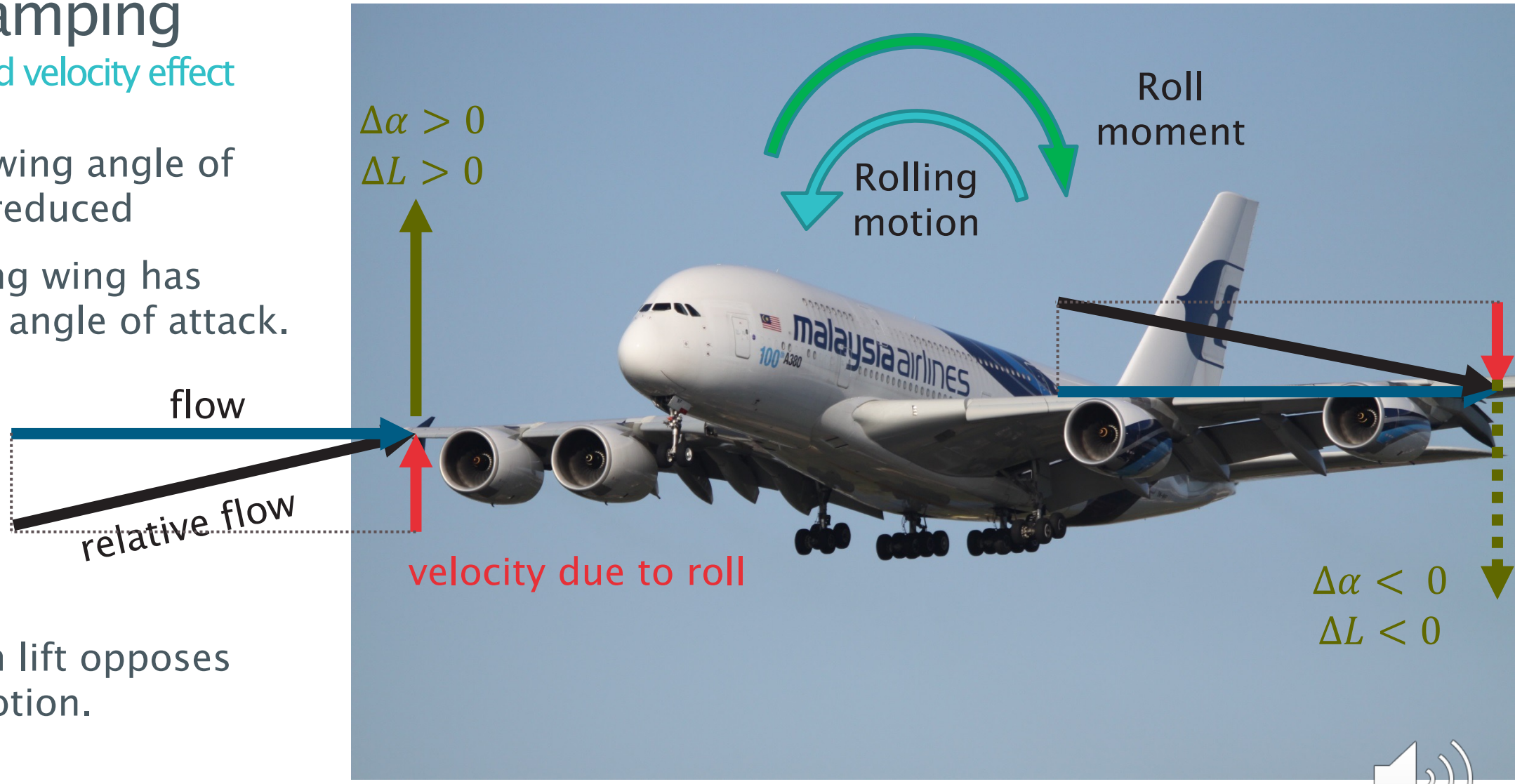
- Left wing in higher speed and right wing in lower speed
- More lift on the left wing and less lift on the right wing
- Starting to roll: left up and right down

Roll Damping

Roll induced velocity effect

Upgoing wing angle of attack is reduced

Downgoing wing has increased angle of attack.



Change in lift opposes rolling motion.

Roll & Sideslip

How roll (bank) angle will create sideslip

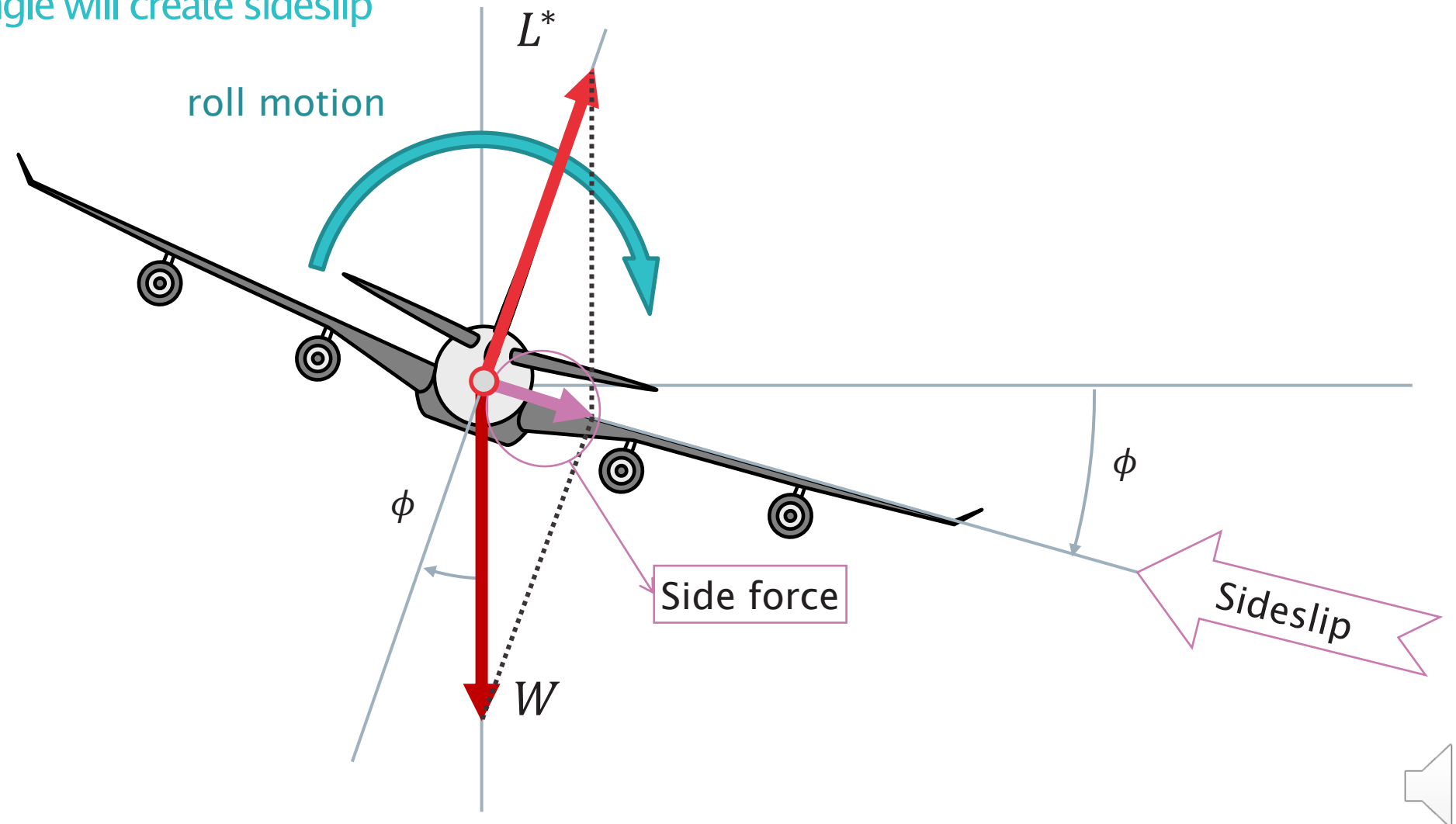
Bank angle

↓

Side force
(out of trim)

↓

Sideslip

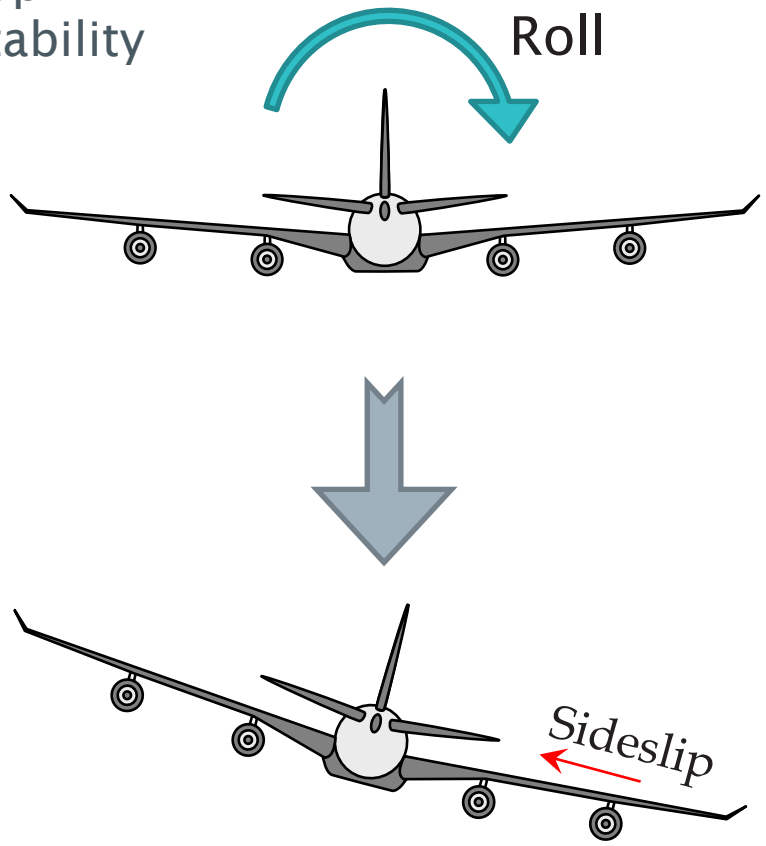


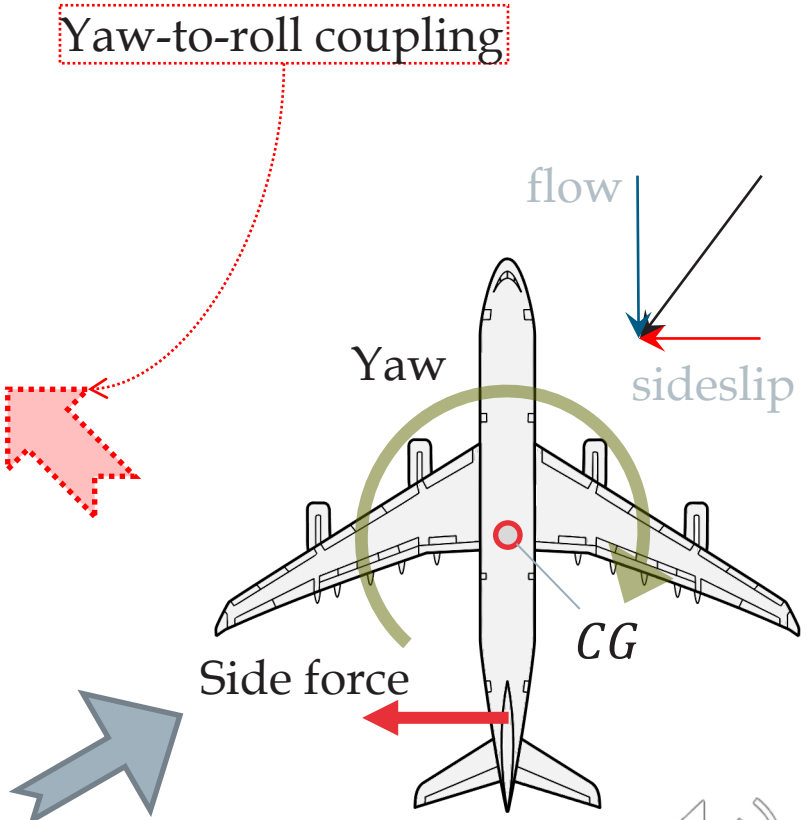
Roll-to-Yaw Coupling Effect

and link to yaw-to-roll coupling effect

Roll generates a yaw moment due to sideslip

- Possibly continuing the loop if not supported by lateral stability
- Need for lateral stability
  - Dihedral wing
  - High wing
  - Swept wing





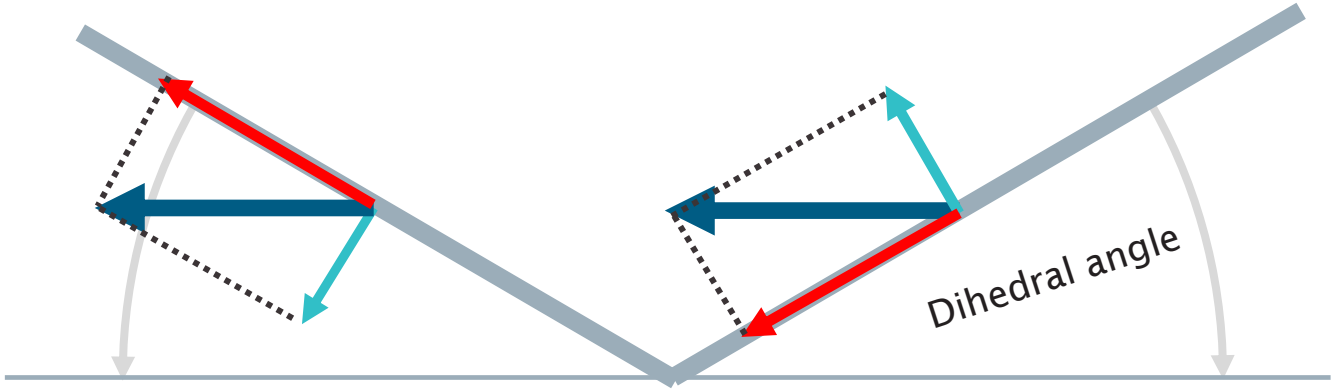
Dihedral Wing & Lateral Stability

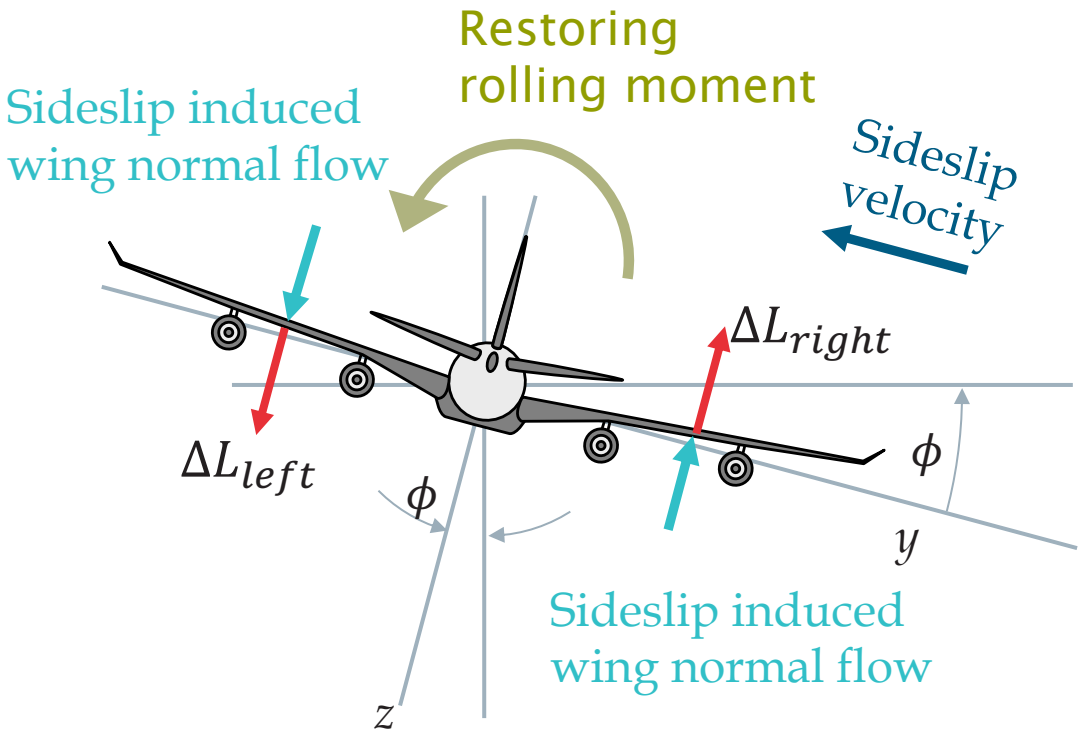
Sideslip induced Wing normal velocity creates a restoring moment

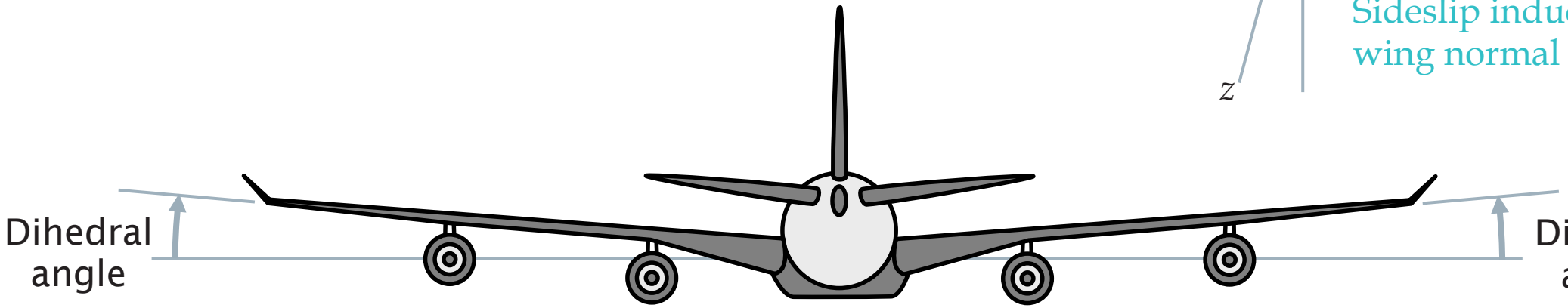
Sideslip velocity

Sideslip-induced wing-parallel flow

Sideslip-induced wing-normal flow







High Wing & Lateral Stability

Side force effect due to skin friction force in sideslip

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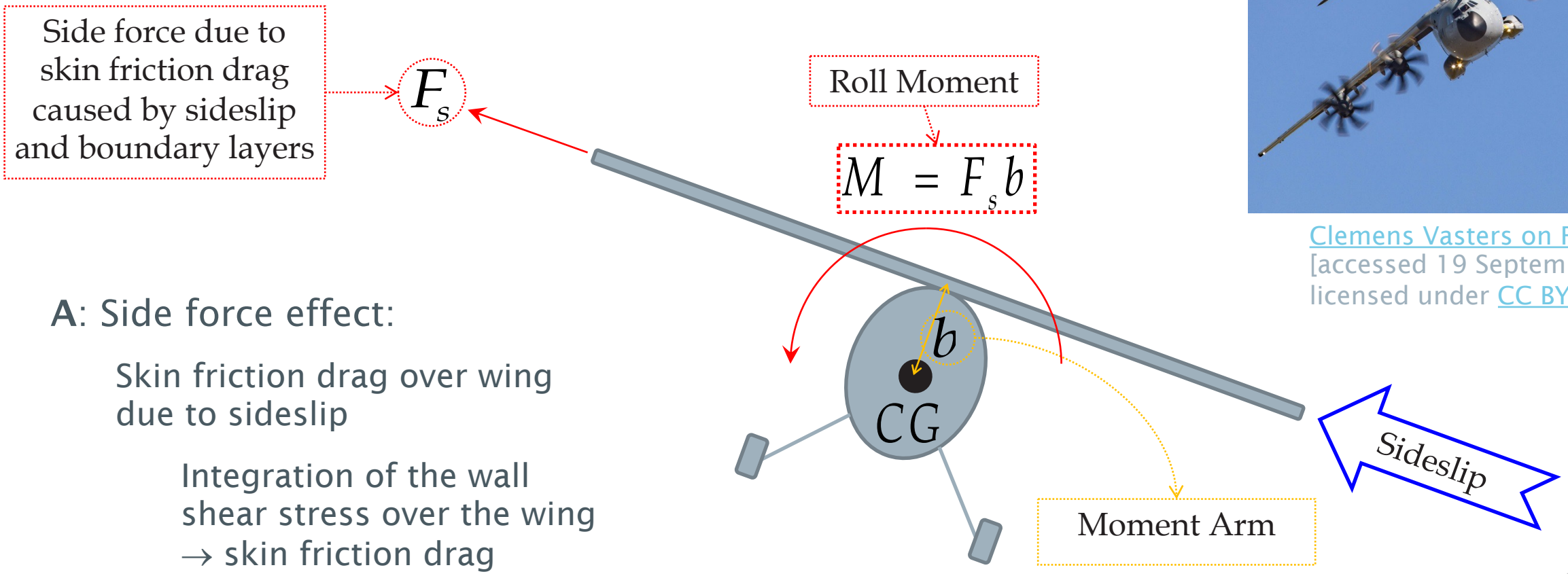


A: Side force effect:

Skin friction drag over wing due to sideslip

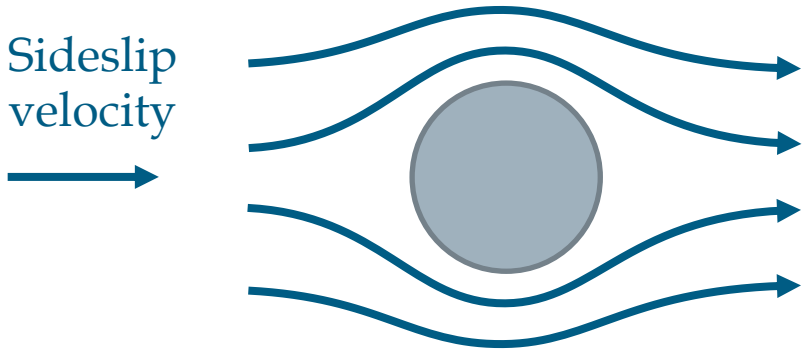
Integration of the wall shear stress over the wing
→ skin friction drag

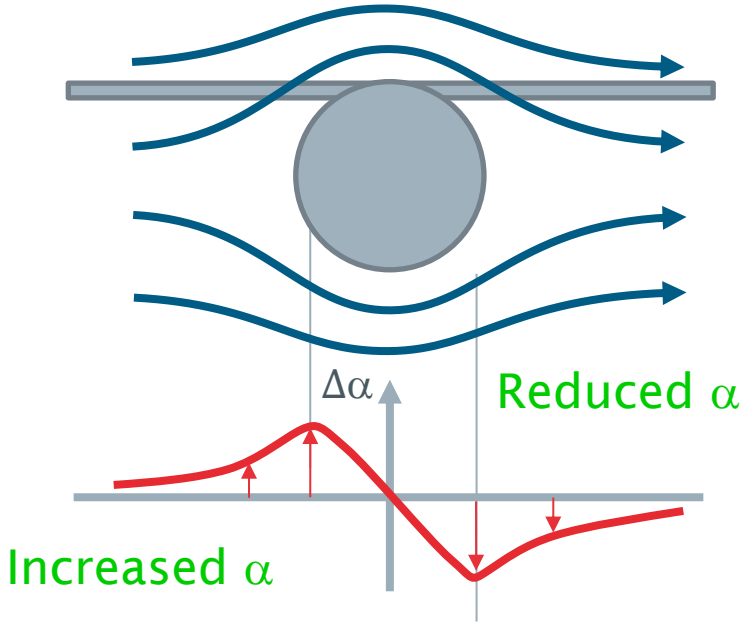
High Wing & Lateral Stability

Fuselage interference effect

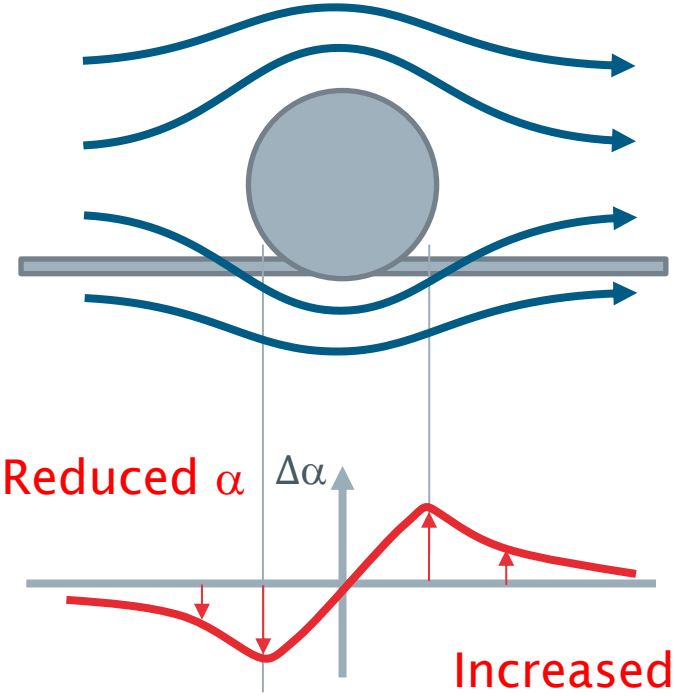
B: Fuselage interference

Sideslip (spanwise flow) interfering with fuselage affects the angle of attack of a high or low wing

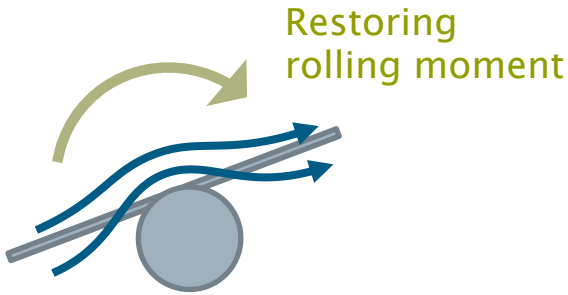


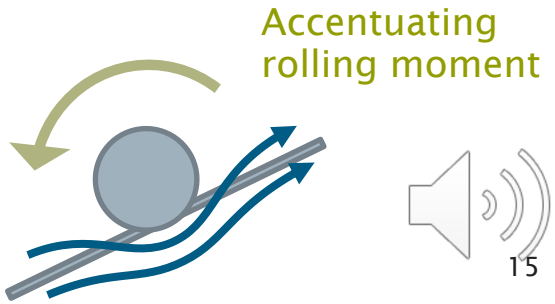


High wing stabilising



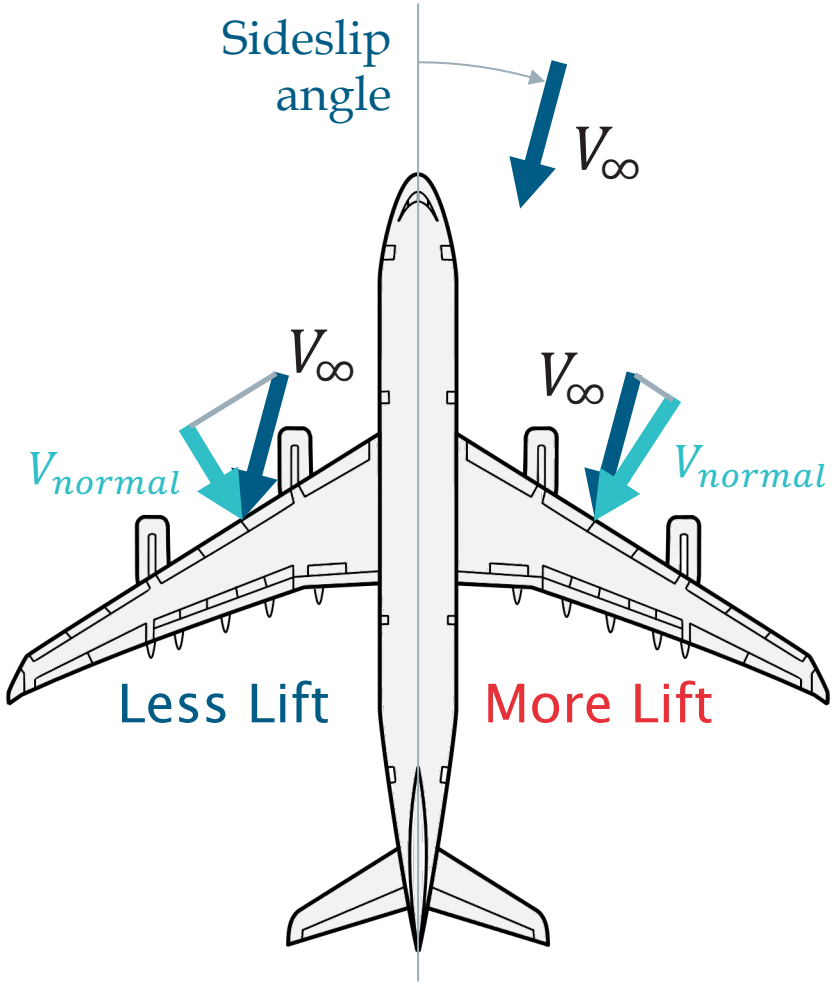
Low wing destabilising

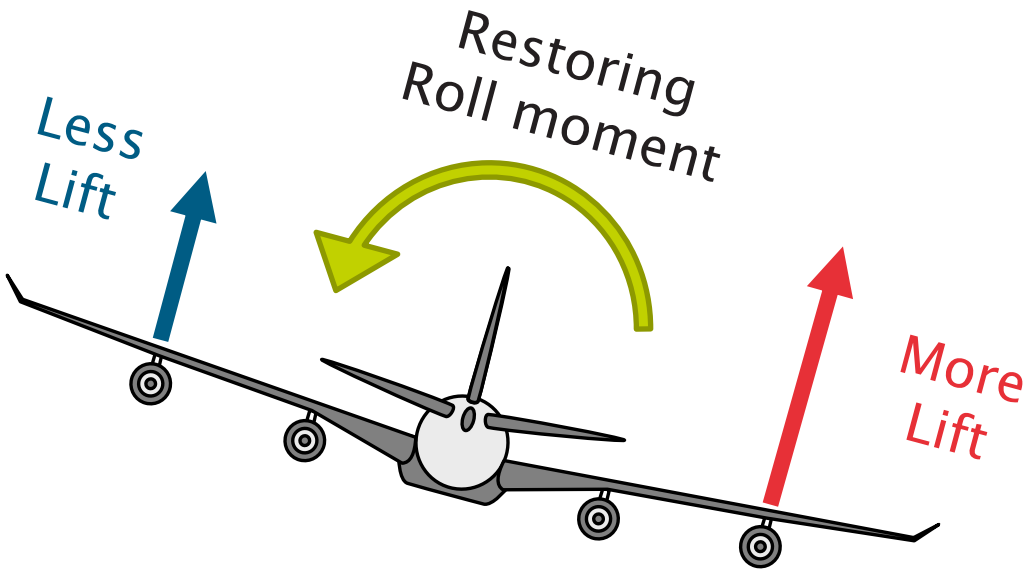




Swept Wing & Lateral Stability

Normal flow difference creates restoring rolling moment





Rolling moment returns wings level

High wing + dihedral + sweep

Too stable

Dihedral + high + swept wing

- Excessive lateral stability
  => poor controllability

Anhedral for high swept wing

- Compromise solution
- Example: Sea Harrier

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