Longitudinal Static Stability

Lecture 10

ME EN 415
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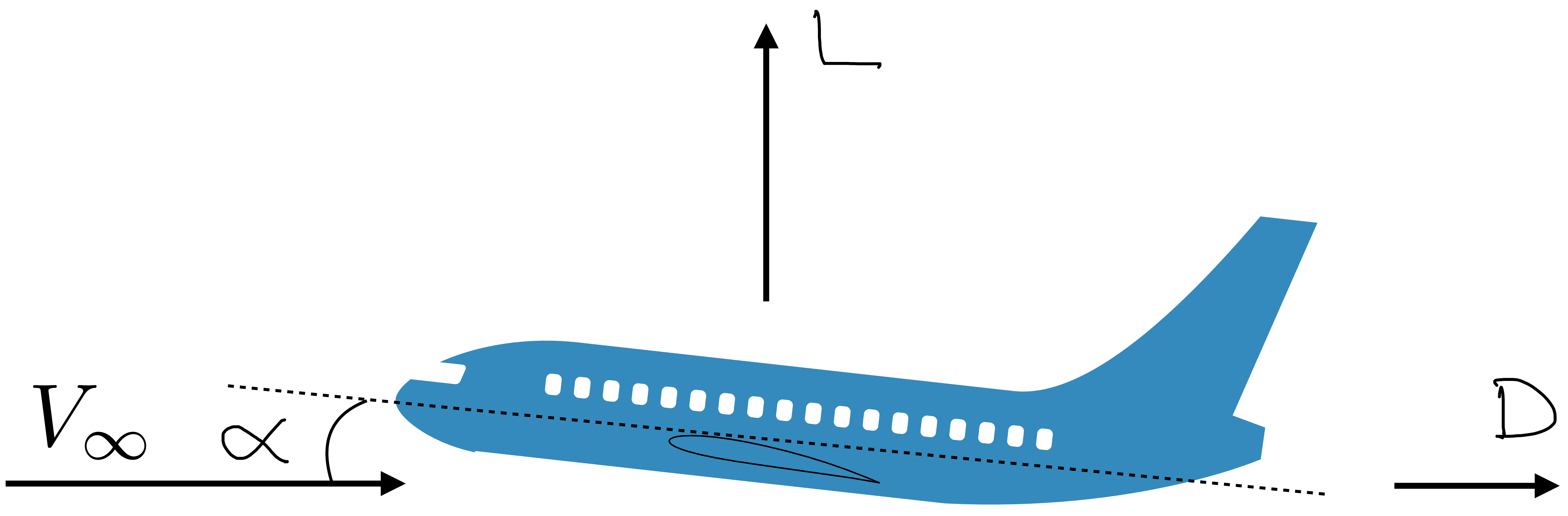
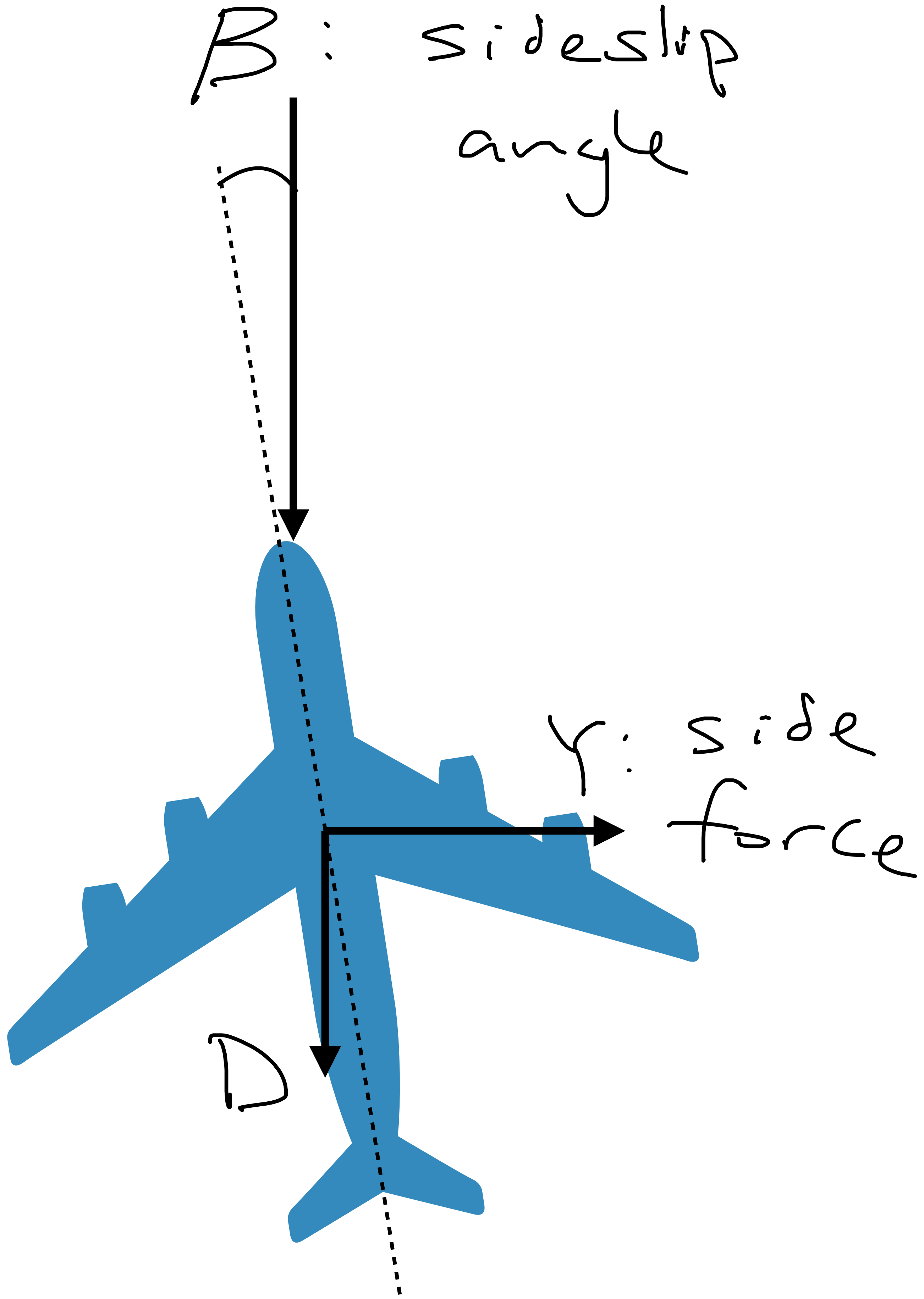
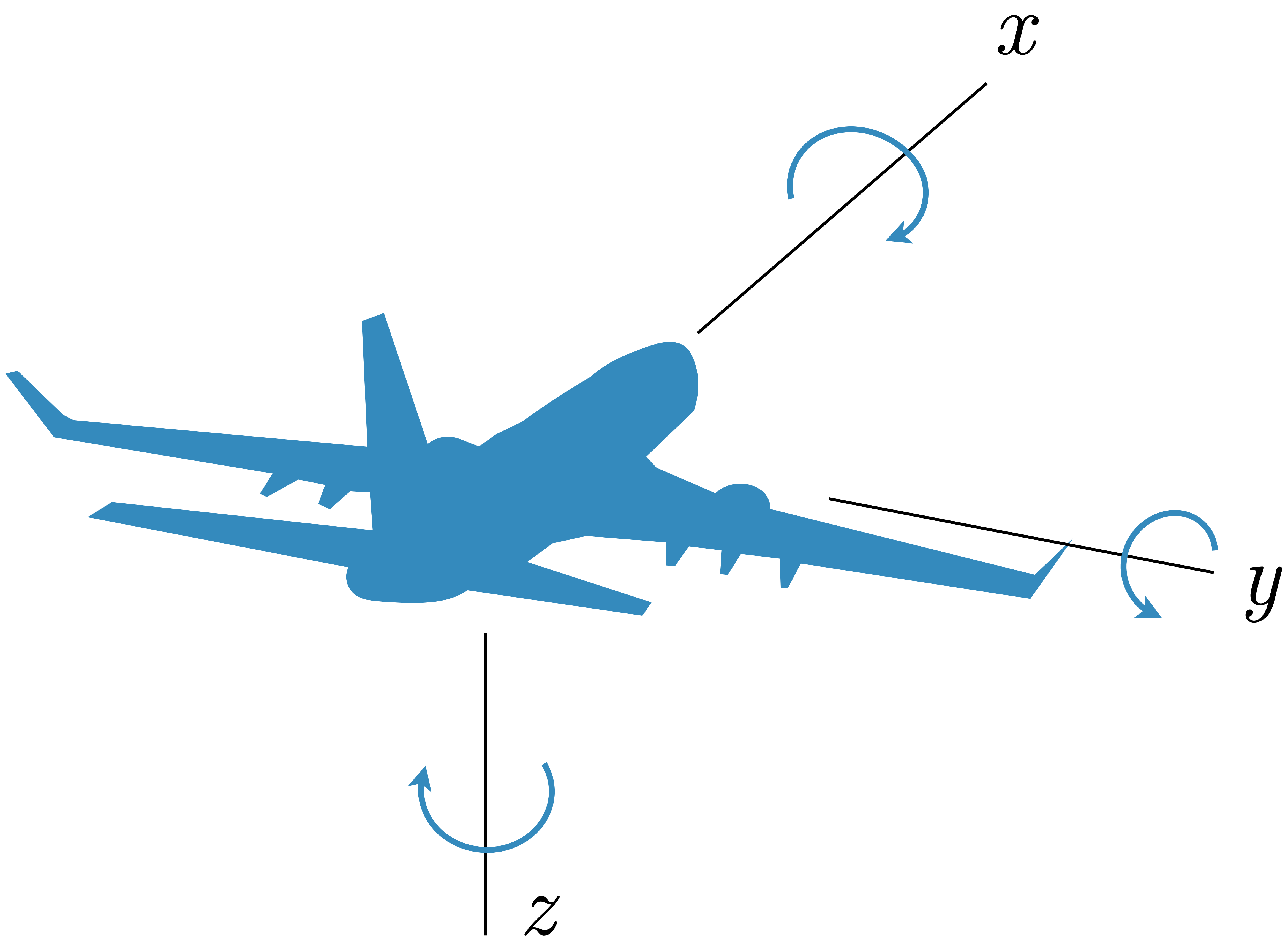
Definitions





wind axes

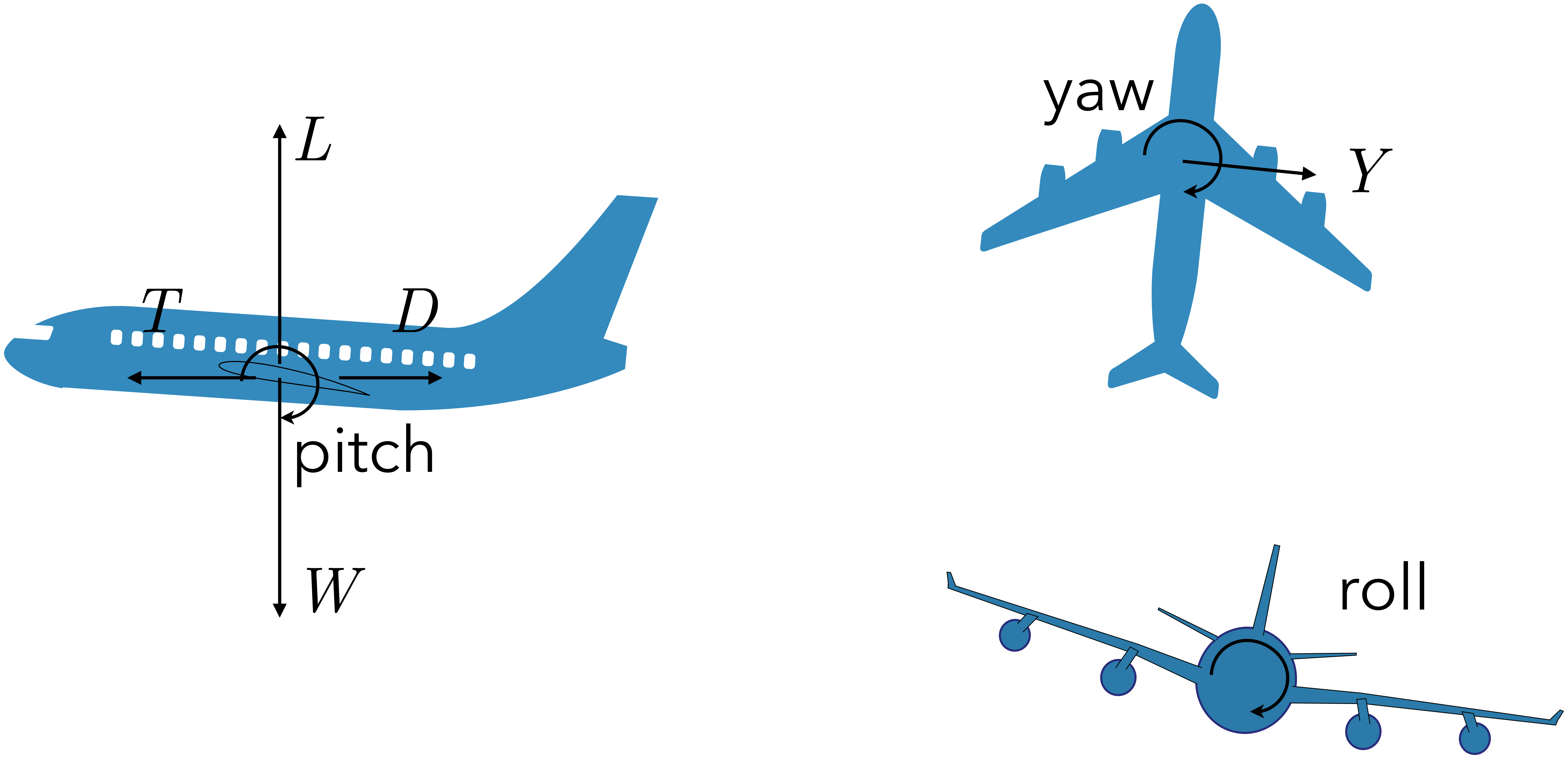
Definitions



body axes

l	rolling moment
m	pitching moment
n	yawing moment
Θ	pitch angle
Ψ	yaw angle
Φ	bank angle
p	roll rate
q	pitch rate
r	yaw rate

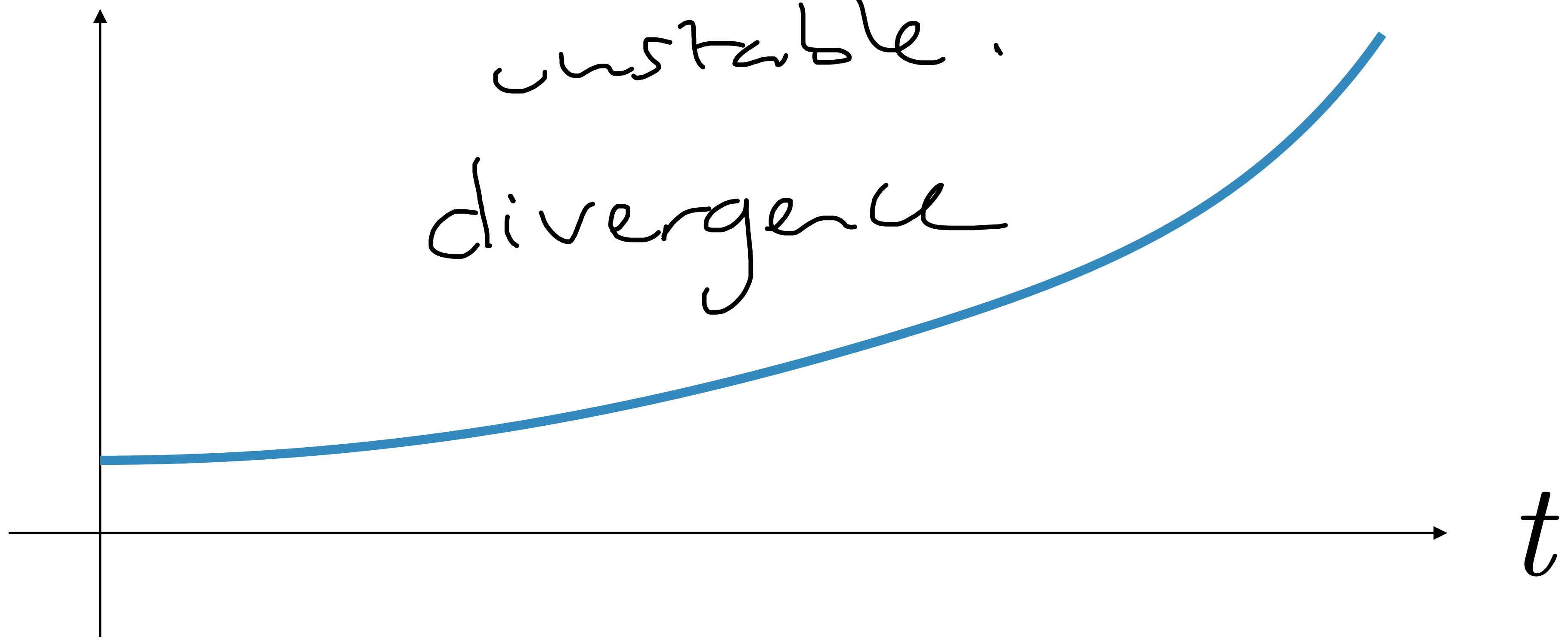
Static Equilibrium (Trim)



Stability

statically unstable.

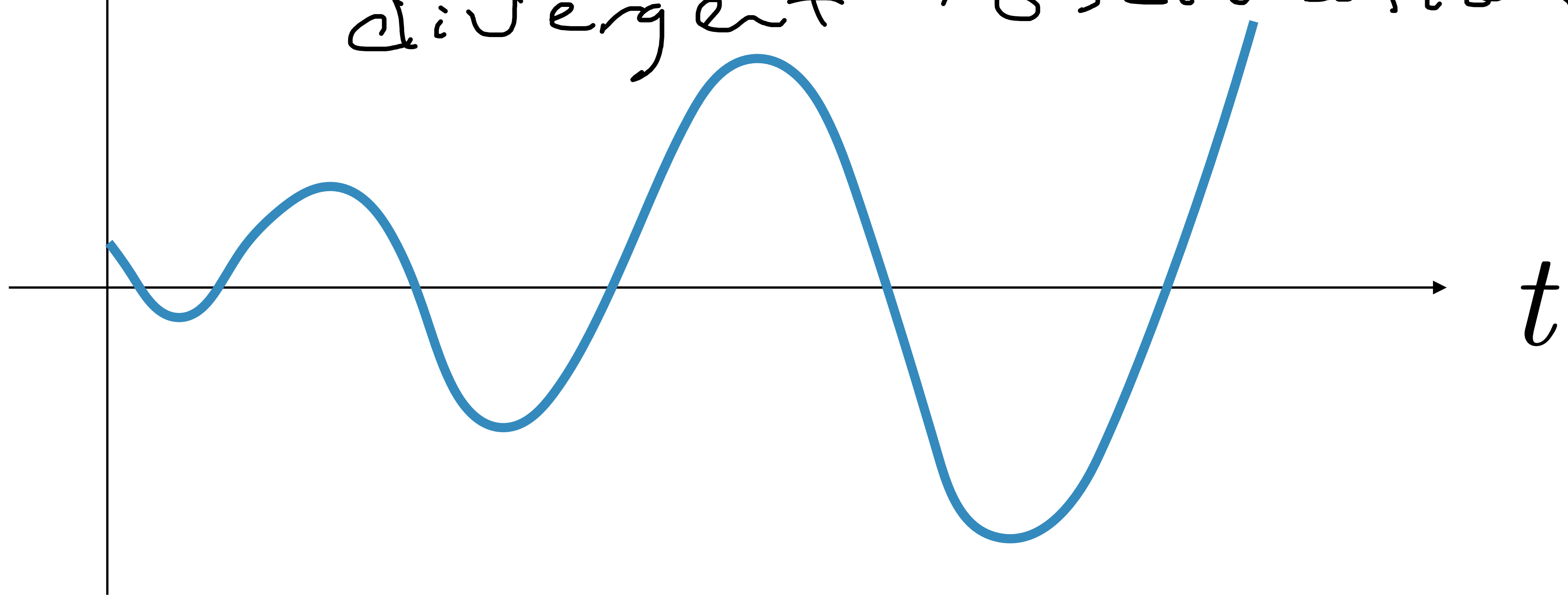
divergence



(statically stable)

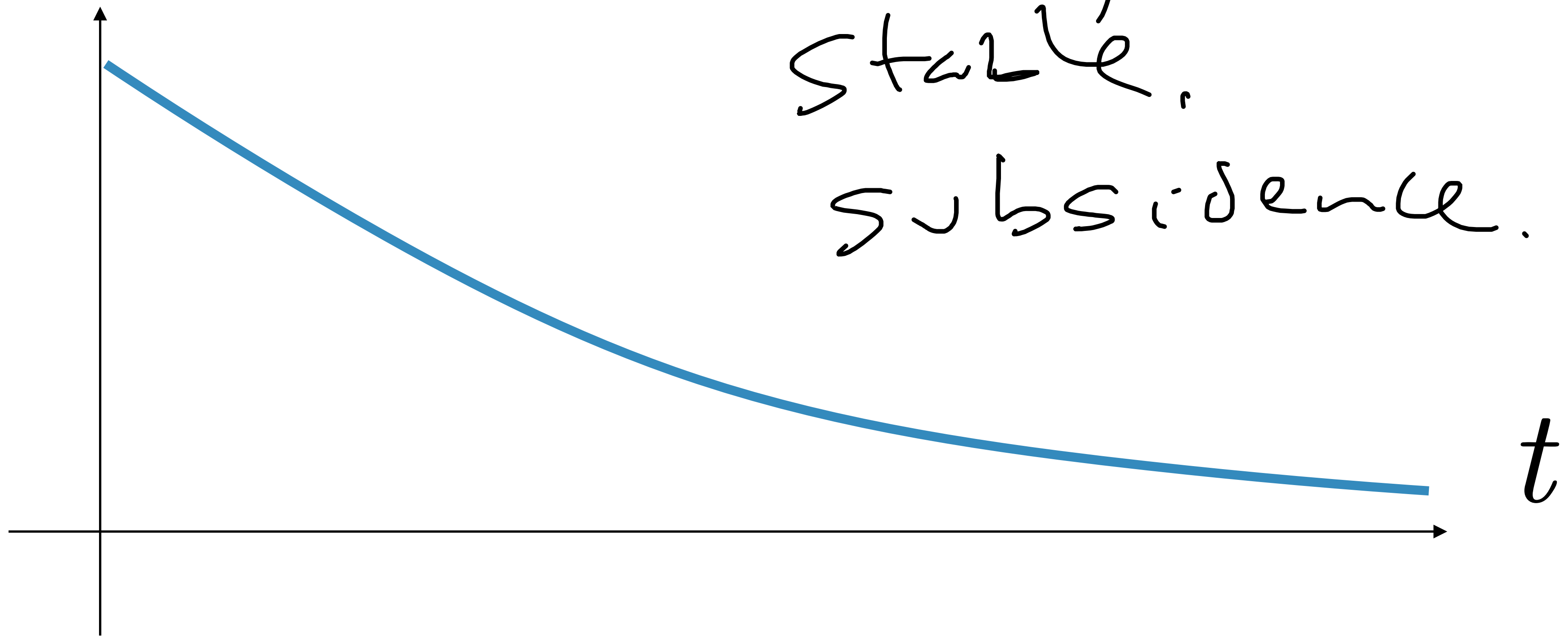
dynamically unstable.

divergent oscillation



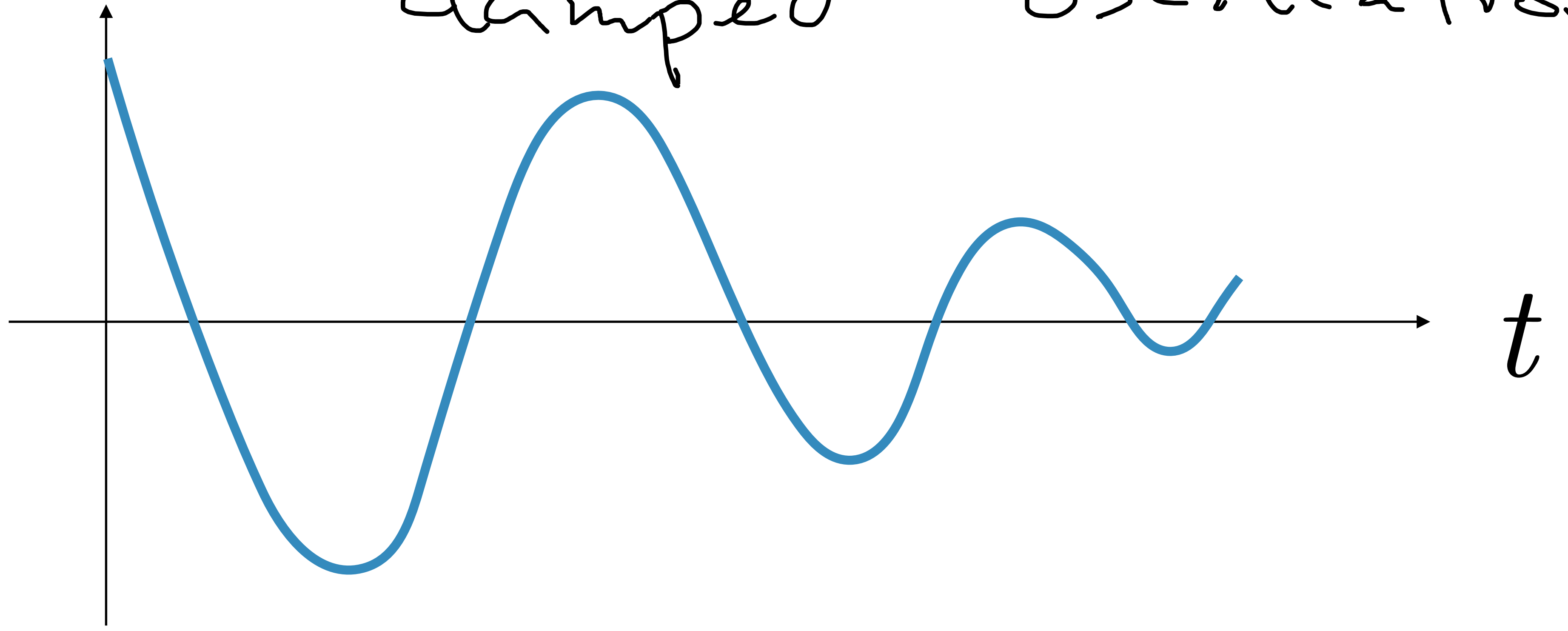
statically stable.

subsidence.

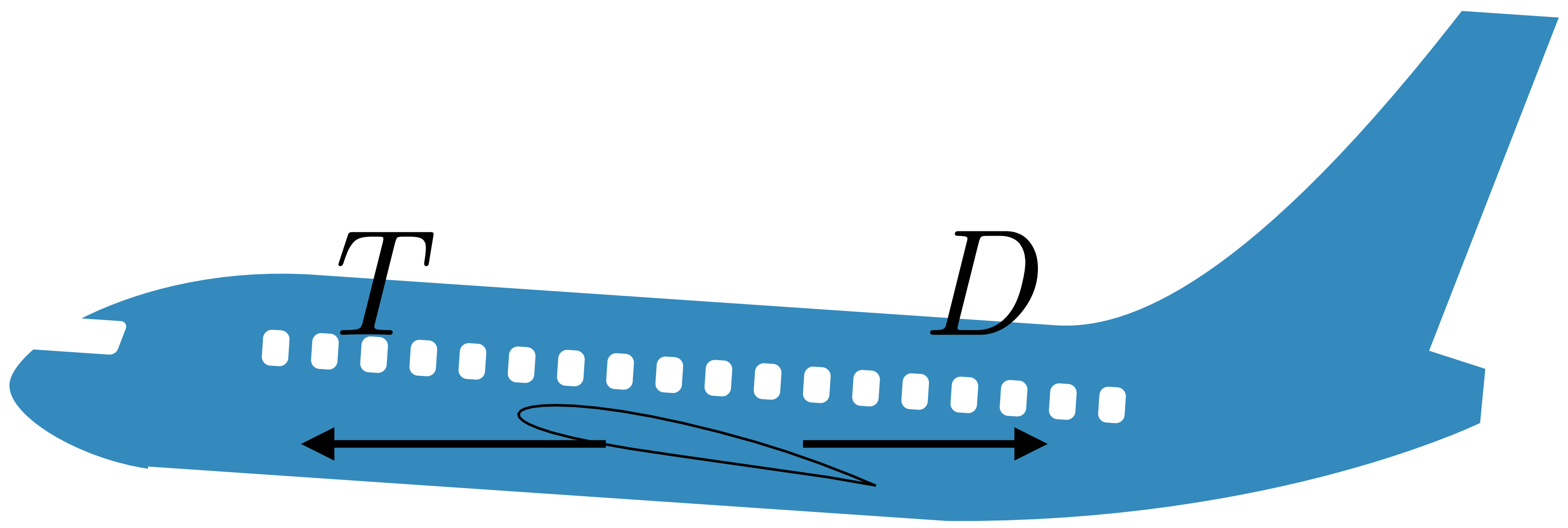


dynamically stable.

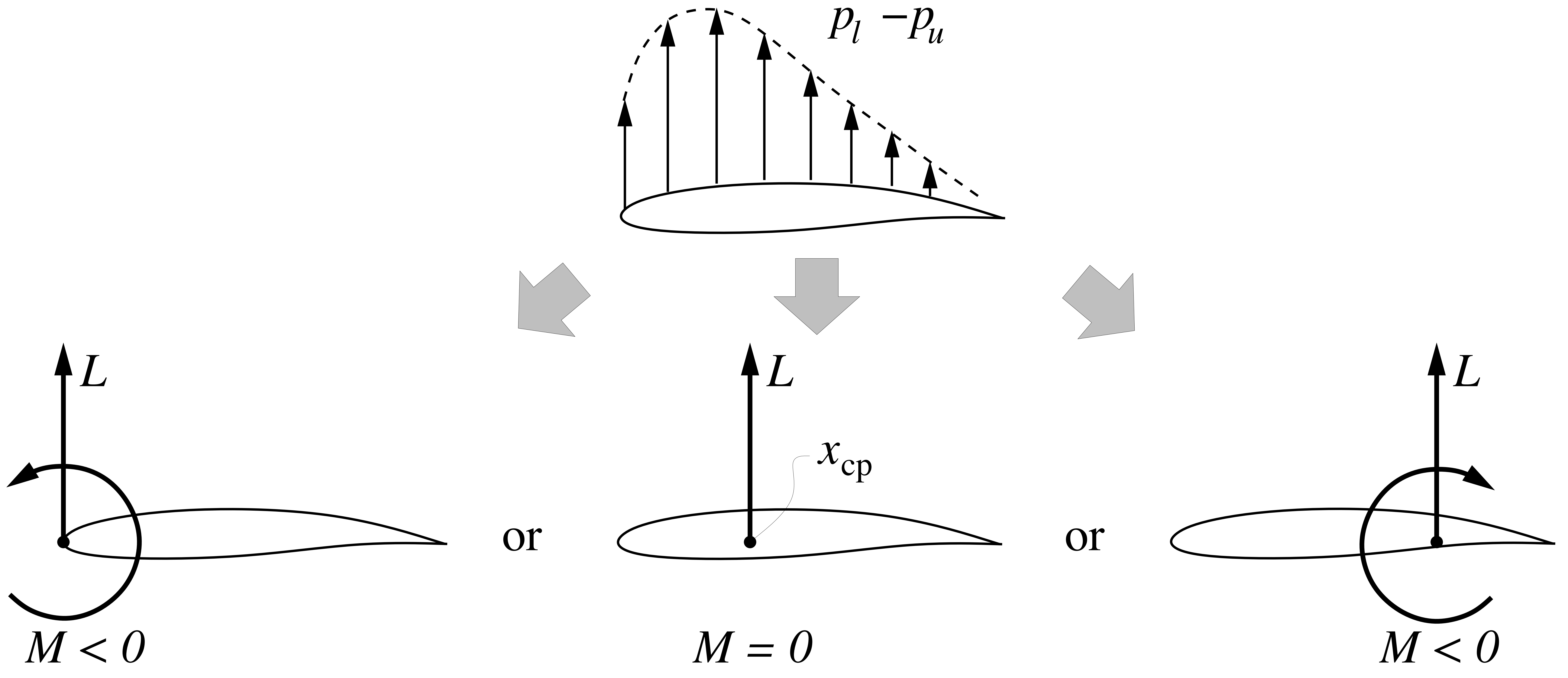
damped oscillation.



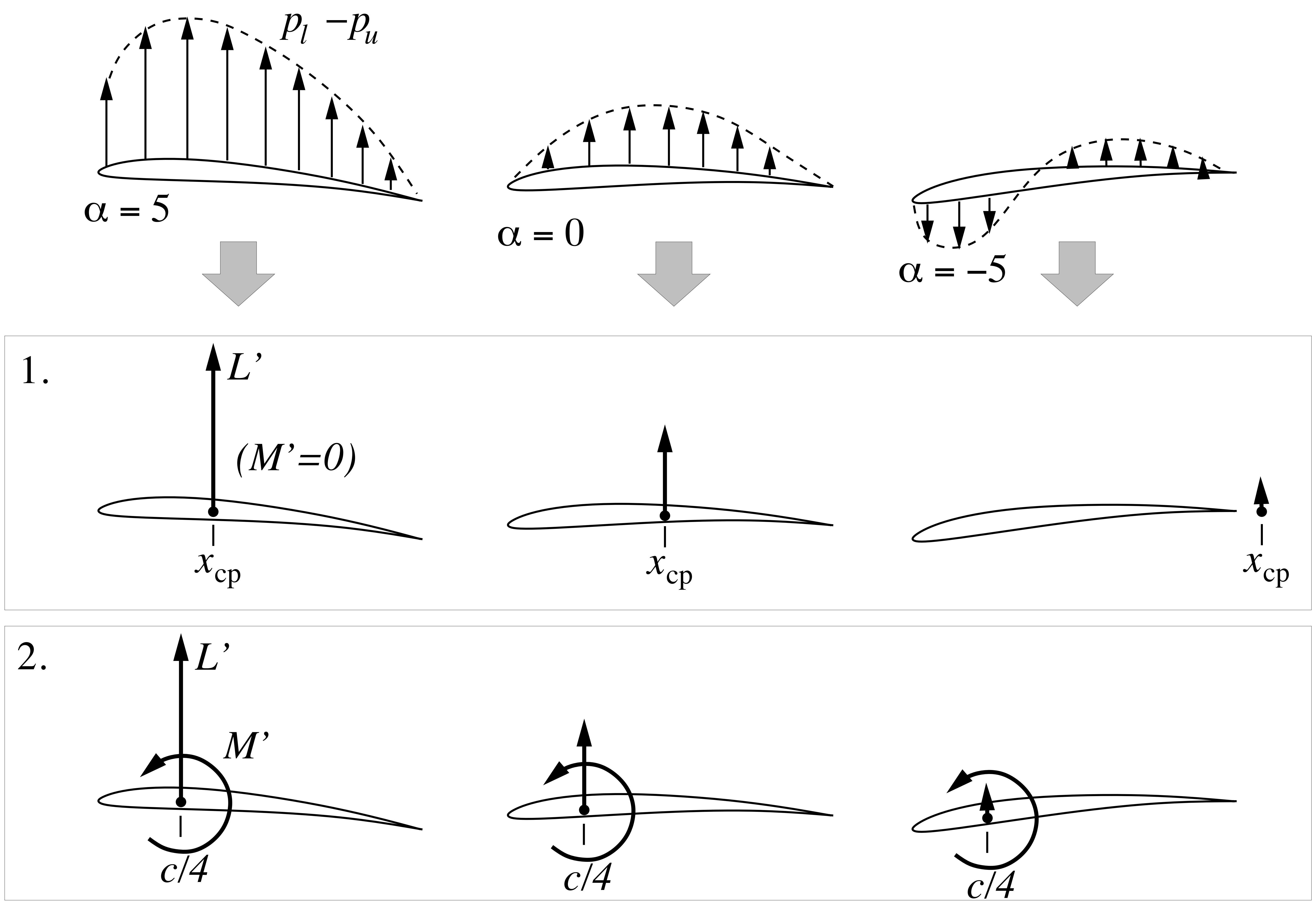
Forward Stability



Center of Pressure

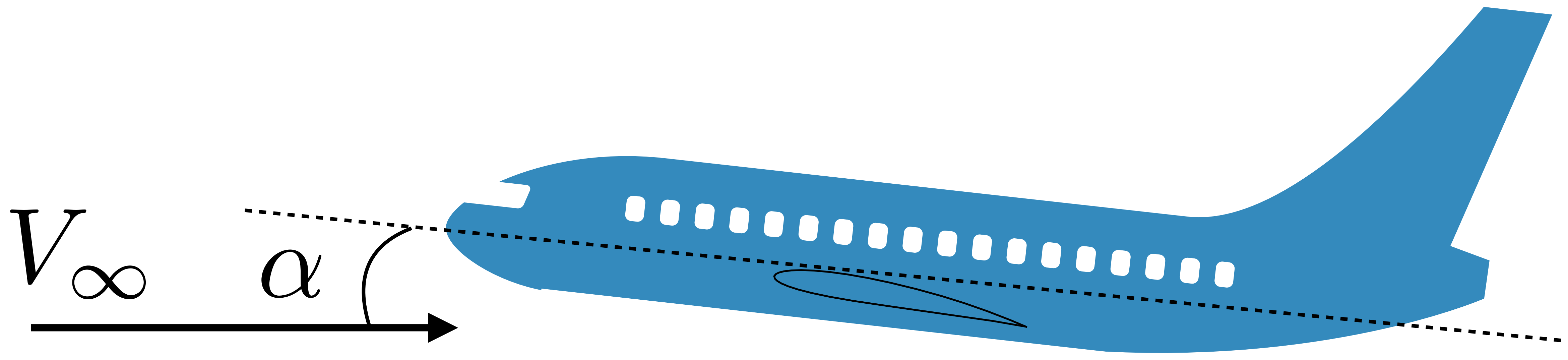


Aerodynamic Center



Joaquim Martins

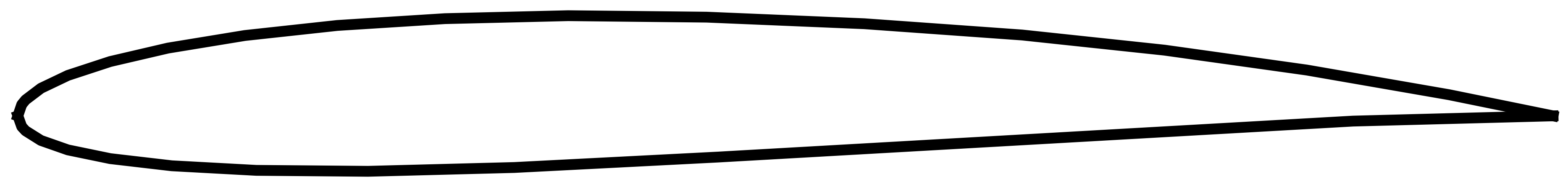
Longitudinal Stability



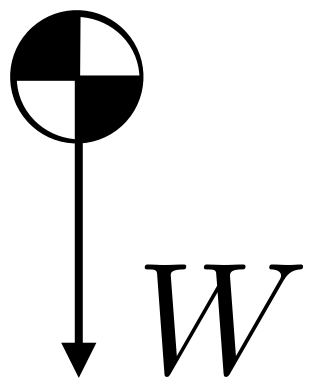
$$\frac{dC_{m_{cg}}}{d\alpha} < 0 \qquad C_{m,\alpha} < 0 \qquad \text{(stability derivative)}$$

Flying Wing: Try It!

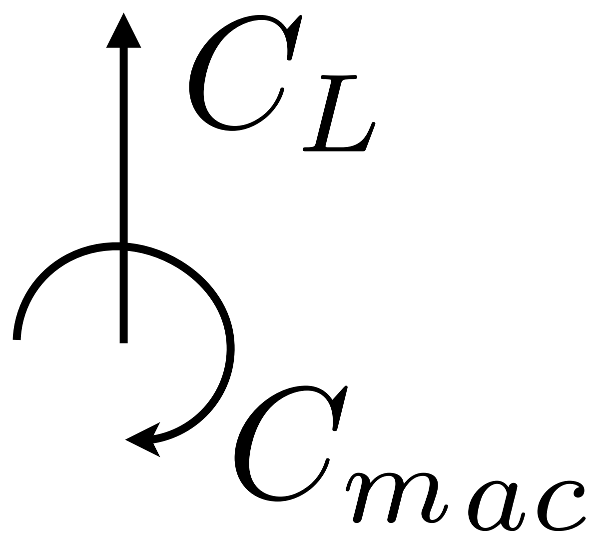
wing:



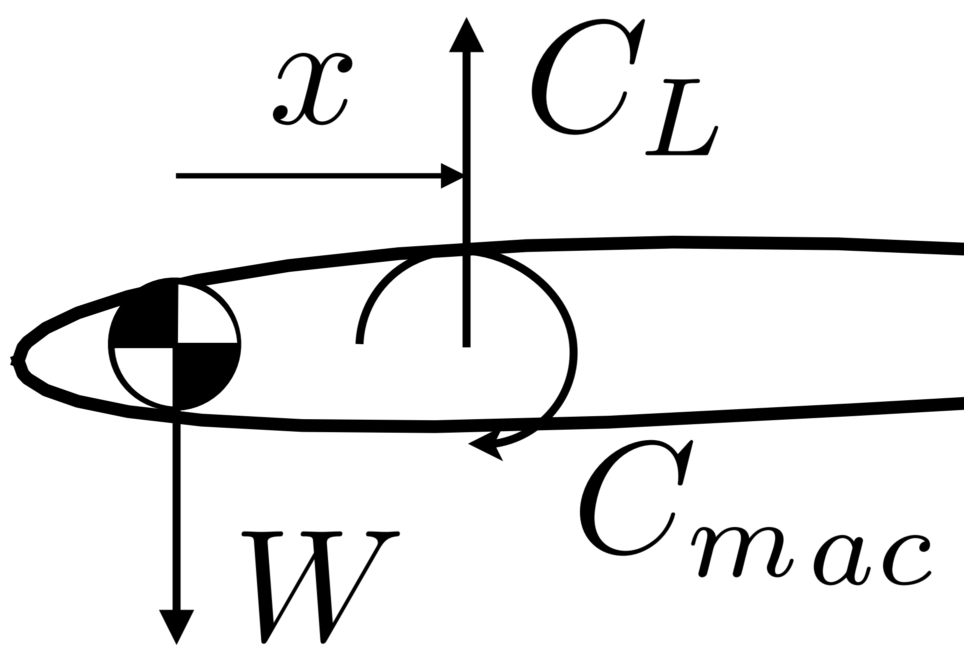
c.g.:



a.c.:



Flying Wing

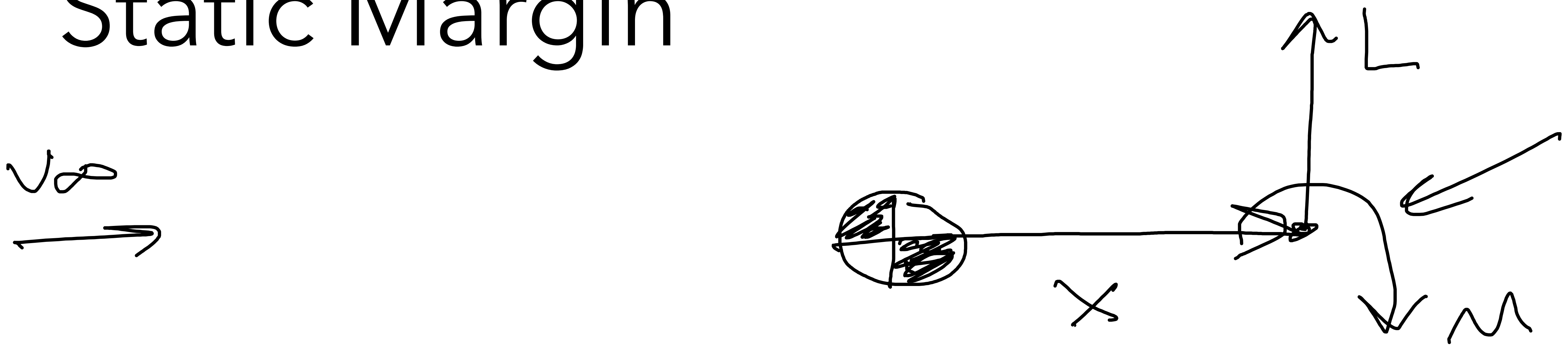


$$\frac{M_{cg}}{qSc} = \frac{M_{ac}}{qSc} - \frac{xL}{qSc} \Rightarrow C_{m_{cg}} = C_{mac} - \frac{x}{c} C_L$$

$$\frac{dC_{m_{cg}}}{d\alpha} < 0 \Rightarrow -\frac{x}{c}\overset{\text{positive}}{\frac{dC_L}{d\alpha}} < 0 \Rightarrow \underline{x \text{ positive}}$$

$$\Sigma M = 0 \Rightarrow \underset{\text{neg. for cambered airfoil}}{C_{mac}} = \frac{x}{c} \overset{\text{positive}}{C_L} \Rightarrow x \text{ negative?}$$

Static Margin



a.c. of full aircraft

- a.c. of full aircraft must be behind c.g. for long. static stability

$\frac{X}{C}$: static margin.

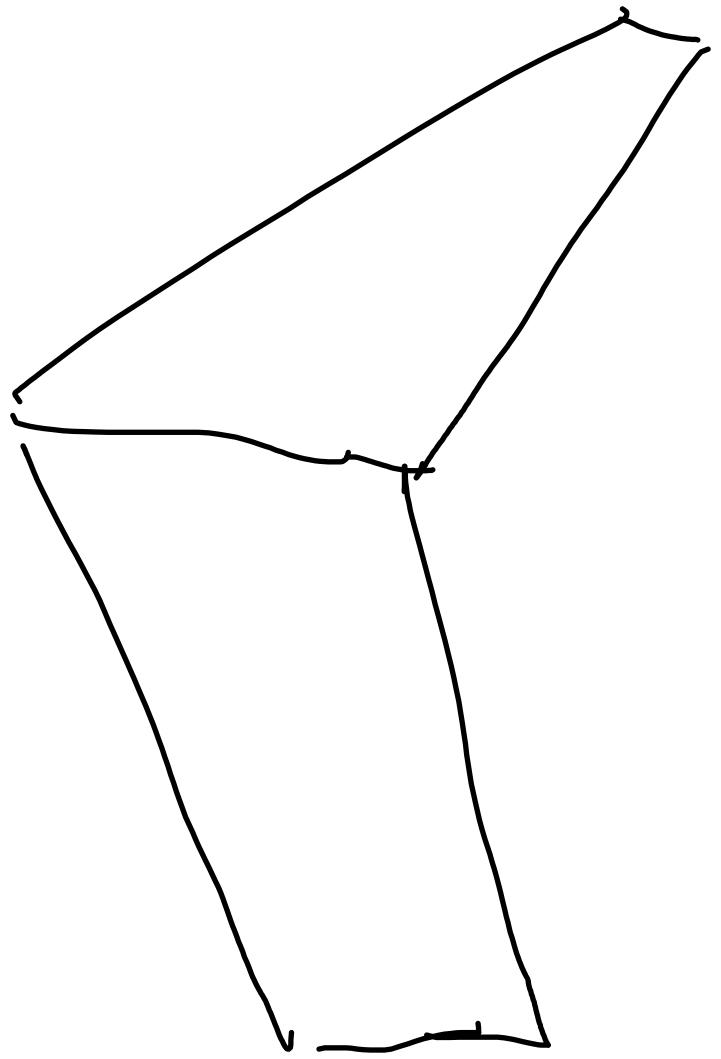
C ← mean aerodynamic chord

$\frac{X}{C} = 0 \Rightarrow$ neutral point

Three Options

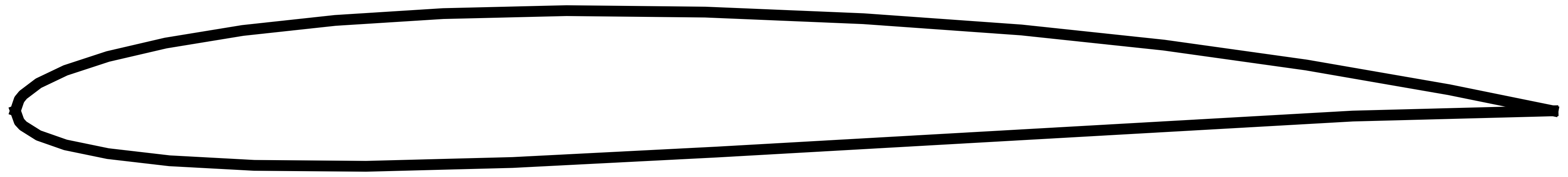
1. reflexed airfoil

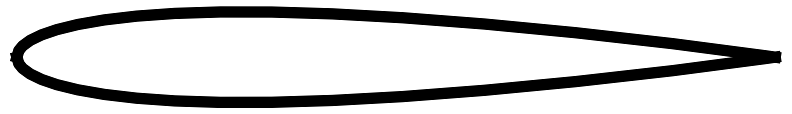
2. Sweep & washout

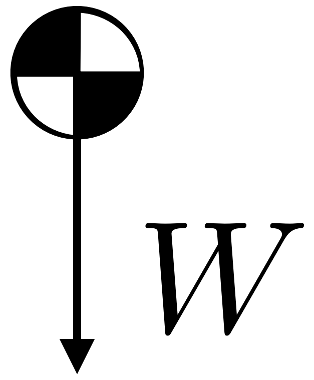


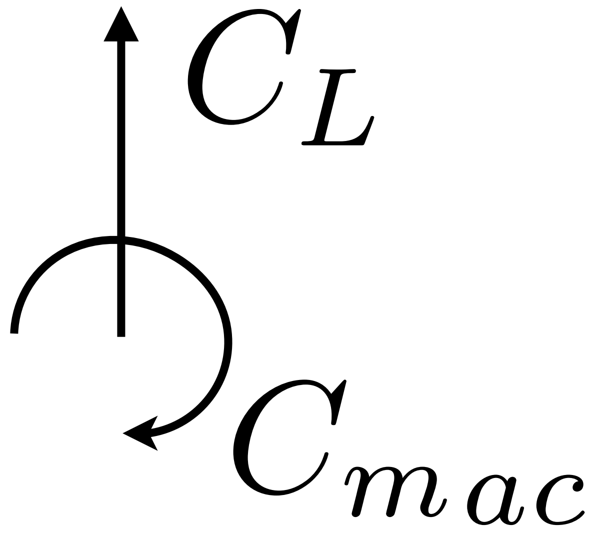
3. let the aircraft be unstable & use active controls

Wing/Tail: Try It!

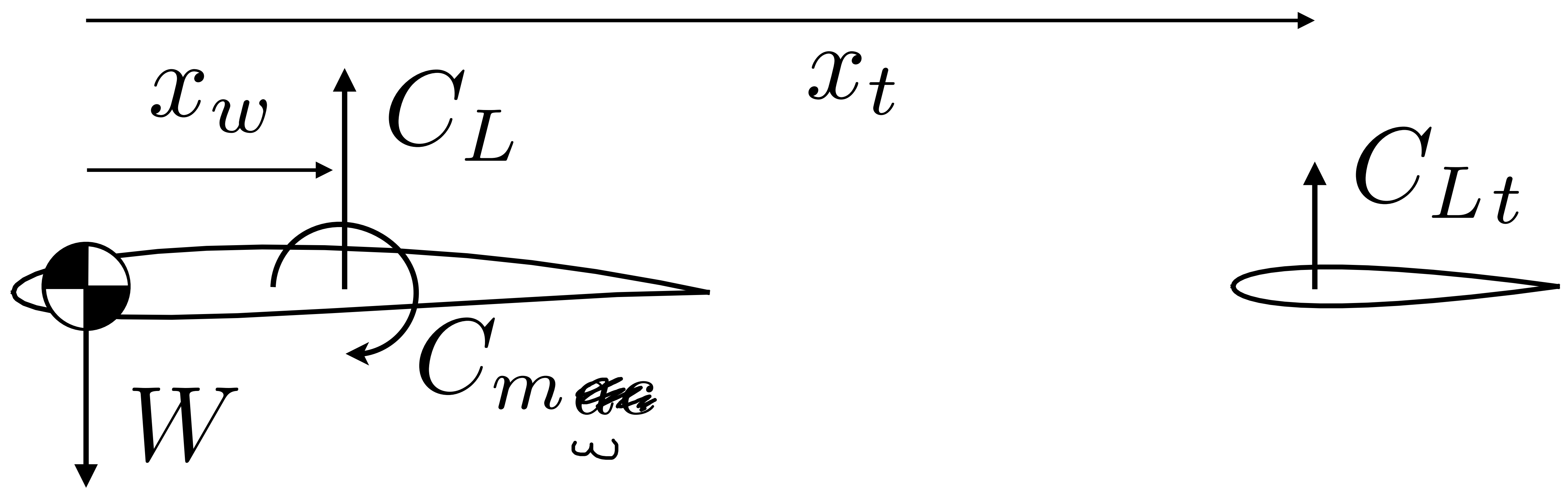
wing: 

tail: 

c.g.: 

a.c.: 

Wing/Tail

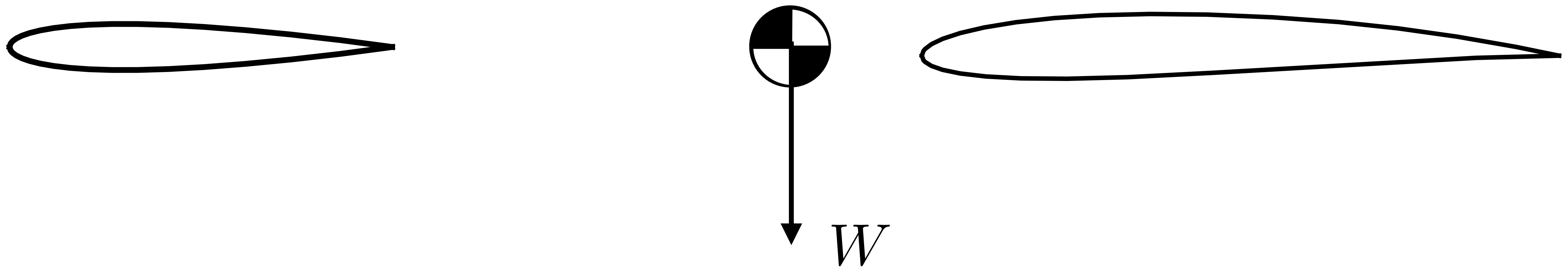


$$M_{cg} = M_w - x_w L_w - x_t L_t + \cancel{M_{fn}} \quad \text{(small)}$$

$$C_{m_{cg}} q_w S_w c_w = C_{m_w} q_w S_w c_w - x_w C_{L_w} q_w S_w - x_t C_{L_t} q_t S_t$$

$$C_{m_{cg}} = C_{m_w} - \frac{x_w}{c_w} C_{L_w} - \underbrace{\frac{x_t S_t}{c_w S_w}}_{\text{horizontal tail volume coefficient}} \underbrace{\frac{q_t}{q_w}}_{\eta_t:\ \text{tail efficiency}} C_{L_t}$$

Canard



+ canard generate pos. lift. (smaller wing)

− larger interference drag.

− canard must stall first. → generally means the wing must be larger.

+ can be (virtually) stall proof