北京航空航天大學
BEIHANG UNIVERSITY

# 飞行力学
# Flight Mechanics

Chen, Song（陈松）

School of General Engineering (SGE)

chensong@buaa.edu.cn； Office: D-1109

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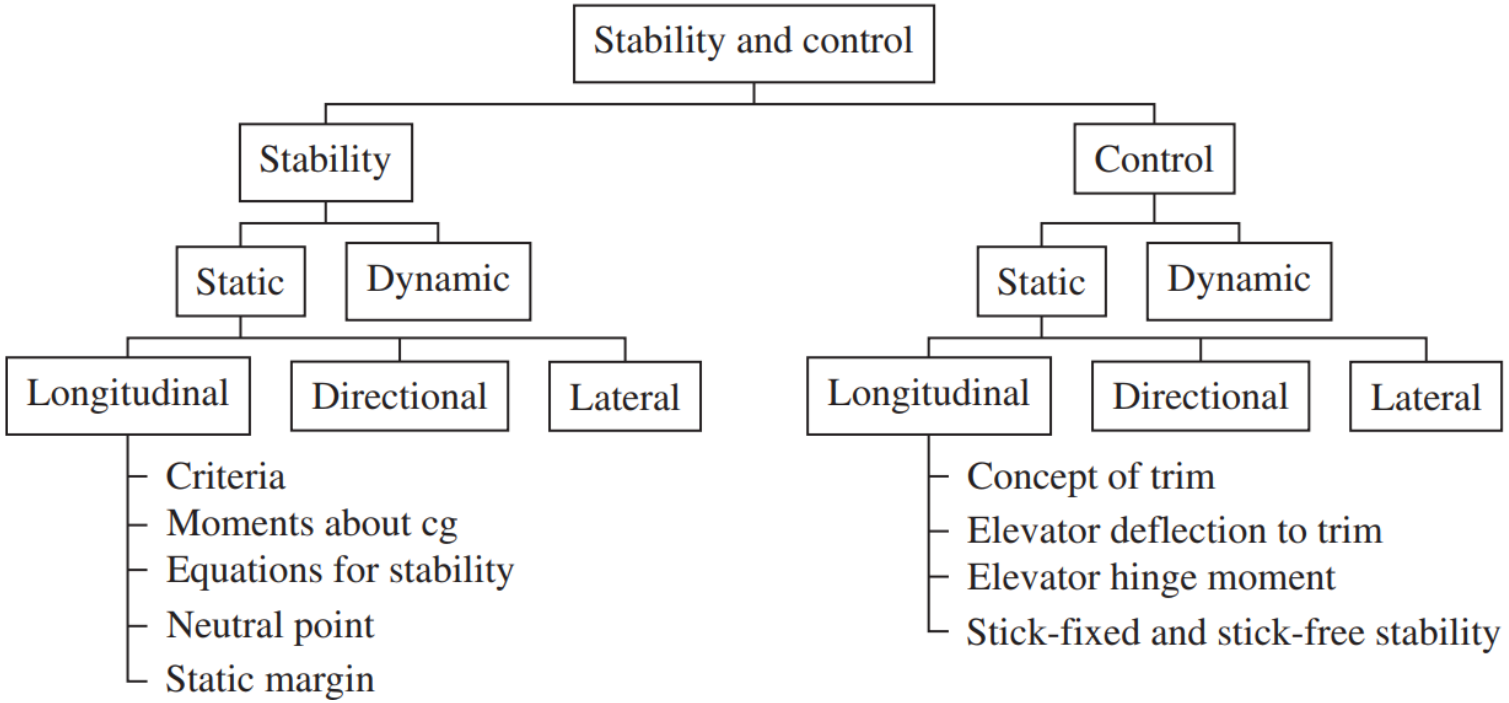
# Contents

# Introduction




Road map for Stability and Control.

# Introduction

Some early design of aircraft (1/3)


https://www.deutsches-museum.de/en/museum-island/exhibitions/historic-aviation

# Introduction

Some early design of aircraft (2/3)

https://www.deutsches-museum.de/en/museum-island/exhibitions/historic-aviation

# Introduction

Some early design of aircraft (3/3)

https://www.deutsches-museum.de/en/museum-island/exhibitions/historic-aviation

# Introduction

## Question

- What are major challenges for these early aircrafts ?

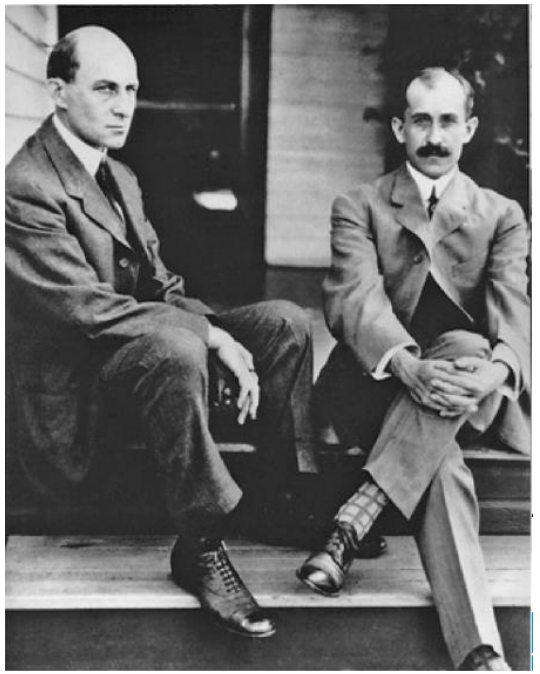
Otto Lilienthal took off from the “Fliegeberg” hill in Berlin with his glider. Photo: Deutsches Museum

# Introduction

## Wright brothers:

"*When this one feature (**balance and control**) has been worked out, the age of flying machines will have arrived, for all other difficulties are of minor importance…*"

- Papers of Wilbur and Orville Wright

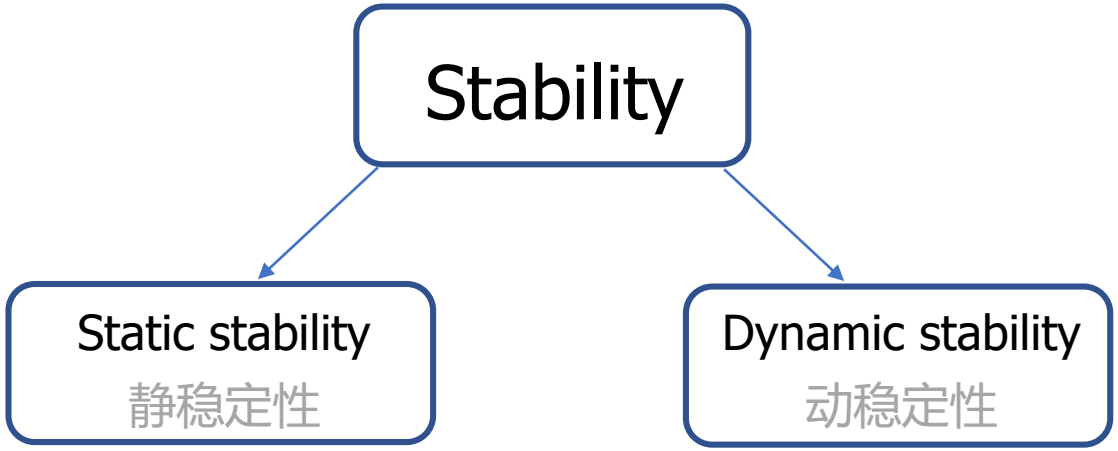


Wright brothers

*(Left: Wilbur; Right: Orville)*

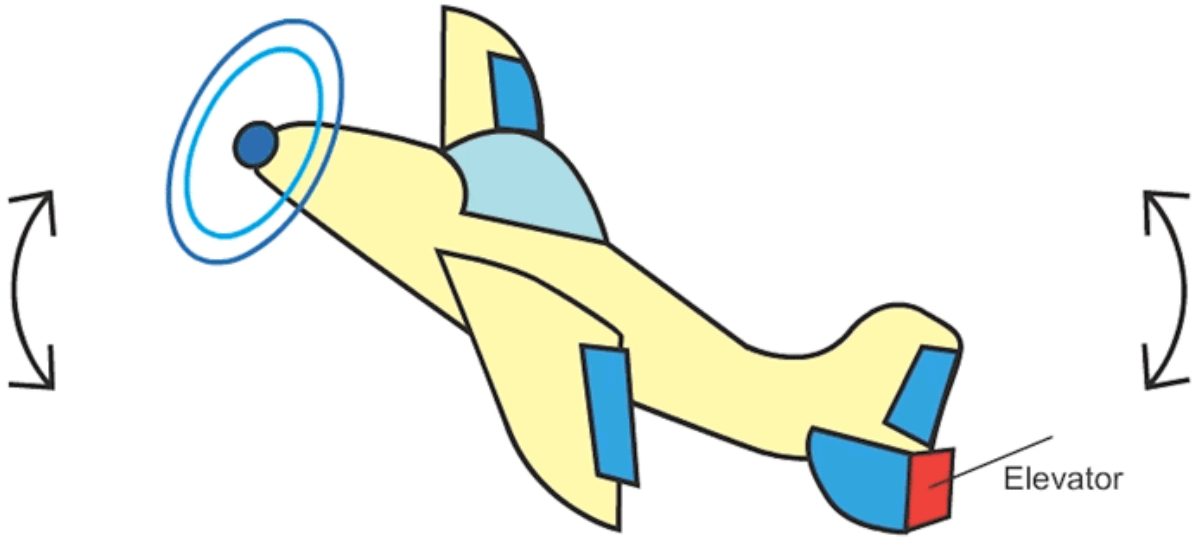
# Stability

What is stability ?



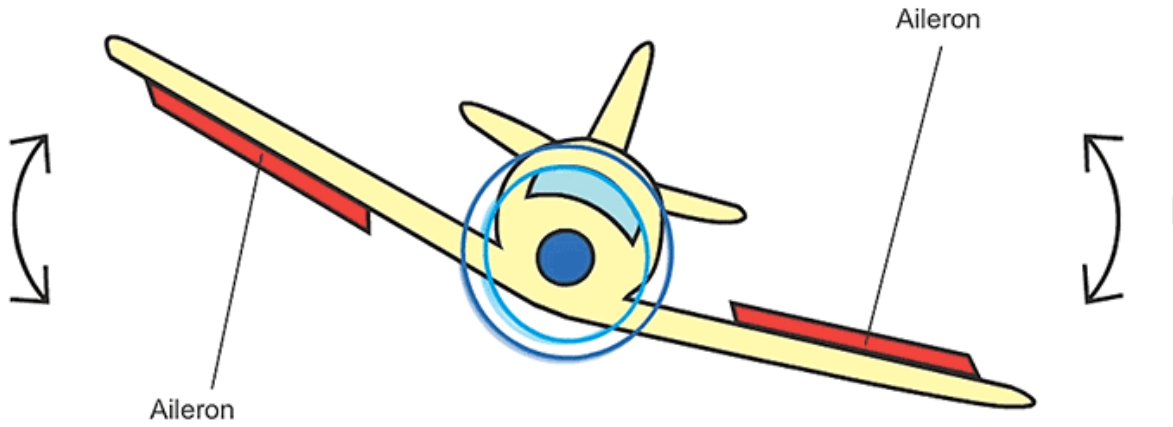

The ability of the aircraft to withstand disturbances, and continue with normal flight.

# Review - Pitch Motion



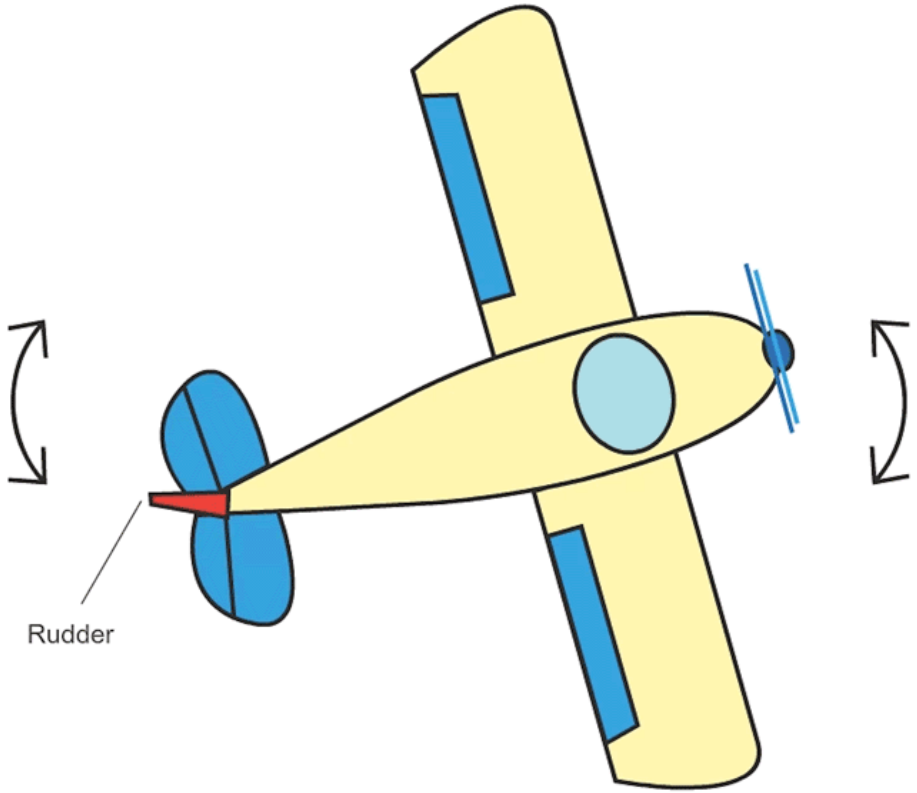

Source: https://howthingsfly.si.edu/flight-dynamics/roll-pitch-and-yaw

# Review - Roll Motion




Source: https://howthingsfly.si.edu/flight-dynamics/roll-pitch-and-yaw

# Review - Yaw Motion

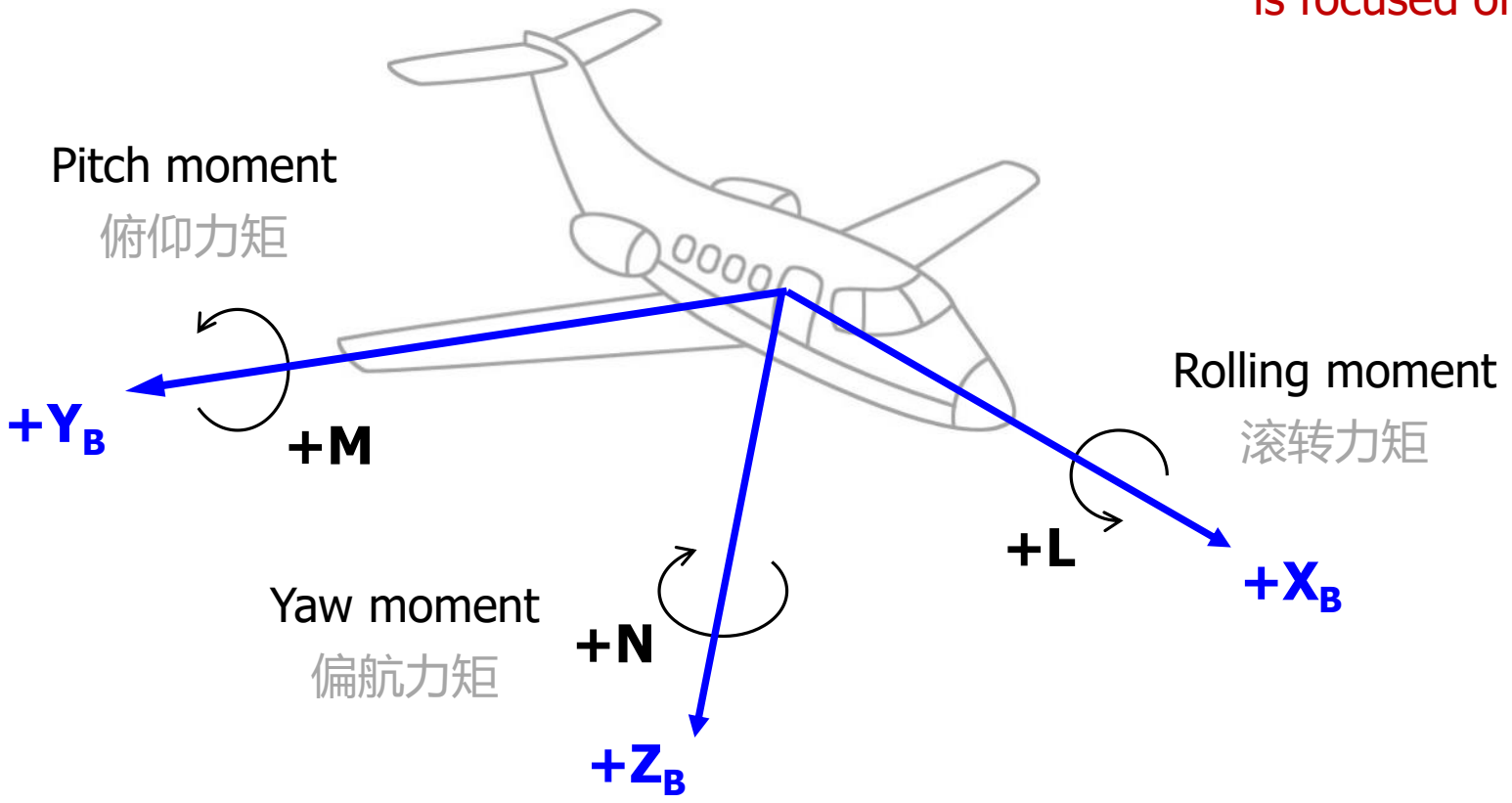



Source: https://howthingsfly.si.edu/flight-dynamics/roll-pitch-and-yaw

# Stability

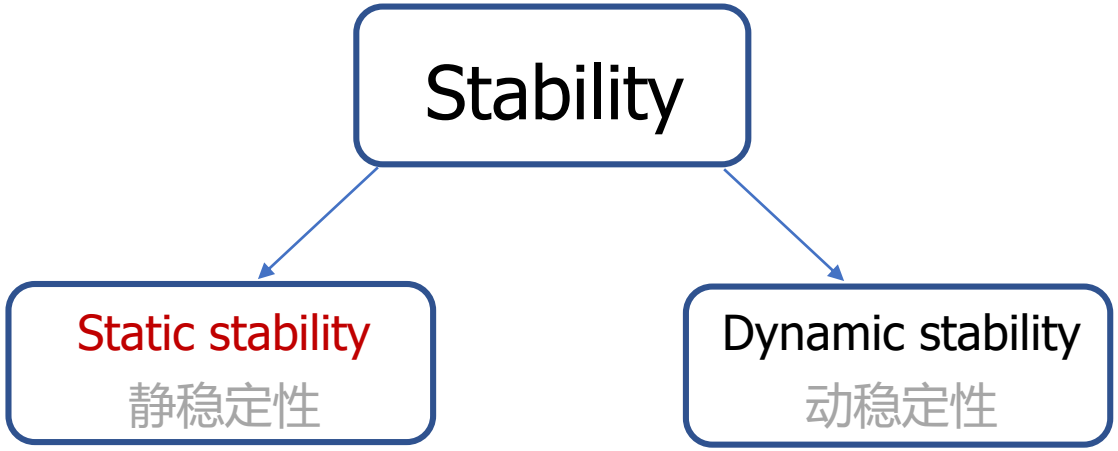
## Aircraft moments

Study of stability and control is focused on moments!

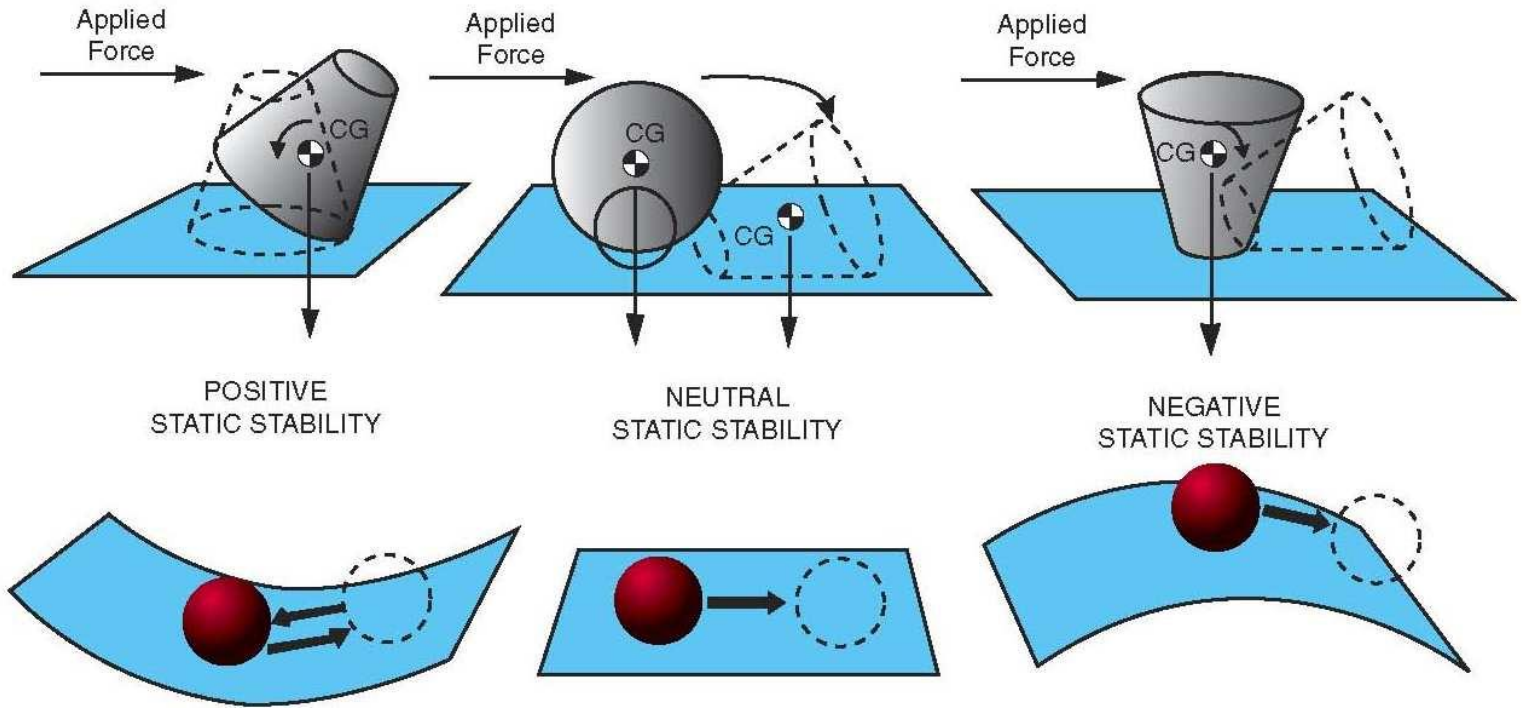


# Stability

Static stability



# Static stability




Static stability: initial response of aircraft after subjected to disturbance.

# Static stability

*After subjected to disturbances, if the aircraft:*

tends to come back to original attitude ☞ **Positive static stability**

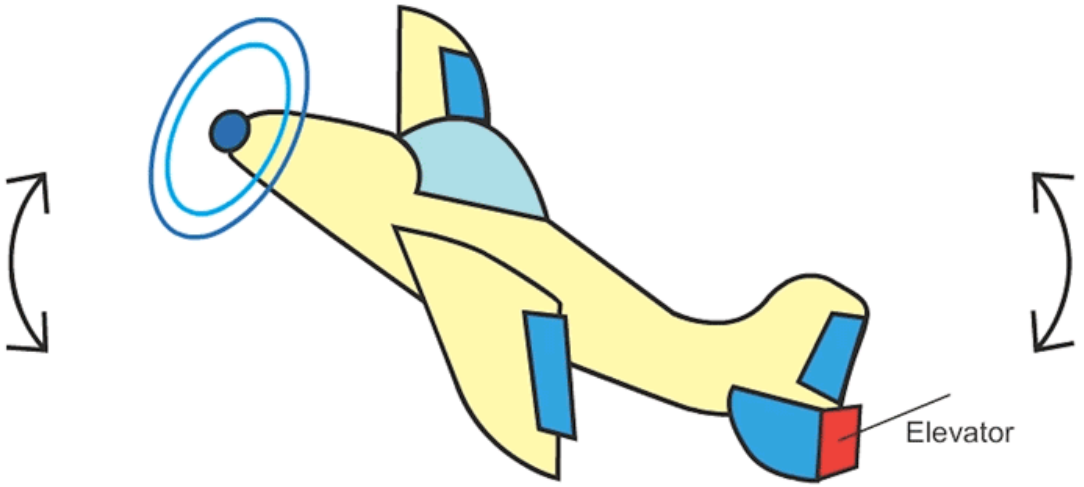
tends to deviate away from original attitude ☞ **Negative static stability**

tends to maintain its original attitude ☞ **Neutral static stability**

Static stability is determined by the aircraft design

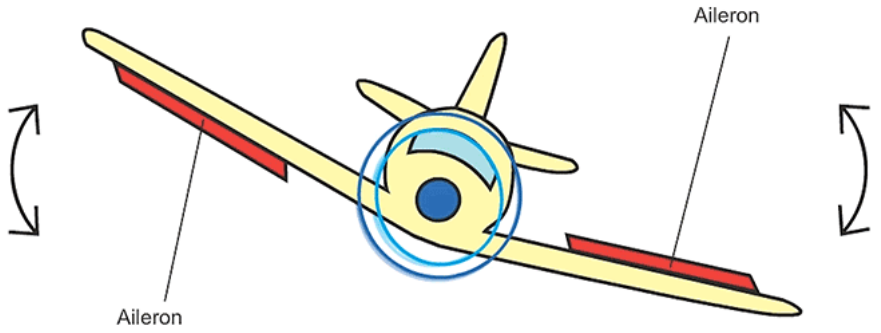
# Static stability

Longitudinal stability – pitch motion



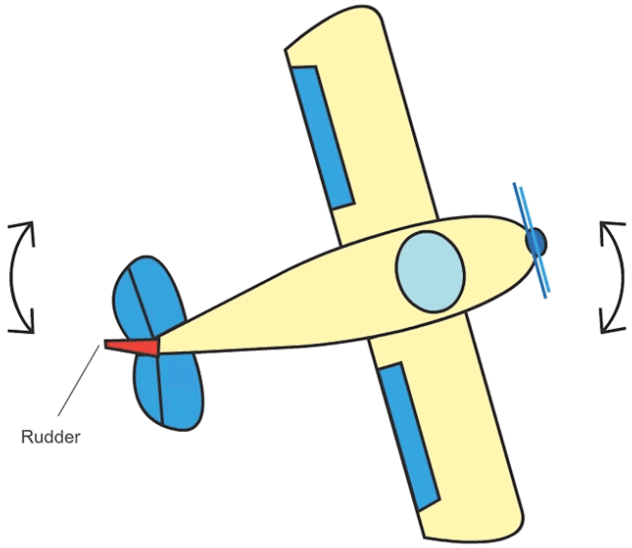
# Static stability

Lateral stability – roll motion



# Static stability

Directional stability – yaw motion



# Static stability

Absolute angle of attack

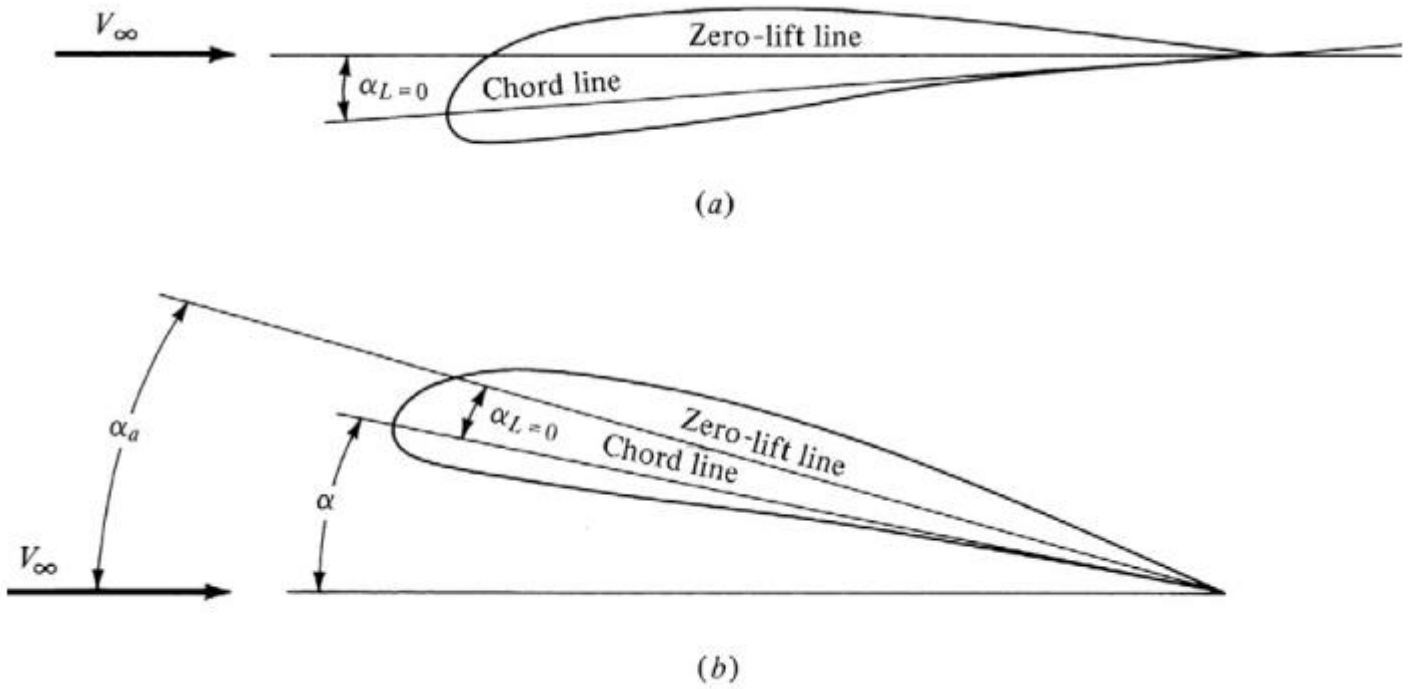



**Figure 7.11** Illustration of the zero-lift line and absolute angle of attack. (*a*) No lift; (*b*) with lift.

# Static stability

Absolute angle of attack

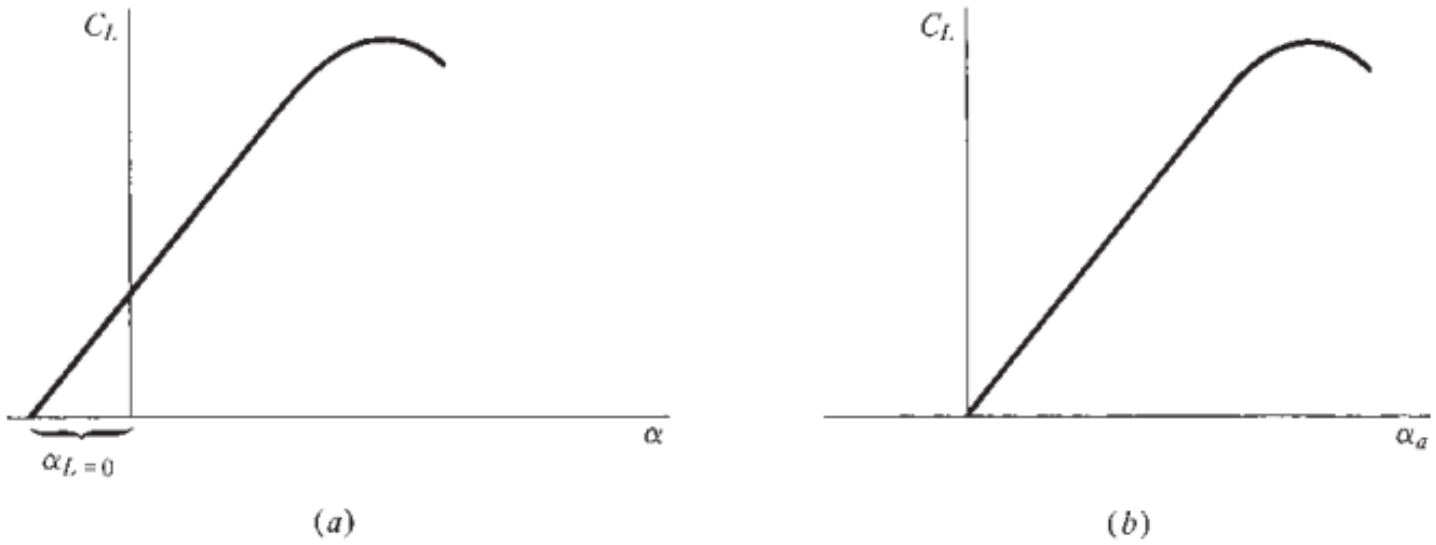
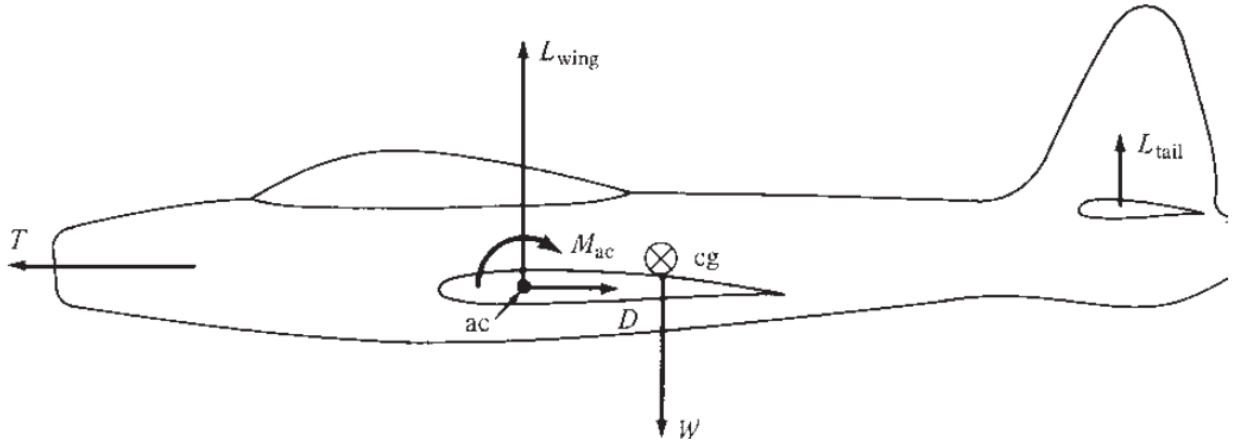



**Figure 7.12** Lift coefficient versus (*a*) geometric angle of attack and (*b*) absolute angle of attack.

# Static stability

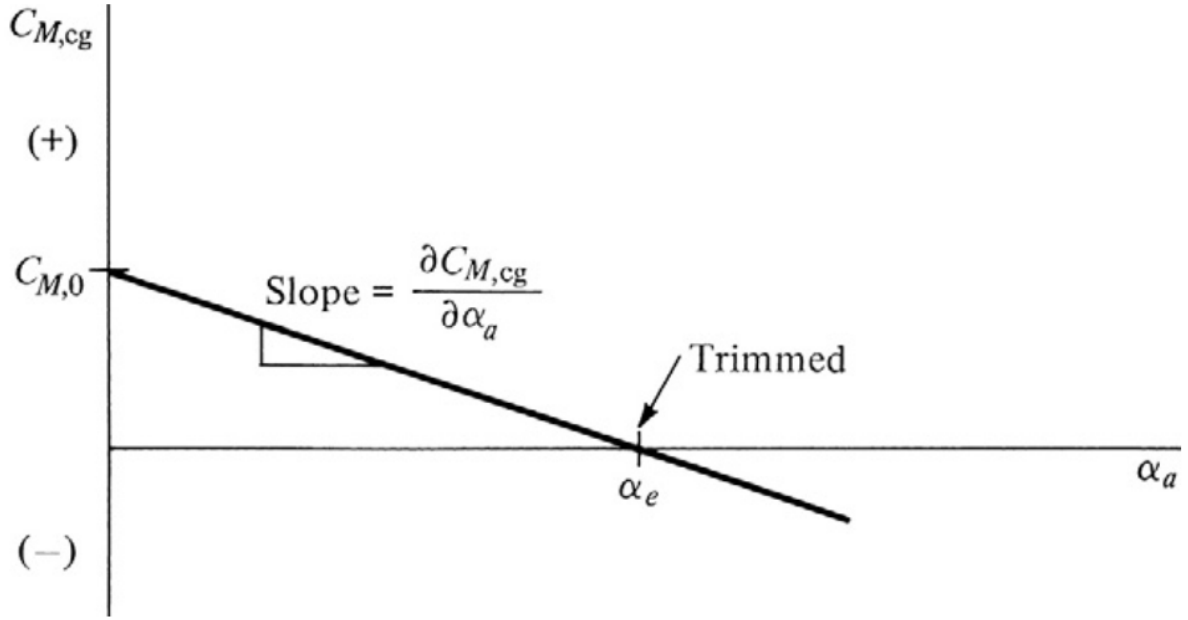
Moments – consider a rigid airplane with fixed controls




$$C_{M,\mathrm{cg}} = \frac{M_{\mathrm{cg}}}{q_\infty S c}$$

# Static stability

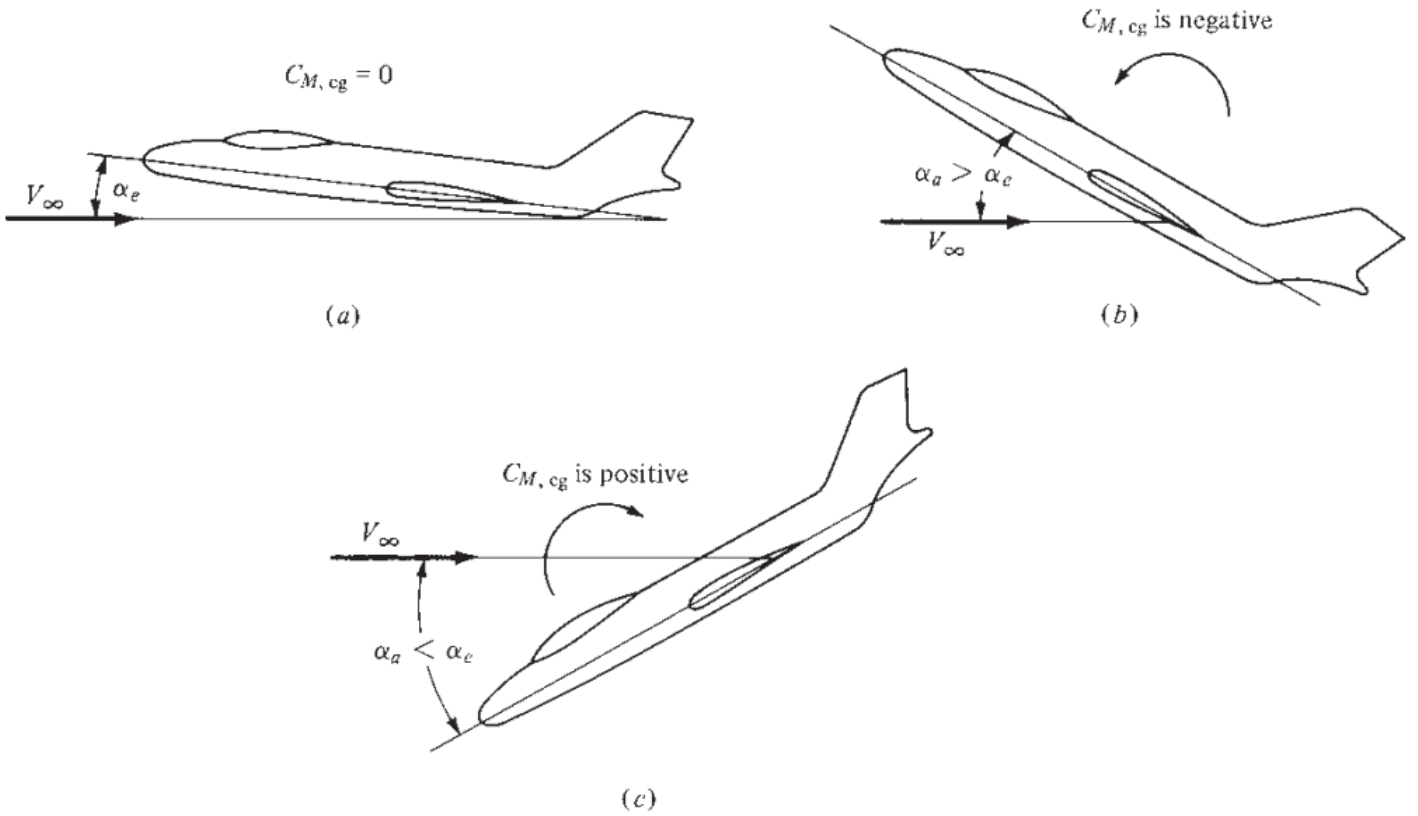
## Longitudinal static stability




Moment coefficient curve with a negative slope

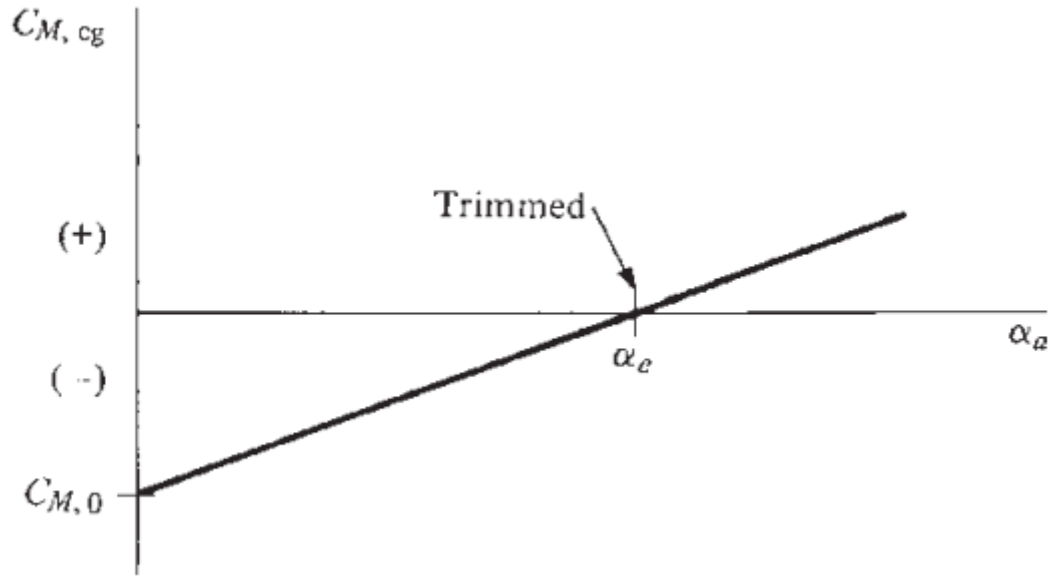
# Static stability

## Longitudinal static stability



# Static stability

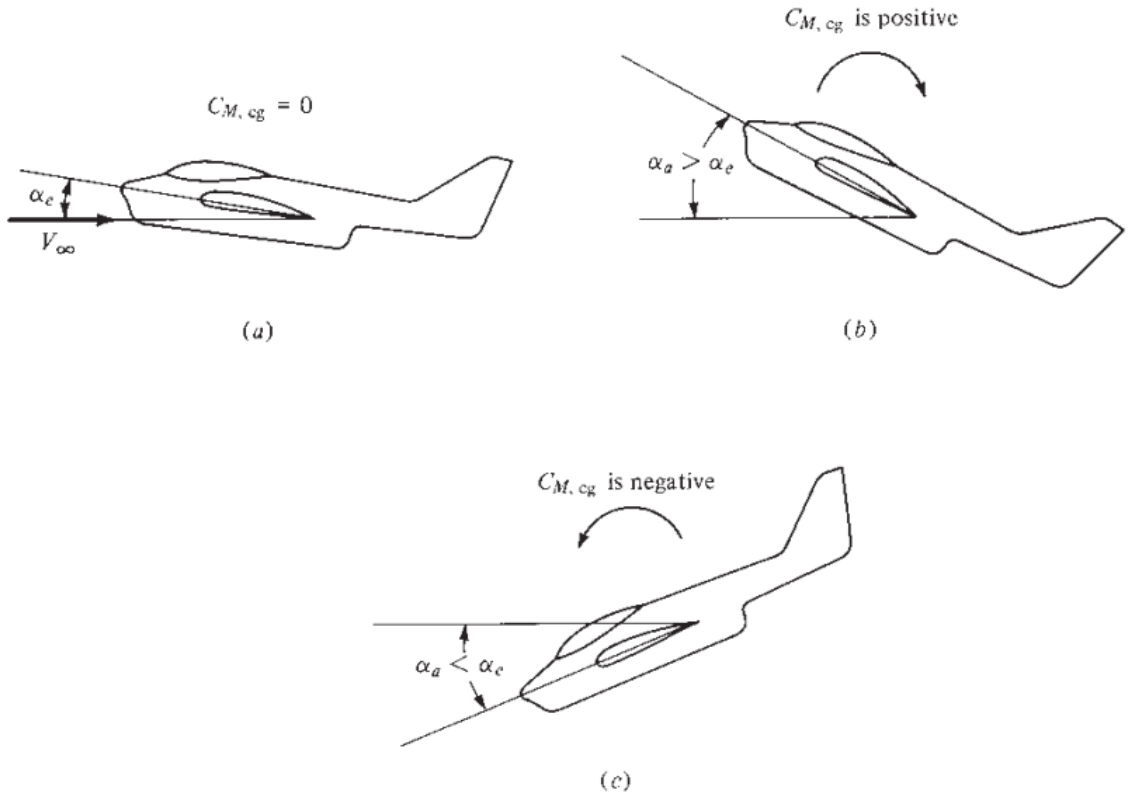
## Longitudinal static stability




Moment coefficient curve with a positive slope

# Static stability

## Longitudinal static stability



# Static stability

Criteria for longitudinal static stability

- $C_{M,0}$ must be positive
- $\partial C_{M,0} / \partial \alpha_a$ must be negative

# Static stability

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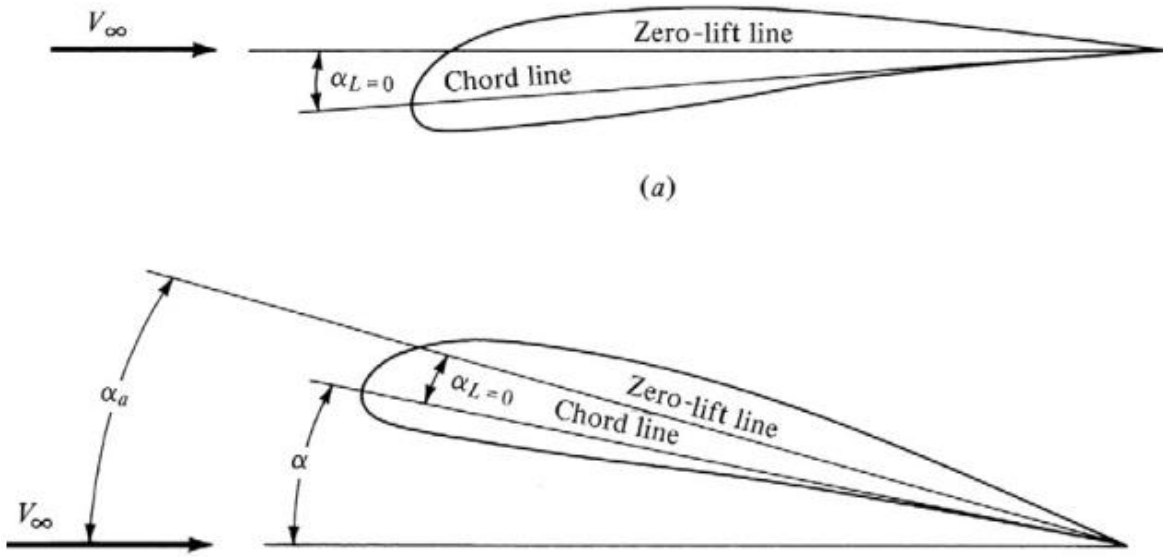

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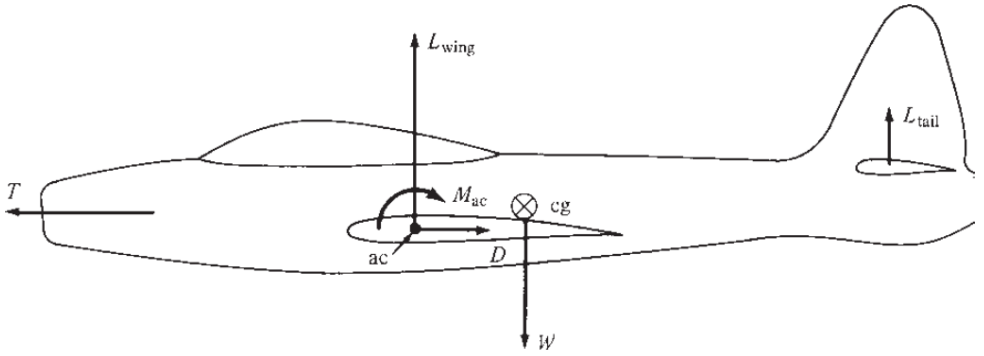
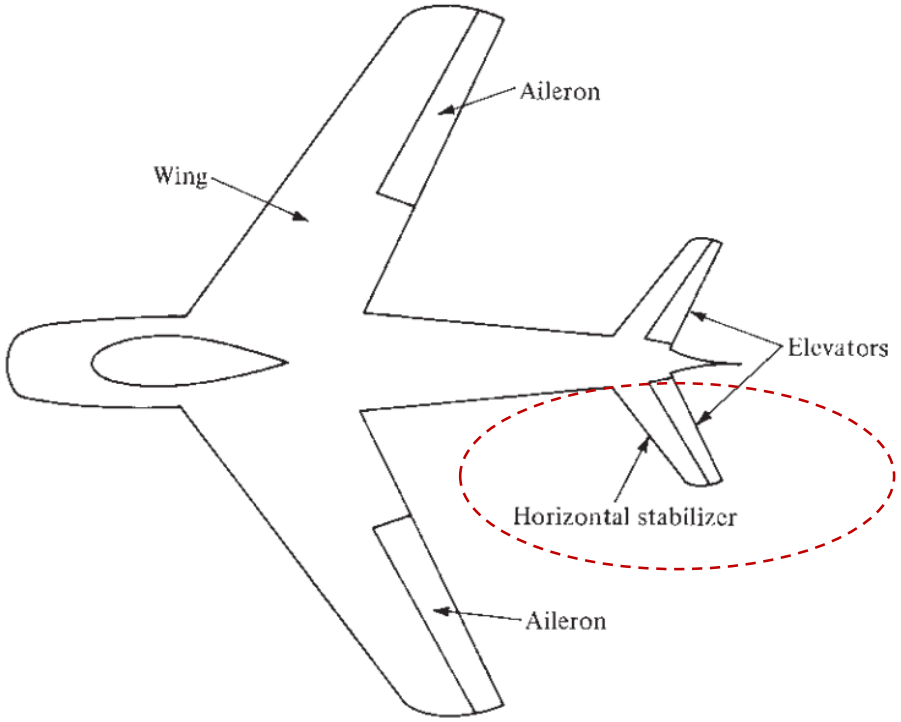


# Static stability

Horizontal stabilizer



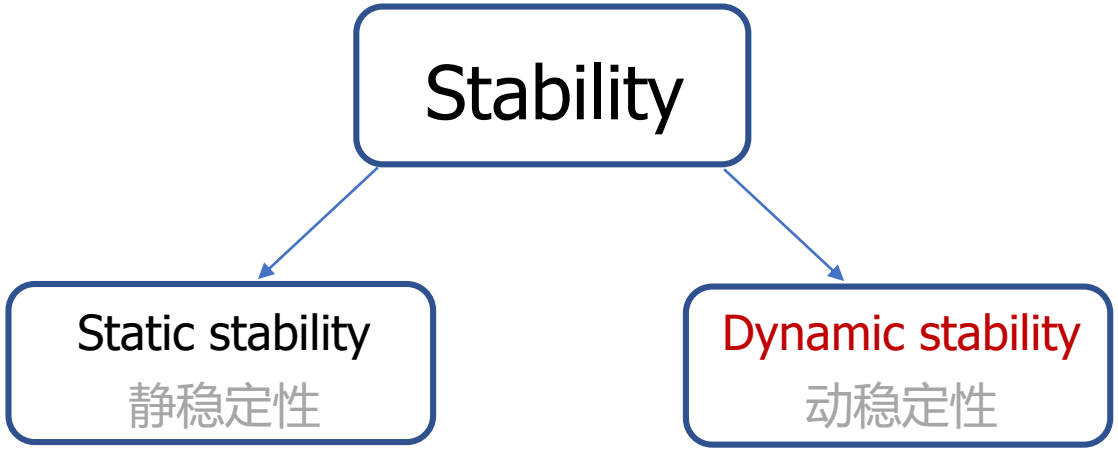
# Static stability

Summary

- Longitudinal Static Stability
- Lateral Static Stability
- Directional Static Stability

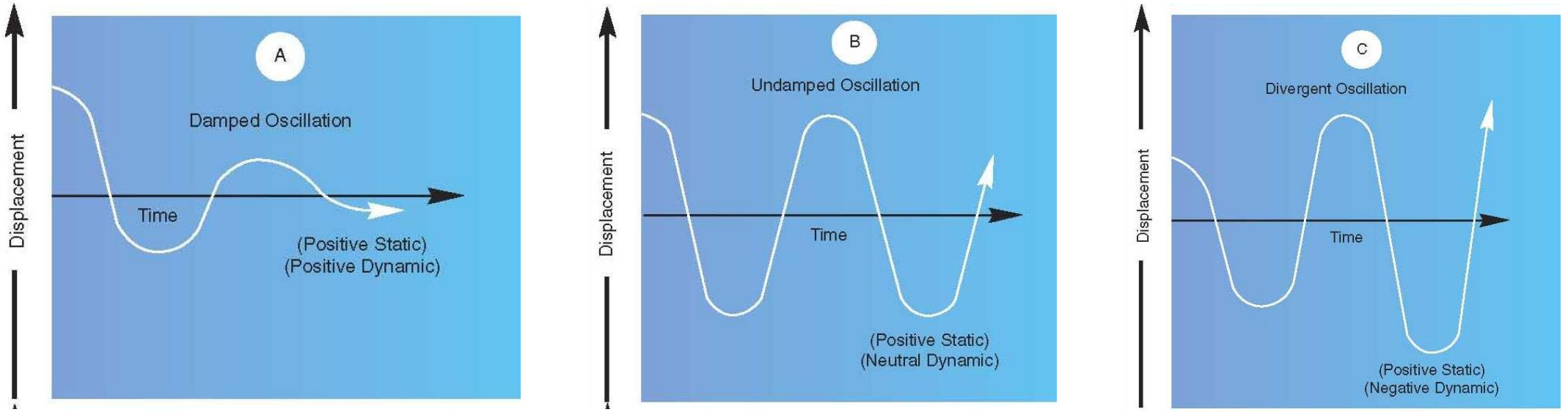
# Stability

Dynamic stability



# Dynamic stability

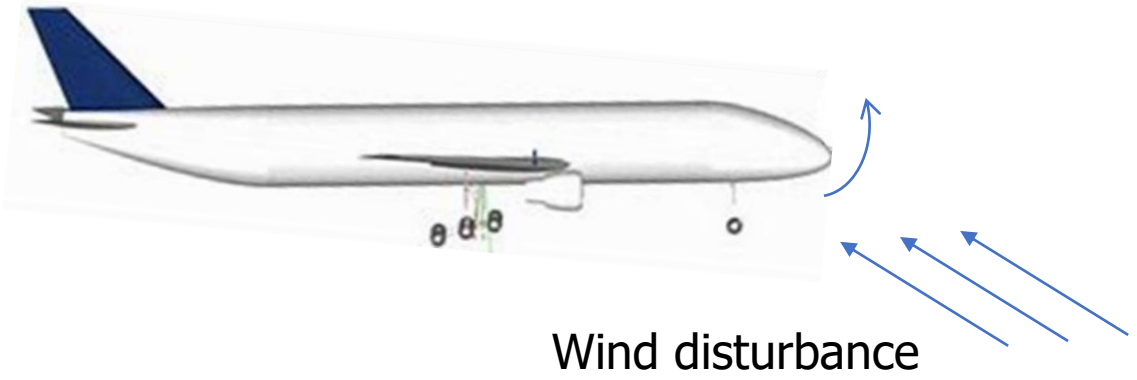
## Definition




Dynamic stability: response of aircraft after subjected to disturbance over certain time period.

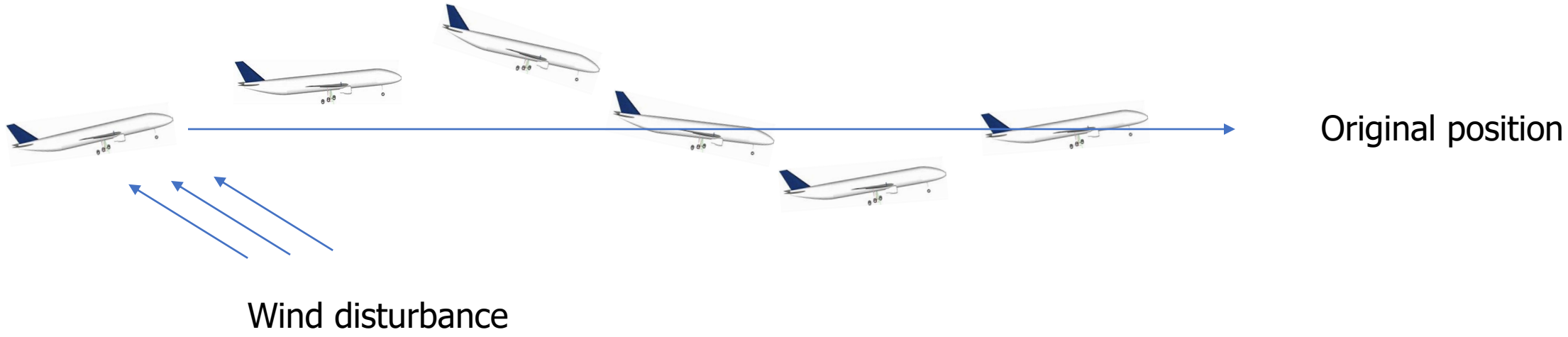
# Dynamic stability

## Longitudinal dynamic stability



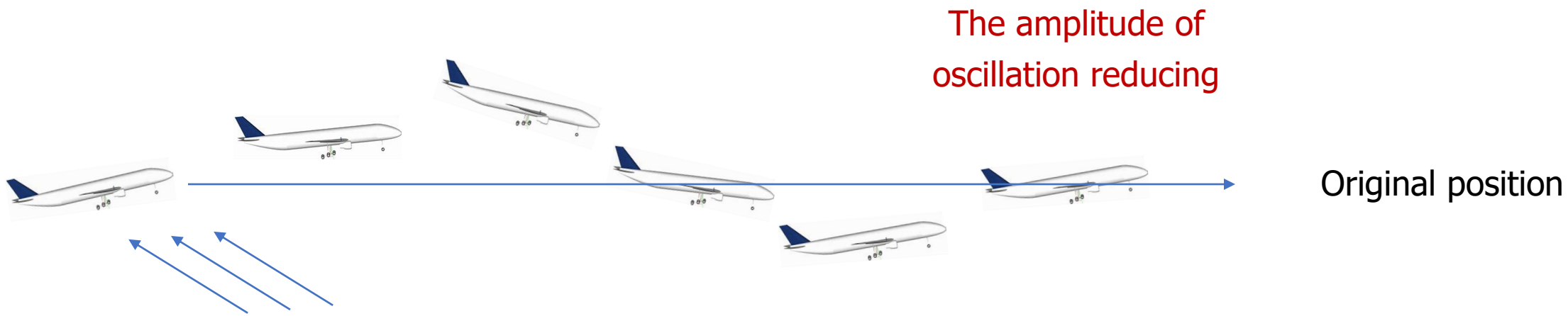
# Dynamic stability

## Longitudinal dynamic stability



# Dynamic stability

## Longitudinal dynamic stability

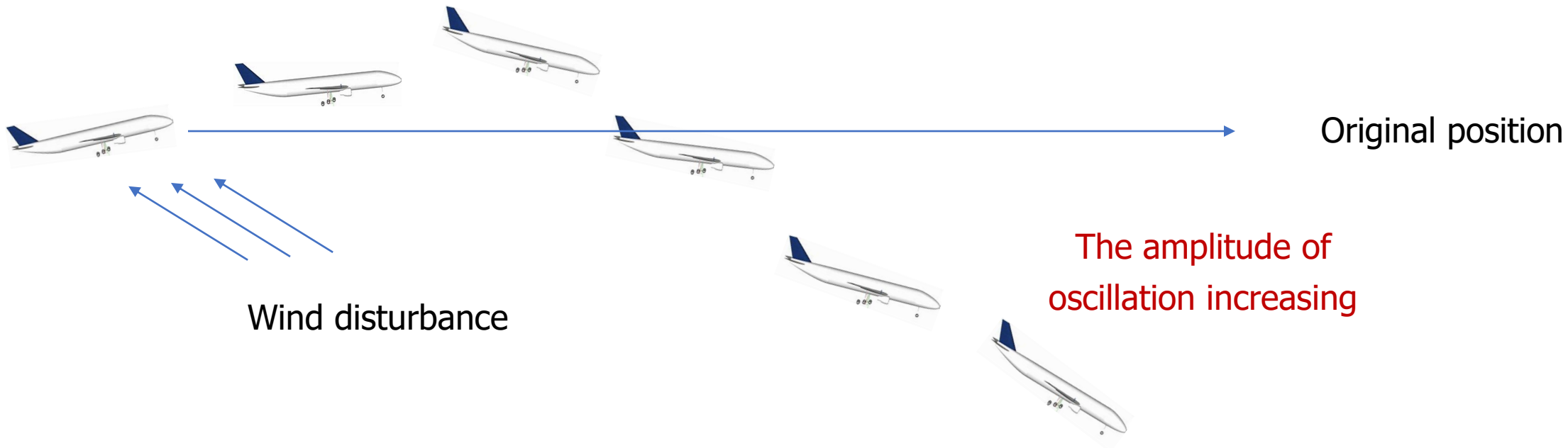



Positive dynamic stability

# Dynamic stability

## Longitudinal dynamic stability

Negative dynamic stability



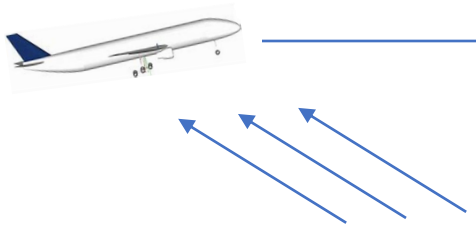
# Dynamic stability

## Longitudinal dynamic stability

Positive dynamic stability

negative dynamic stability

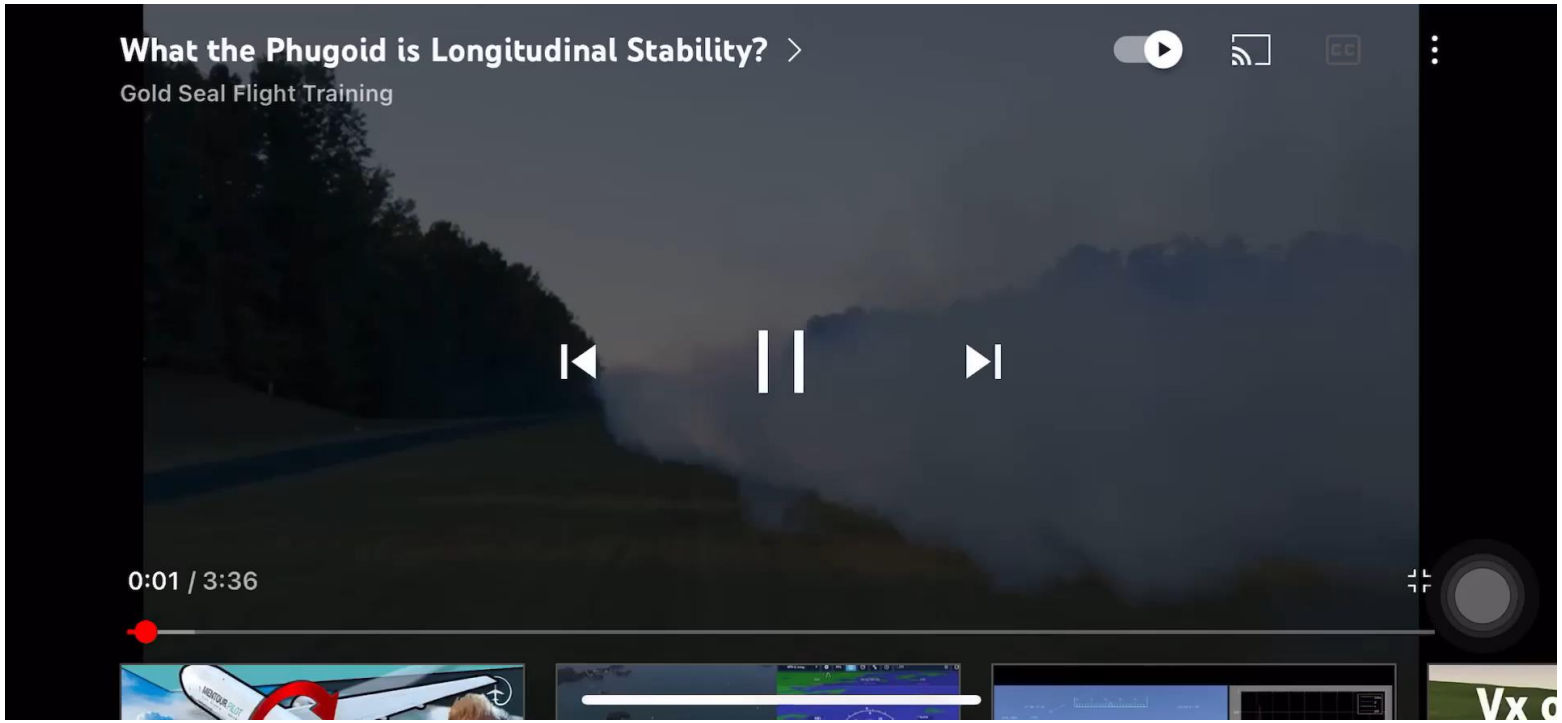
neutral dynamic stability



Original position

# Dynamic stability

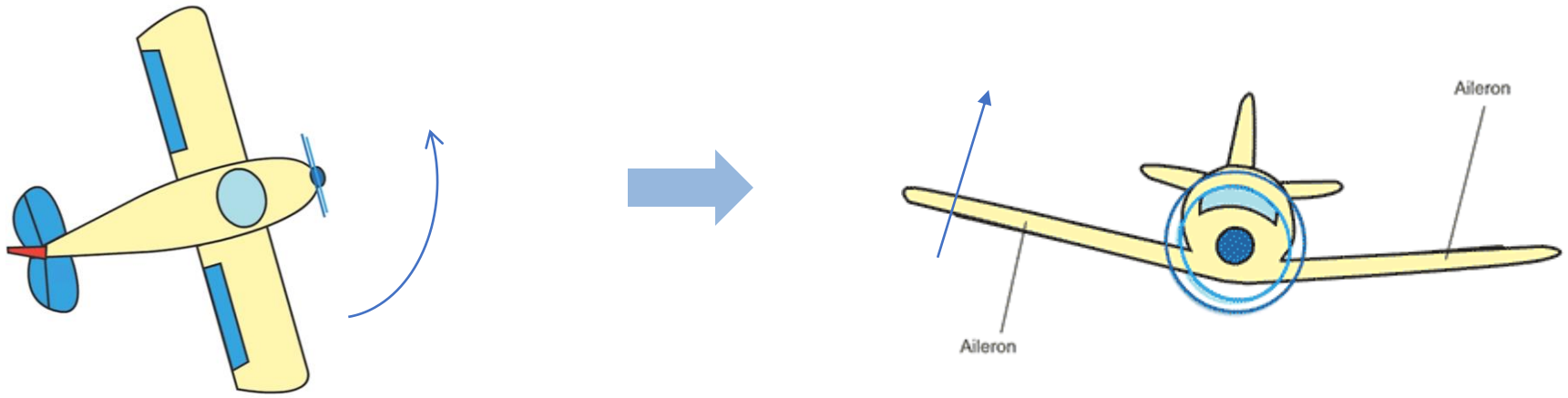
## Phugoid oscillation



# Dynamic stability

## Lateral/Directional stability

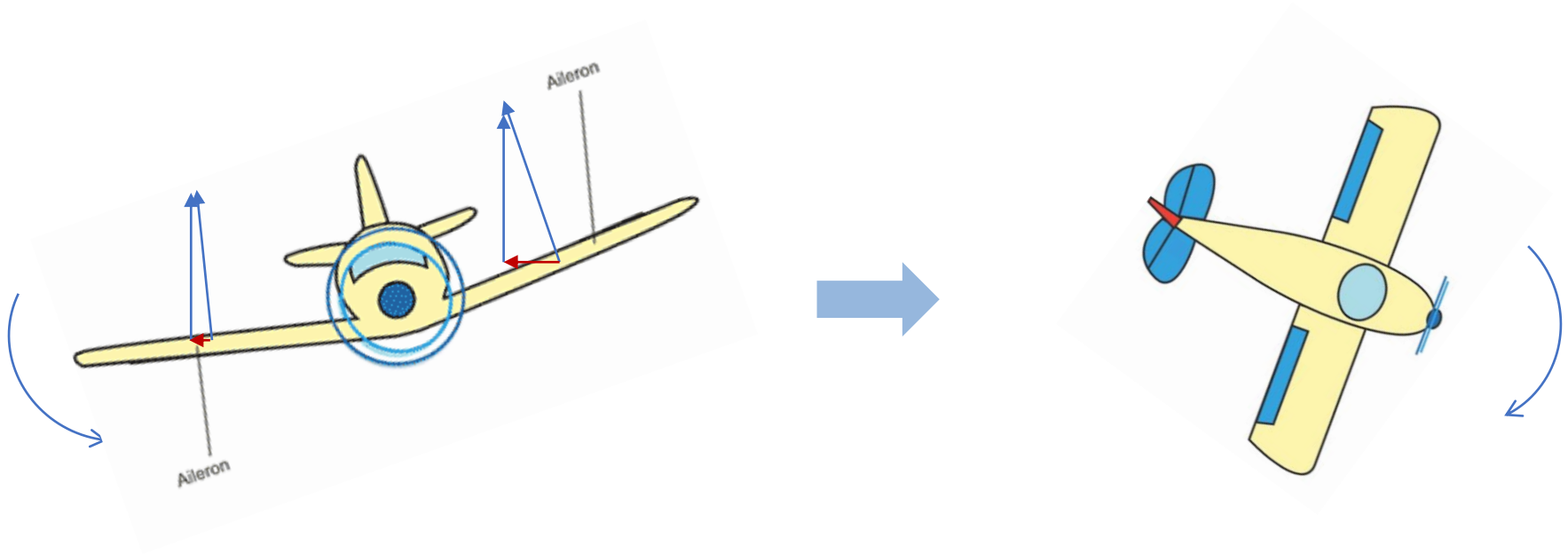
Roll & Yaw interconnected



# Dynamic stability

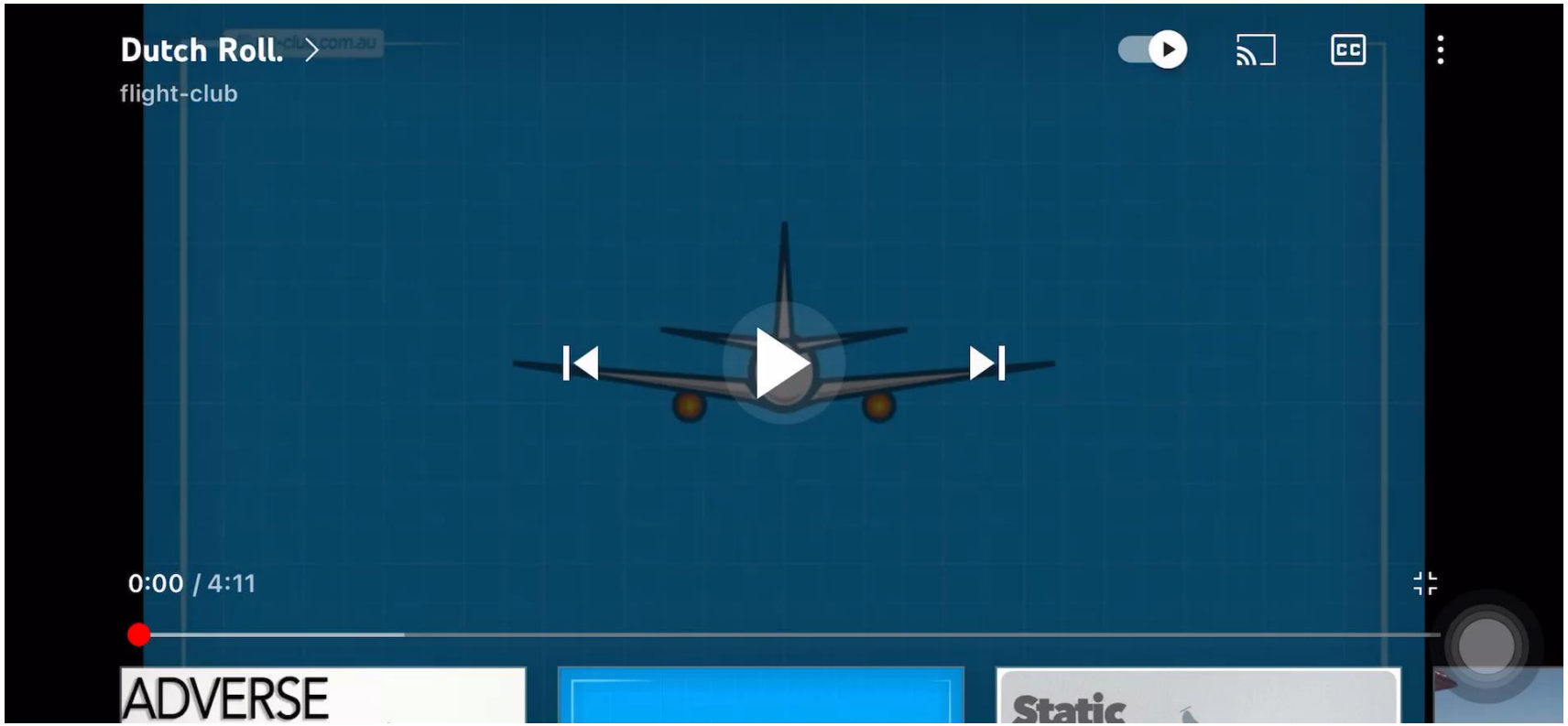
## Lateral/Directional stability

Roll & Yaw interconnected



# Dynamic stability

## Lateral/Directional stability



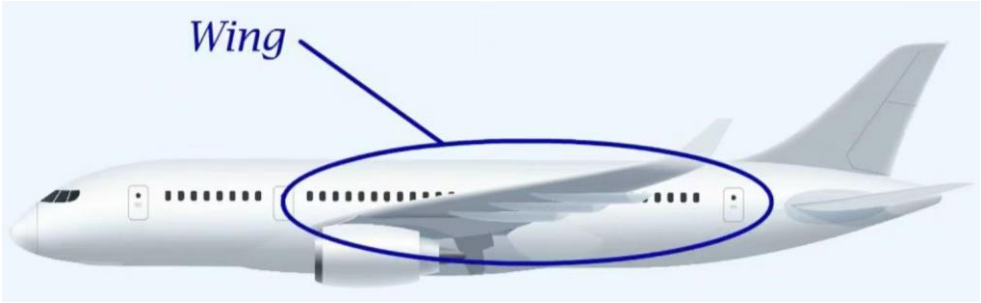
# Dynamic stability

Lateral/Directional stability

# Dynamic stability

How to improve dynamic stability ?

- Positive static stability
- Good wing design (e.g. swept back wing: 后掠翼)
- Good vertical and horizontal stabilizer




# Discussion

## Question

- What's the drawback of positive static stability ?

# Discussion

## Question

- What's the drawback of positive static stability ?

> *However, static stability has one disadvantage: the more stable the airplane, the harder it is to maneuver. An airplane that is highly stable is also sluggish in the air; its natural tendency to return to equilibrium somewhat defeats the purpose of the pilot to change its direction by means of control de-flections.*
>
> - J. D. Anderson

# Discussion

## Comments

- Innovation of Wright brothers:

> *The Wright brothers recognized this problem in 1900. Because Wilbur and Orville were airmen in the strictest meaning of the word, they aspired for quick and easy maneuverability. Therefore, they discarded the idea of inherent stability that was entrenched by Cayley and Penaud. Wilbur wrote that "we ... resolved to try a fundamentally different principle. We would arrange the machine so that it would not tend to right itself*