Aeronautics & Mechanics
AENG11301

Lecture 1: Aircraft Geometry

23/01/18

Dr Ben Woods

University of BRISTOL
DEPARTMENT OF aerospace engineering

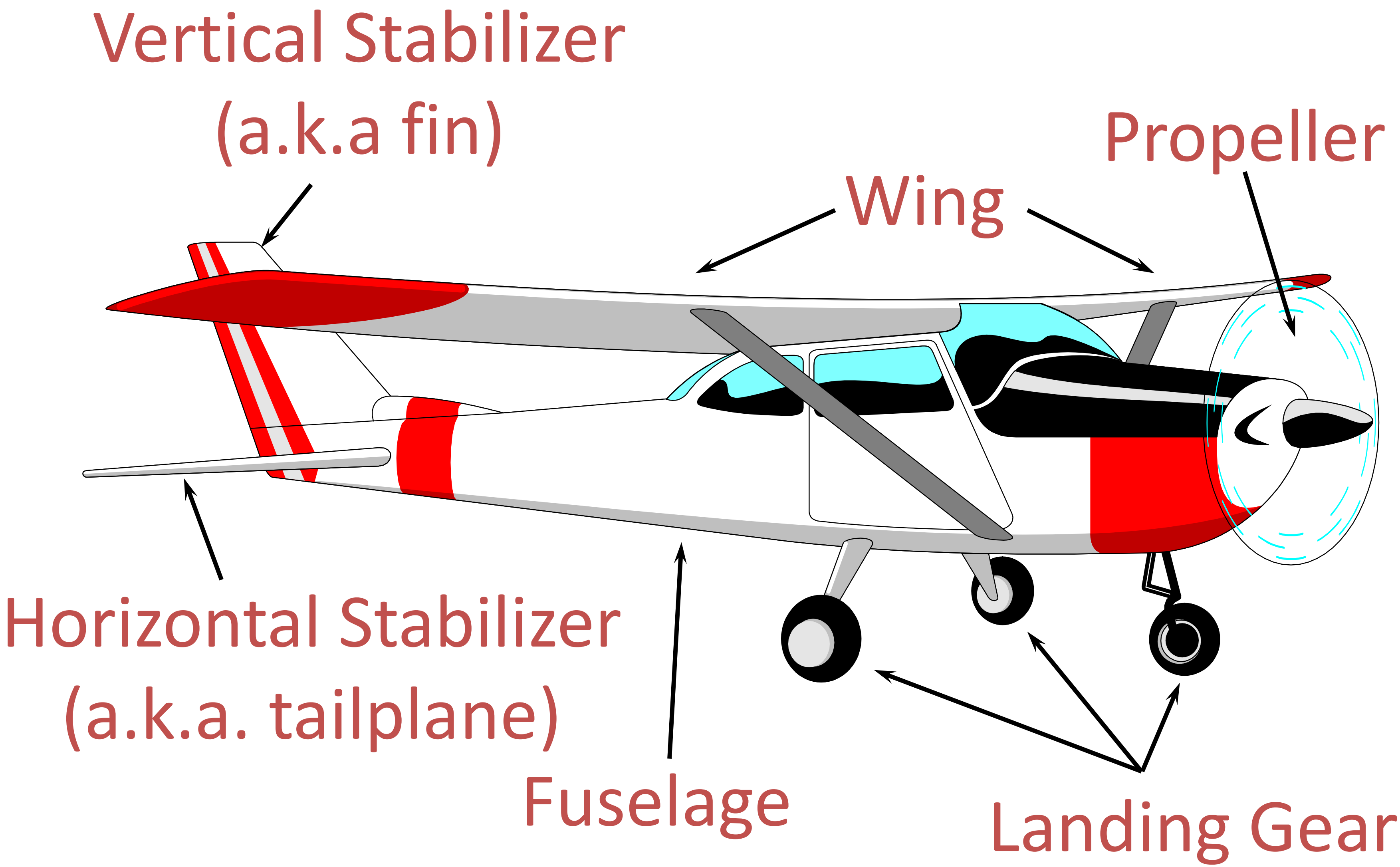
Outline for today

- Parts of an airplane
- Control surfaces and their effects
- Wing geometry
- Aerofoil geometry
- Tail geometry

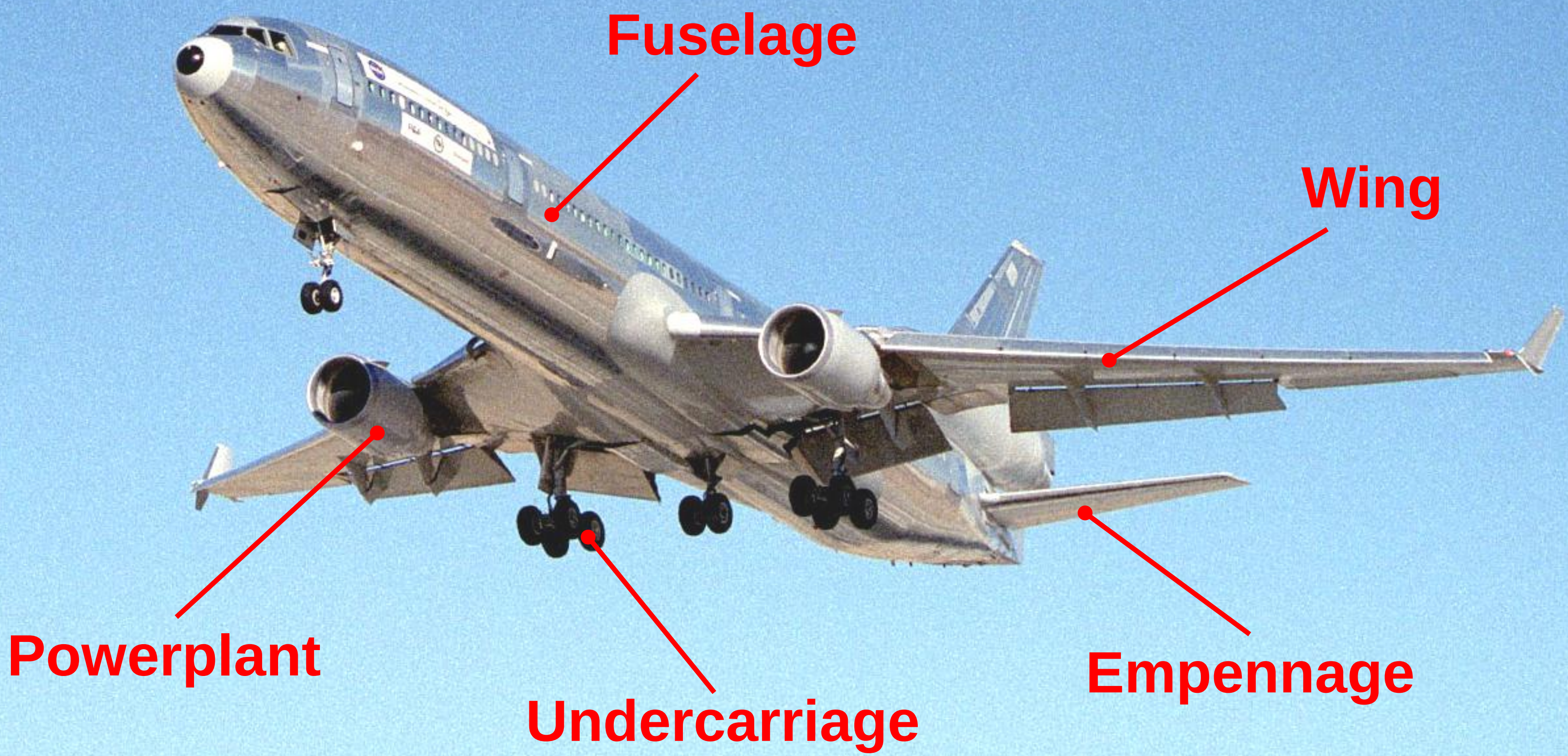
Aims for today

- To be able to identify the different components of an aircraft and to know their function
- To be able to define the different control surfaces and their function
- To appreciate the range of different geometries found across aircraft

Parts of an Airplane

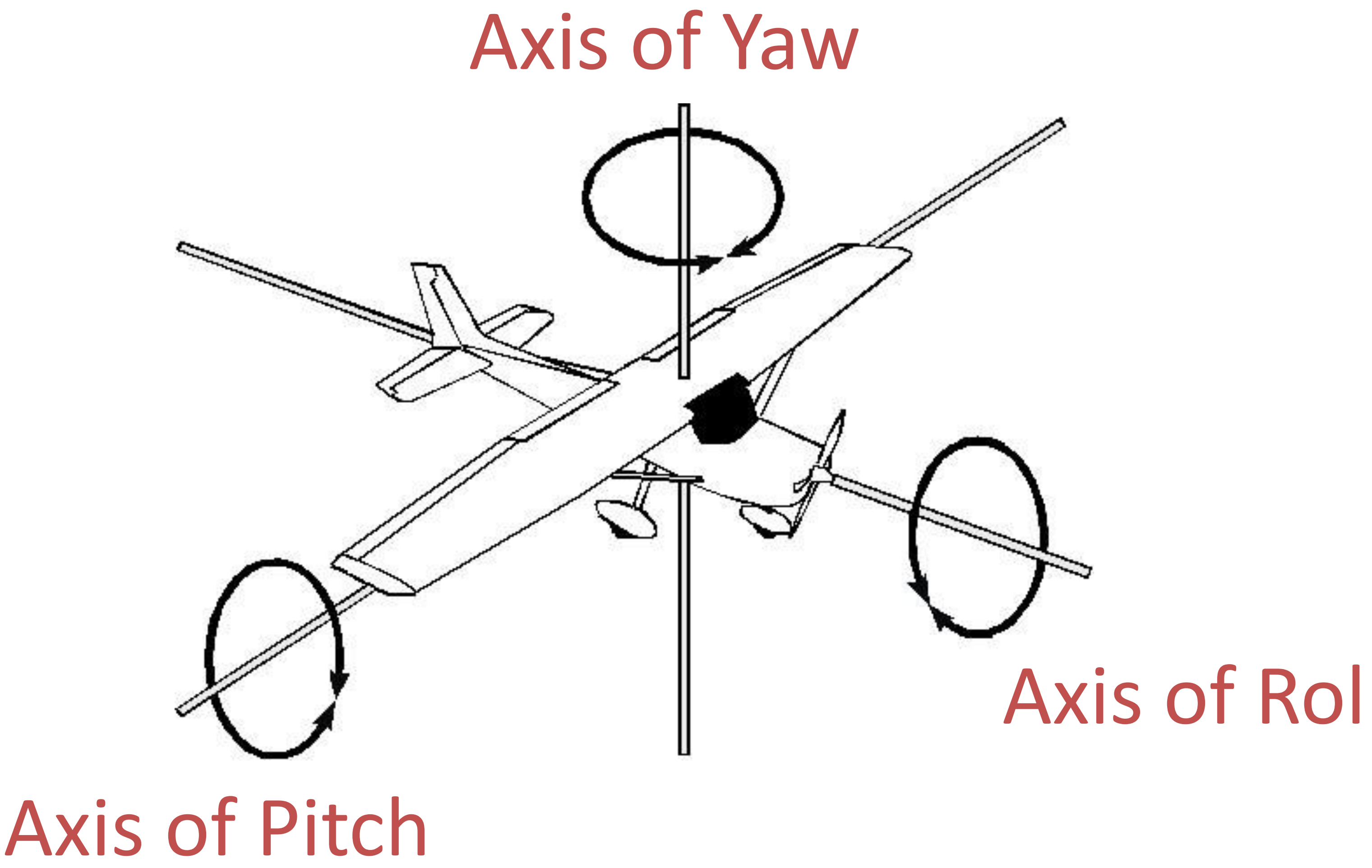


Main Components

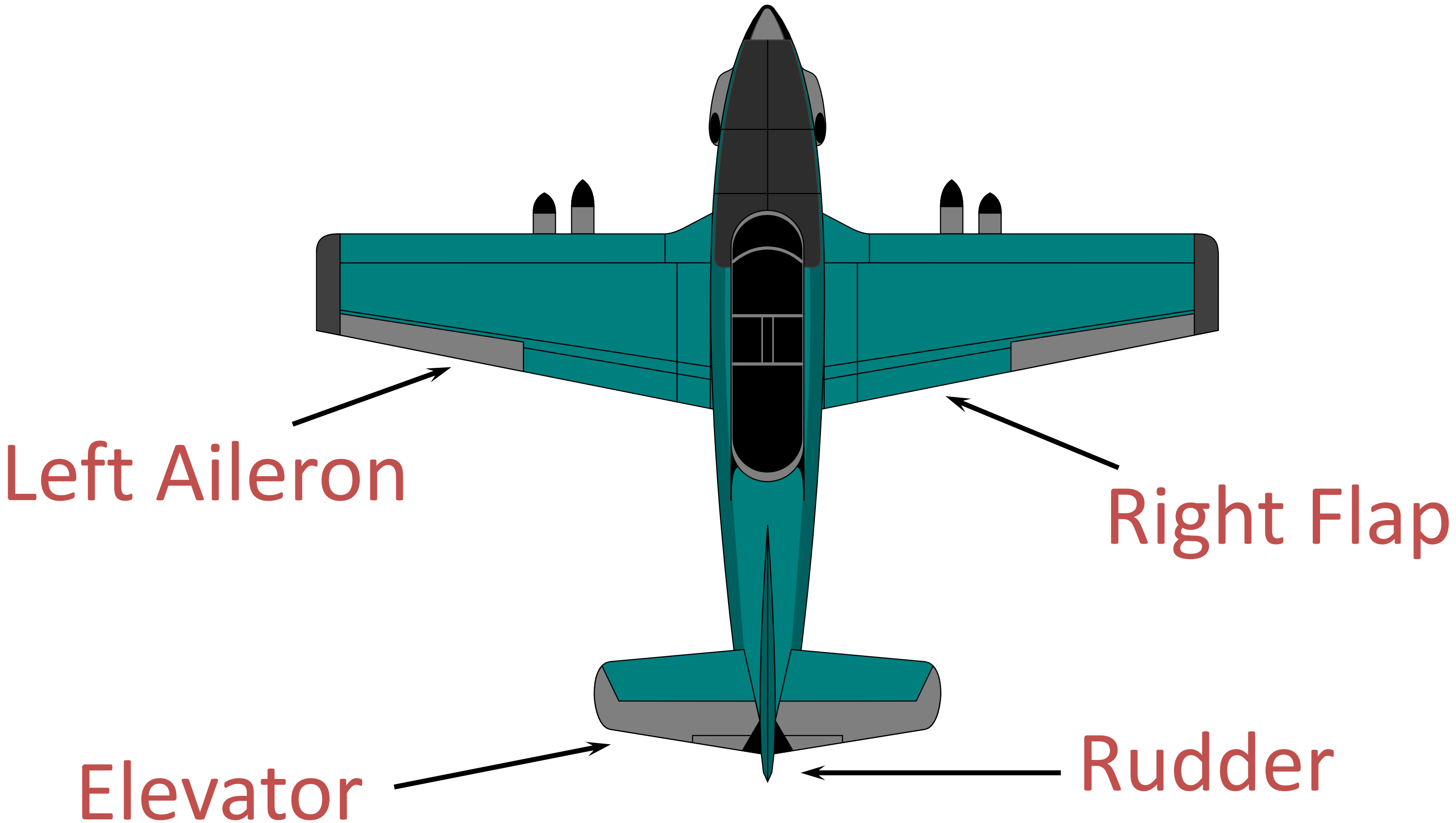


McDonnell-Douglas MD-11

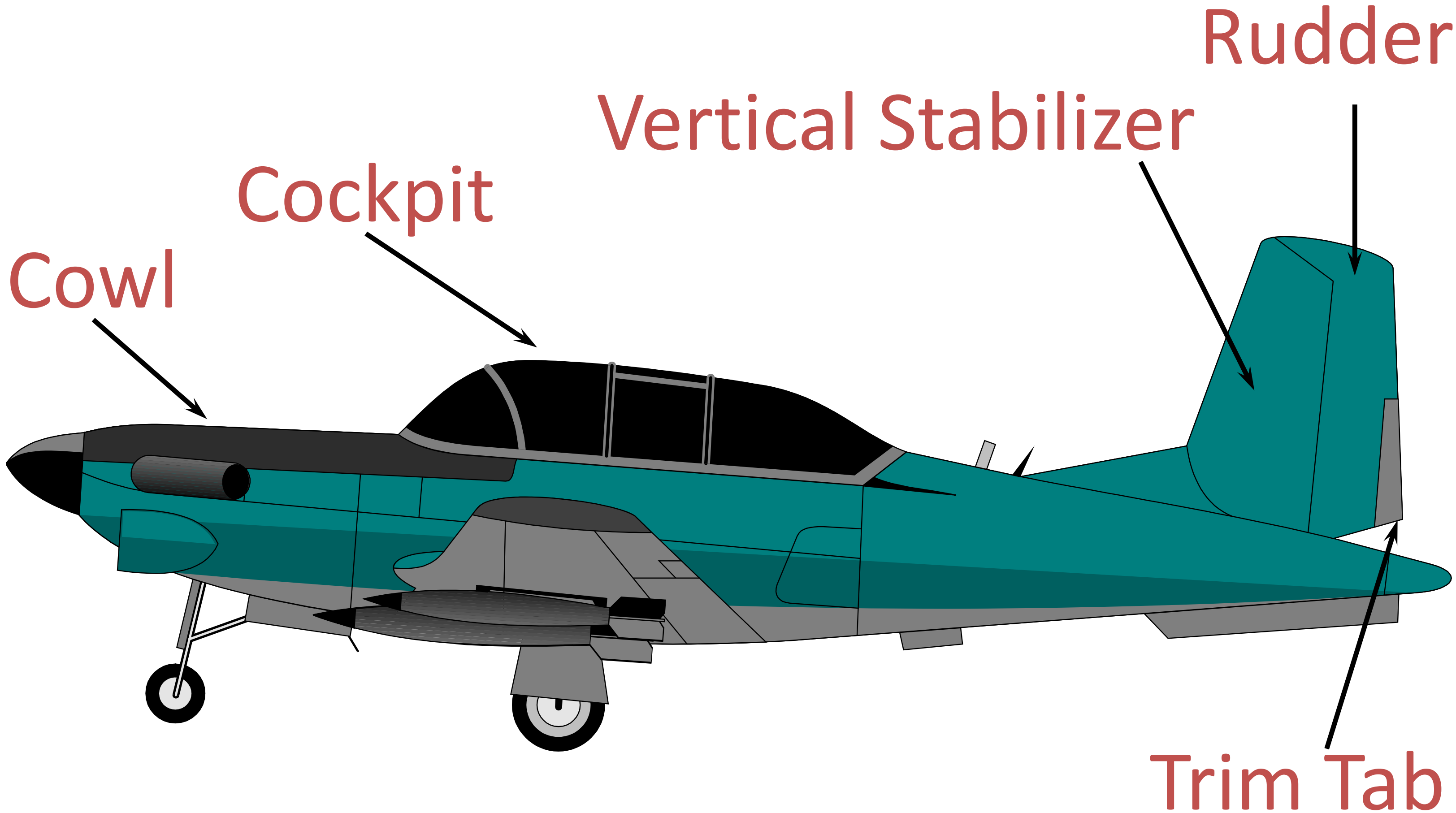
Axis of Rotation



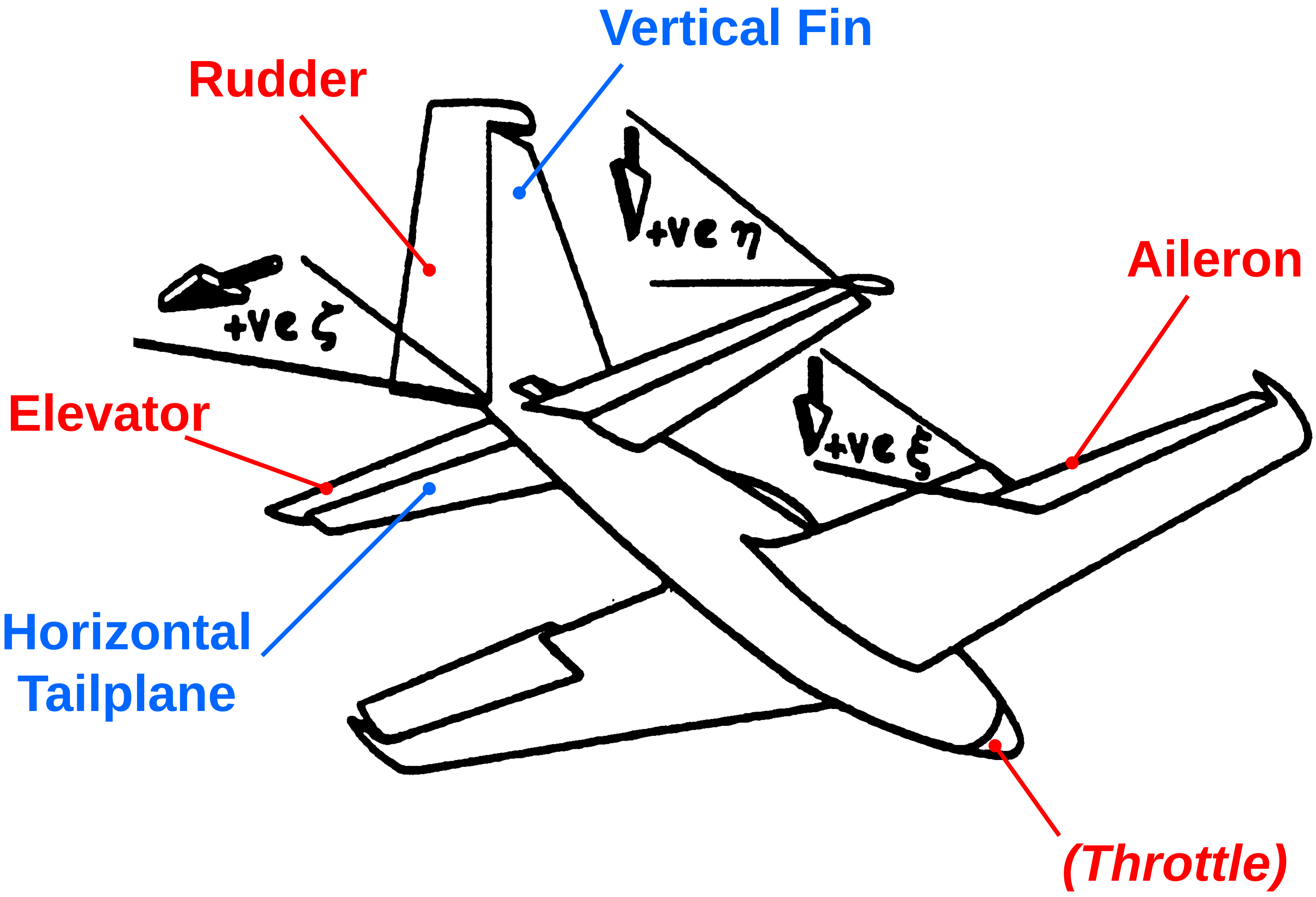
Control Surfaces



Another View



Basic Control Surfaces



Control Surface Effects

Basic three 'flapped' control surfaces generate moments:

elevator (η, δ_e) – **pitch** M (+ve 'nose up') $\rightarrow$ *pitch angle*

rudder (ζ , δ_r) – **yaw** N (+ve 'nose to right') $\rightarrow$ *yaw angle*

aileron (ξ , δ_a) – **roll** L (+ve 'right wing down') $\rightarrow$ *roll <u>rate</u>*

positive deflection gives *negative* moment (!)

Control Surface Effects

- all surfaces have **secondary effects**

1. elevator $\rightarrow$ *height & speed change*

– change in **angle of attack** = change in **lift** & **drag** & therefore change in **longitudinal** motion

2. rudder $\rightarrow$ *roll* due to **sideslip**

3. aileron $\rightarrow$ *yaw* due to **roll rate** & differential aileron drag

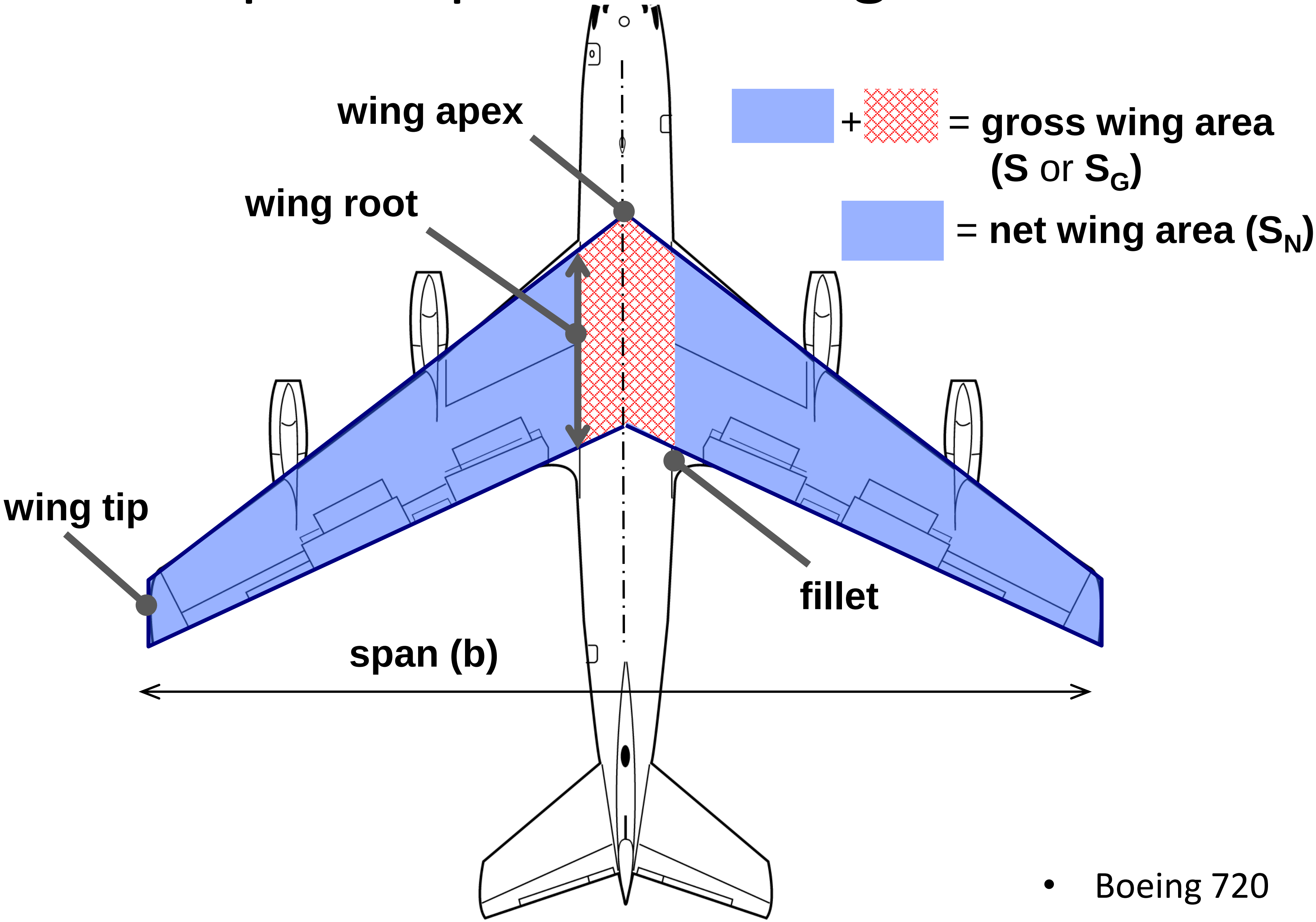
– complex effect of aircraft **lateral** motion

– very dependant on aircraft configuration

Wing geometry

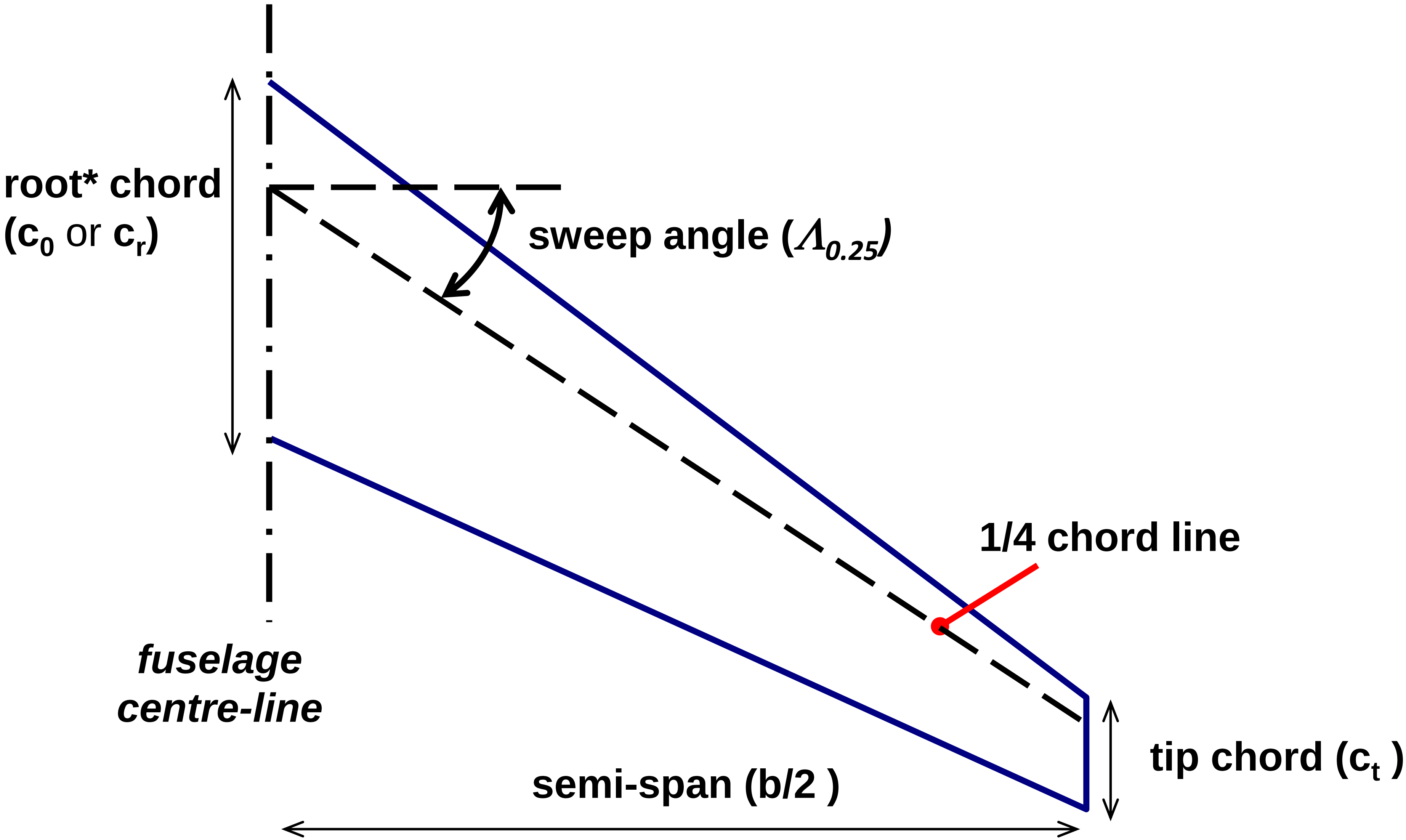
- Planform shape and area
- Trapezoidal wing parameters
- Wing position
- Number of wings
- Non-planar wings
- Variable geometry wings

Simple Trapezoidal Wing Planform



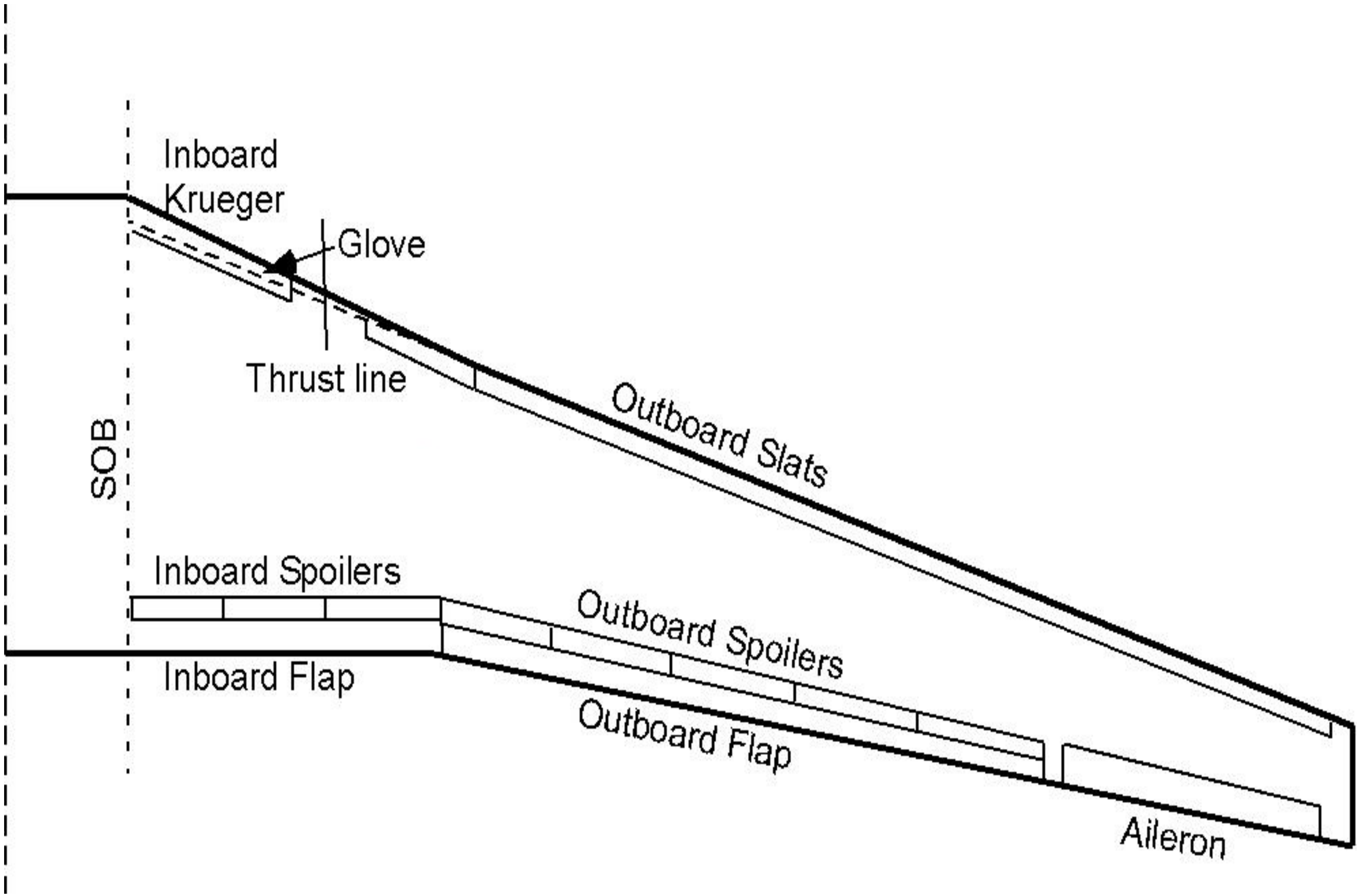
- Boeing 720

Simple Trapezoidal Wing Planform



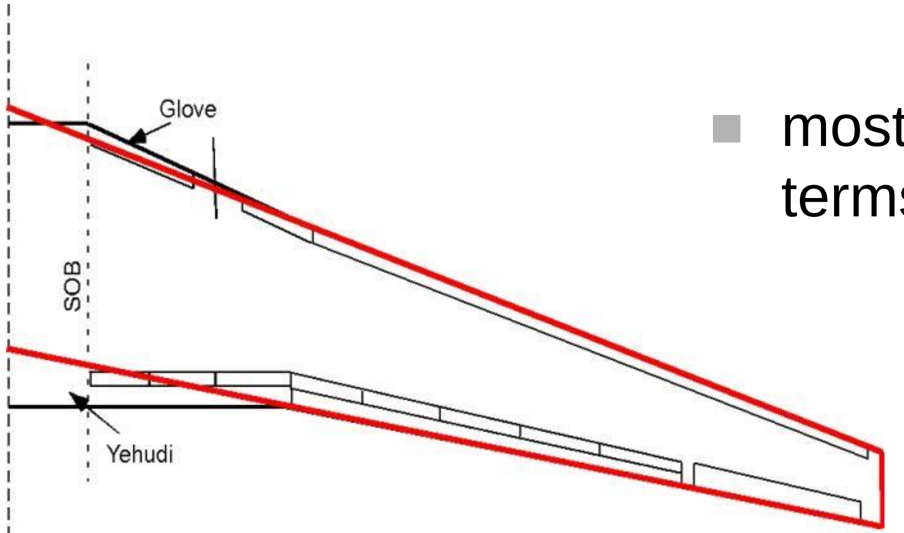
***despite name, usually defined on the centre-line!**

Typical Commercial Airliner Wing

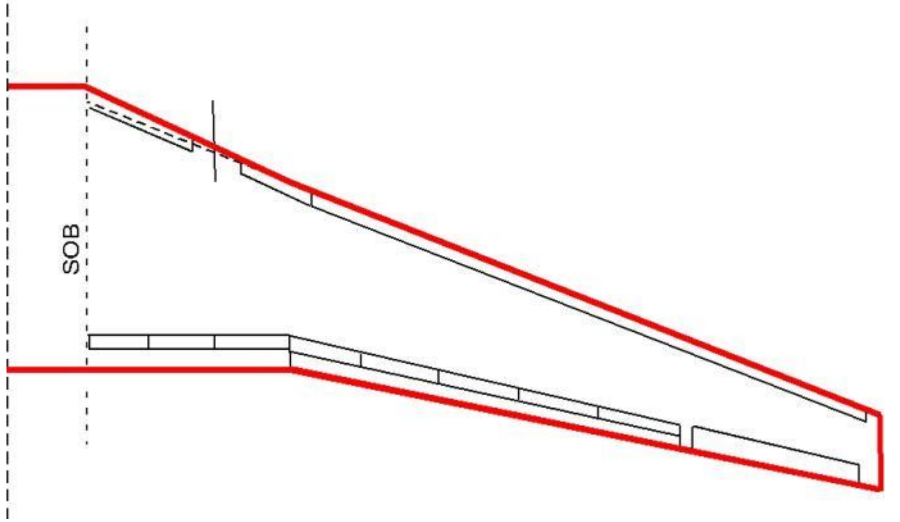


Reference Areas

- most wing parameters defined in terms of **Reference wing** (S_{ref})



Basic Trapezoidal



Airbus

Trapezoidal Wing Parameters

- wing **taper ratio**

$$\lambda = \frac{c_t}{c_r}$$

- **standard mean chord (SMC)** (or geometric mean chord)

$$\bar{c} = \frac{S}{b}$$

- aerodynamic shape of wing defined by its **Aspect Ratio**

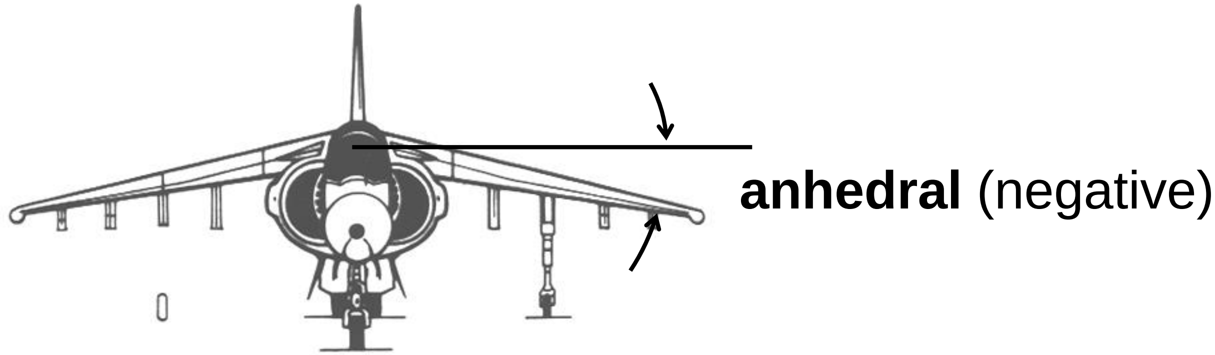
$$AR = \frac{b}{\bar{c}} = \frac{b^2}{S}$$

- **mean aerodynamic chord (MAC)**

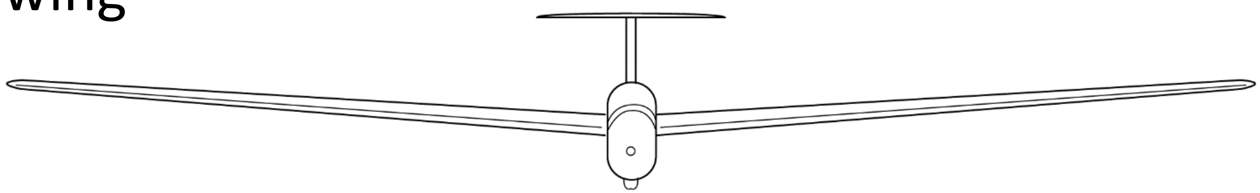
$$\bar{\bar{c}} = \frac{1}{S}\int_{-b/2}^{+b/2} c^2(y)\,dy$$

Wing Position

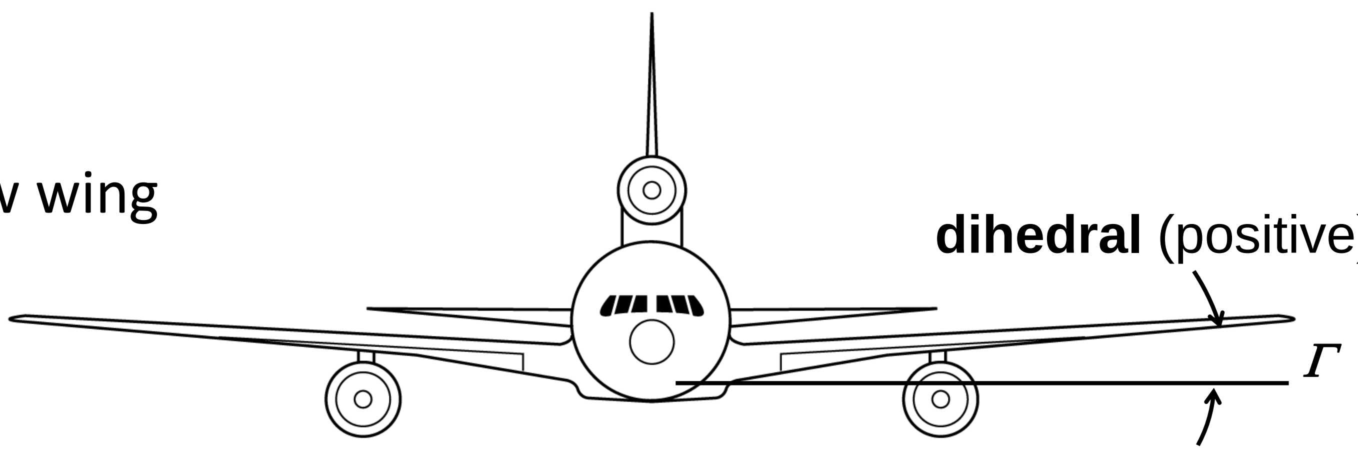
high wing



mid wing

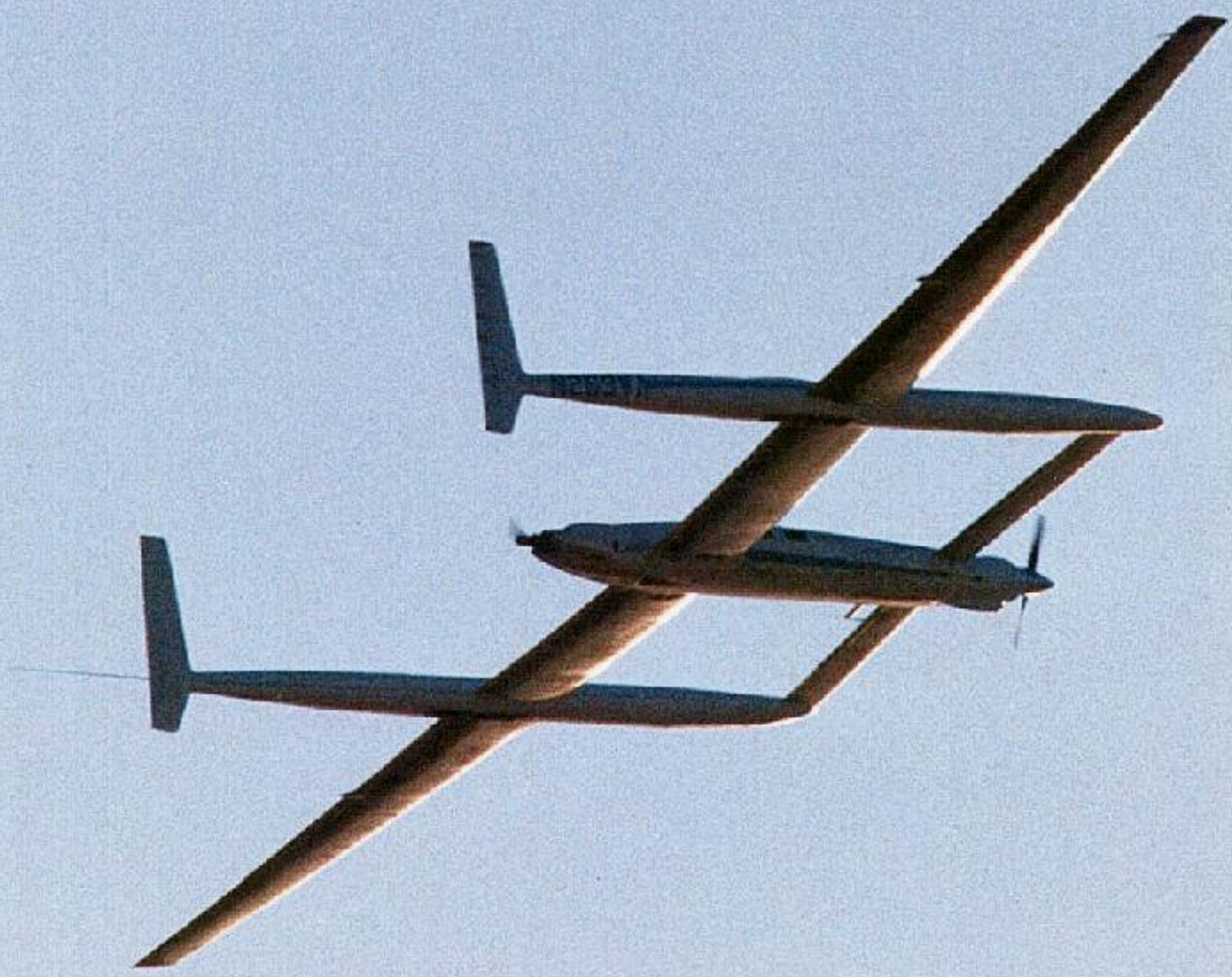


low wing



Examples!

Very High AR – Round-the-World Flight



- Voyager
- Designed by Burt Rutan
- AR = 34

High AR + Sweep – Airliner

- Airbus A350
- AR = 9.5

Medium AR – Subsonic

Spitfire: AR = 5.6

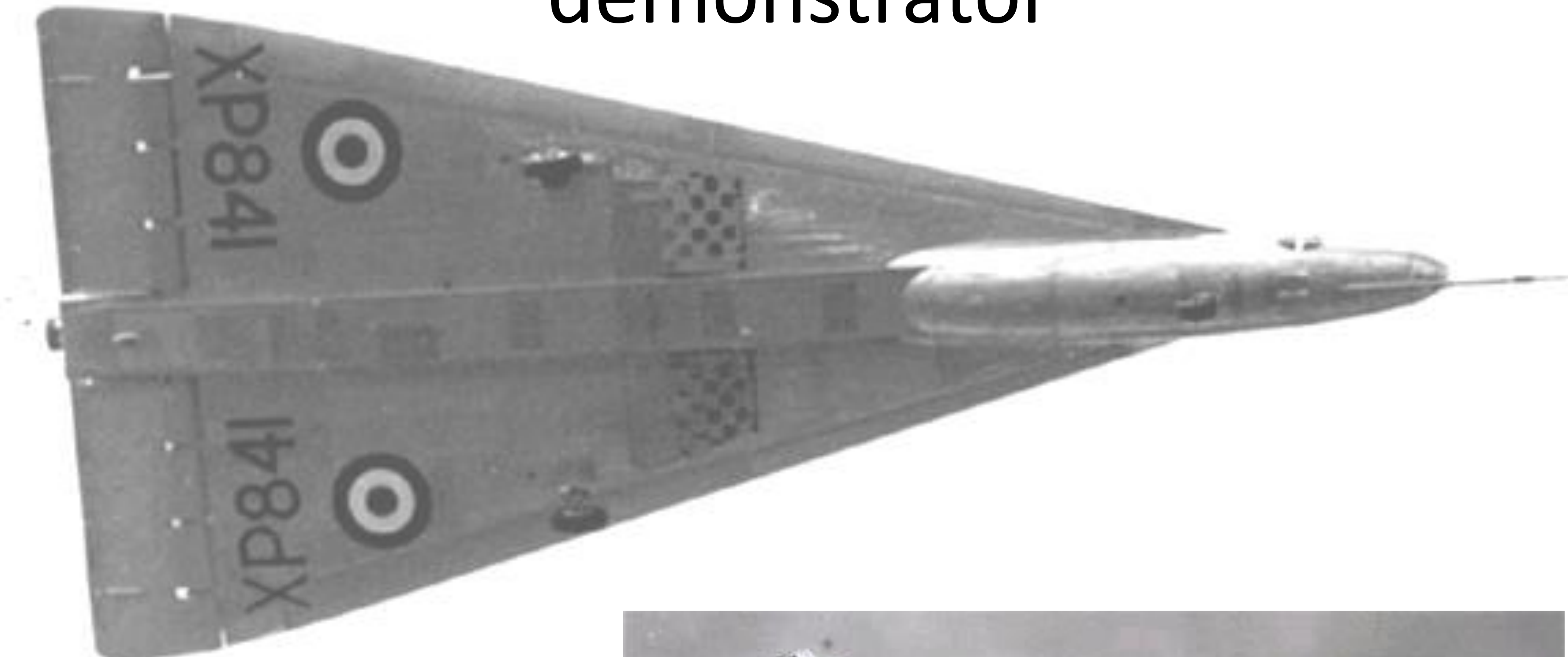
Sea Fury: AR = 5.26

Very Low AR – Mach 2+

(and ridiculously small area)

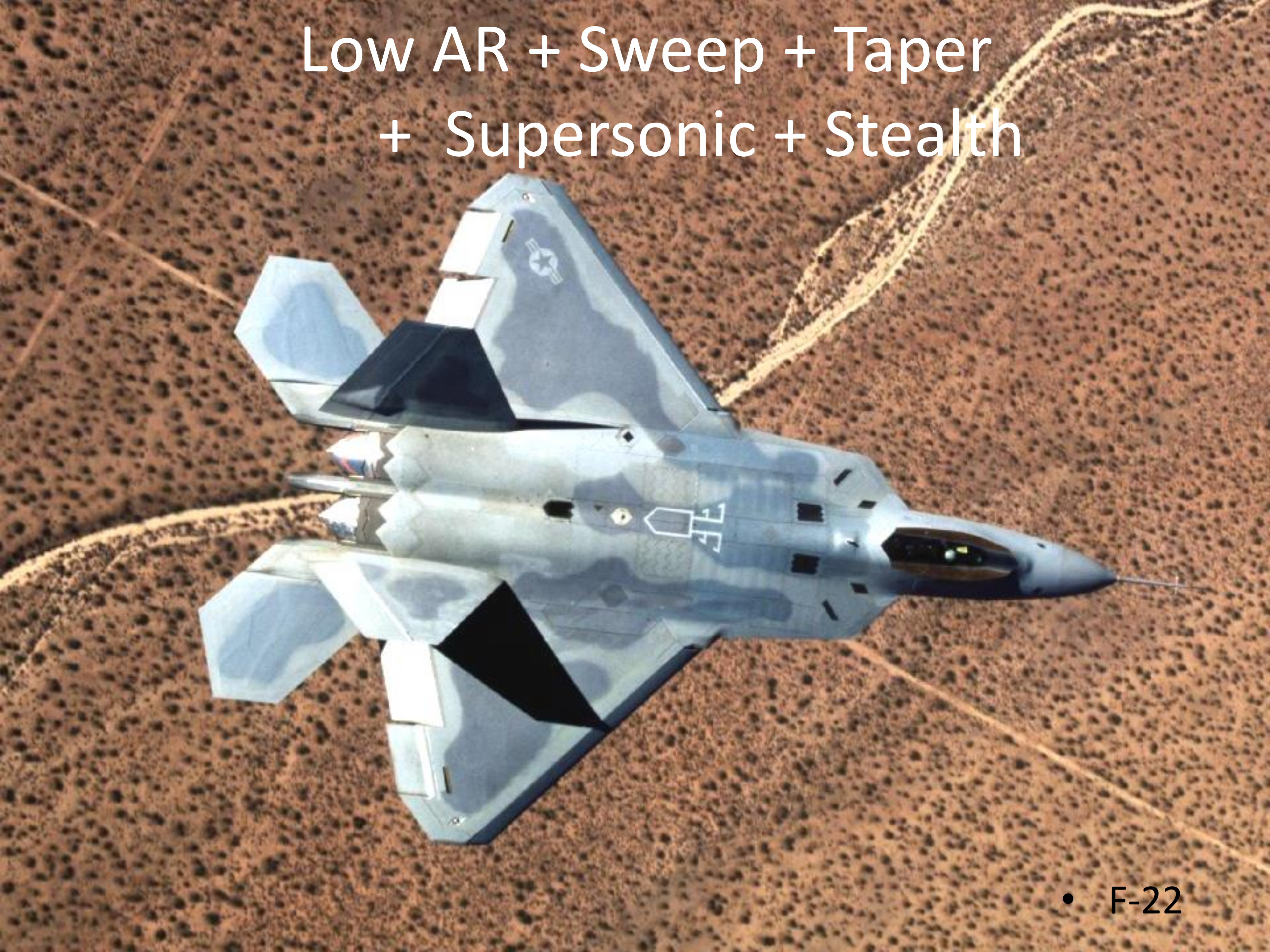
- F-104 Starfighter
- AR = 2.45

Very Very Low AR – SST demonstrator



- Handley Page HP-115
- AR = 0.9!
- Built to test delta wings at low speed… (e.g. Concorde)

Low AR + Sweep + Taper + Supersonic + Stealth



- F-22

Non-Trapezoidal Wing Planforms


Crescent (Victor)


Lambda (B2)


Ogee (Concorde)


Leading-edge extension (F-18)

Non-Planar Wings

Ring wing
(Coléoptère)

Winglets (Learjet 60)

Folding wing tip (XB-70)

Multiple Wings

Biplane (Boeing Stearman)

Sopwith Triplane

Tandem Wing (Proteus)

Box-Wing

Variable Geometry - Sweep

Tornado

Variable sweep

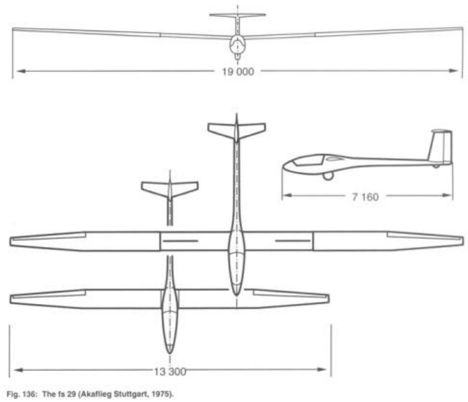
F-14

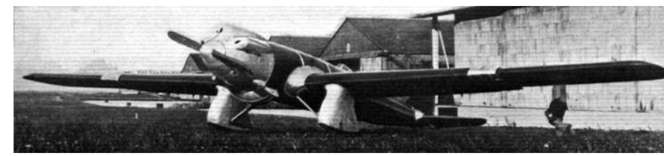
B-1B

Oblique wing (NASA AD-1)

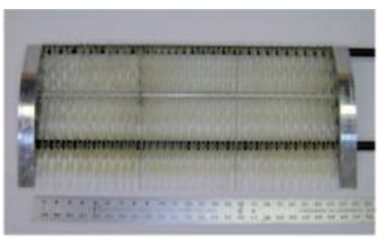
Variable Geometry - Span

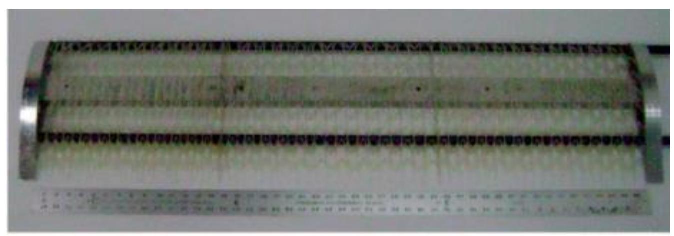
FS-29 (1972)

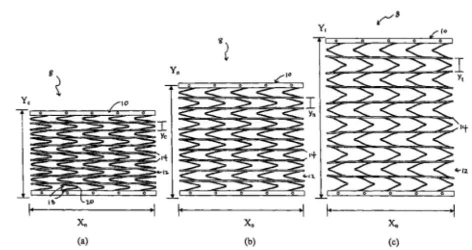


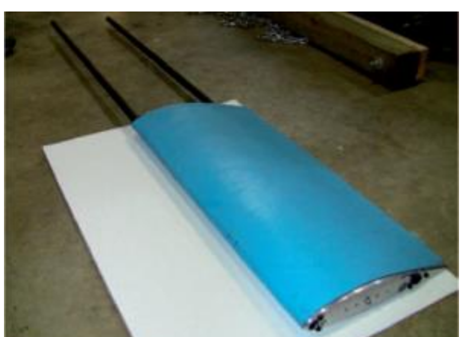


MAK-10 (1931)









Vocke, Kothera, Woods and Wereley (2011)

And one I worked on:

- 100% increase in span/area
- Patented MorphCore honeycomb
- Elastomeric Matric Composite skin

Tail Unit (Empennage)

- provides **stability** and **control** functions
- usually mounted at rear of fuselage – **aft-tail**
  - occasionally mounted at front – **foreplane** or **canard**
  - very rarely have both – **three-surface** configuration
- lateral stability provided by **fin**
  - also known as **vertical stabiliser**
  - may have multiple fins (rare on civil aircraft now)
- longitudinal stability provided by **tail-plane**
  - also known as **horizontal stabiliser**
  - usually mounted below fin, but can be at top – **T-tail**
- **V-tail** on some older aircraft (and on stealth configurations)
- flying wing aircraft dispense with tail-plane
  - but often retain vertical fin

Tail Units

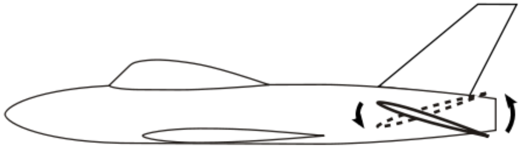
Canard Foreplane (X-29)

T tail (BAe 146)

V-tail (Beechcraft Bonanza)

3-Surface (AFTI F-15)

All-moving tail surfaces

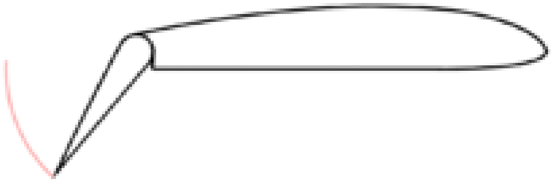


- move entire surface rather than flaps – e.g. (F16, Tornado)
- common on high-speed aircraft (X-1)

F16: all-moving tailplane

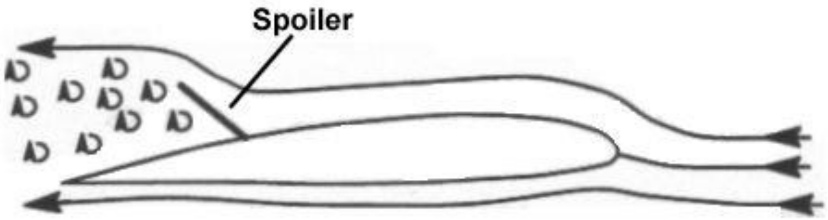
X-15: all moving tailplane and fin
(also… max speed – Mach 6.7 = 4,520 mph!)

Flaps



- increase camber to increase lift
- use for take-off & landing, allow optimisation of cruise performance

Spoilers



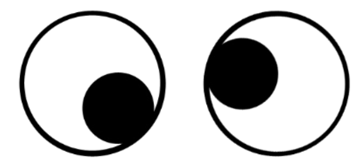
- also known as speed brakes or air brakes
- increase drag and/or reduce lift
- reduce landing distance, roll control at high speed

B-52 uses “spoilerons” for roll control

Thrust vectoring

– generate moments by changing thrust direction (Su-35, F-22, F-35)

MiG-29



Googly eyes!


FF

Vertol VZ-2


AND NOW FOR
SOMETHING
COMPLETELY
DIFFERENT


NAVY
ARMY
NASA
ARMY
VERTOL
NAVY
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Summary

- Large number of technical terms used to describe an aircraft's geometry
- Ailerons control roll rate
- Elevator control pitch angle
- Rudder control yaw angle
- There are a large range of different aircraft geometries, with each aircraft being designed to meet a certain set of requirements.

Follow-up materials

- Introduction to Flight – 2.6
- Understanding Flight – Chapter 2