Chapter 4

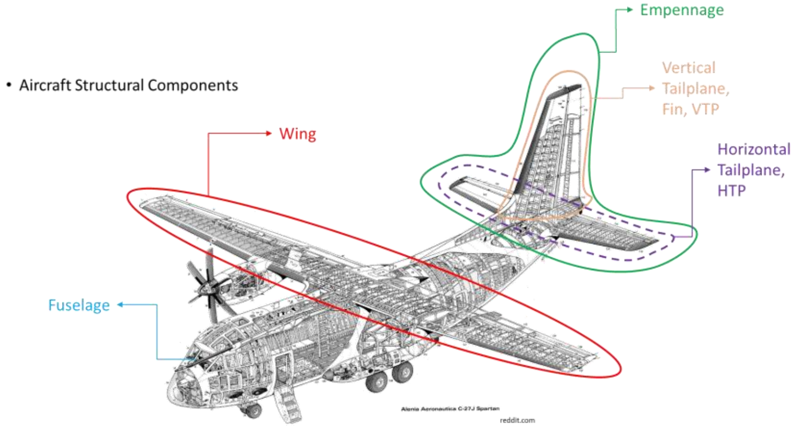
Structure Concepts

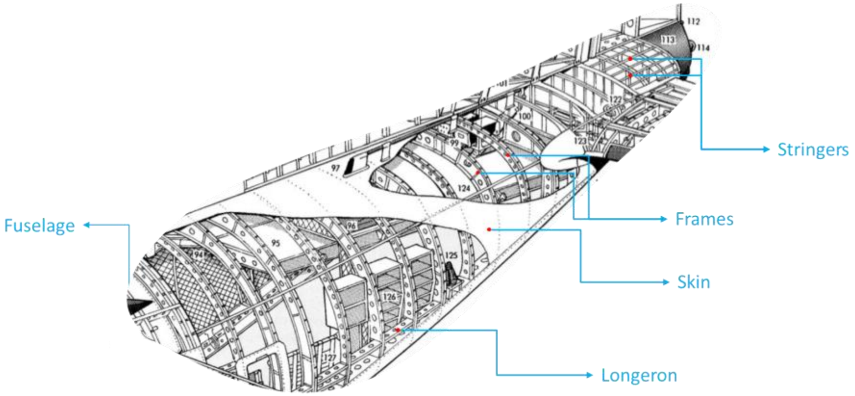
Content

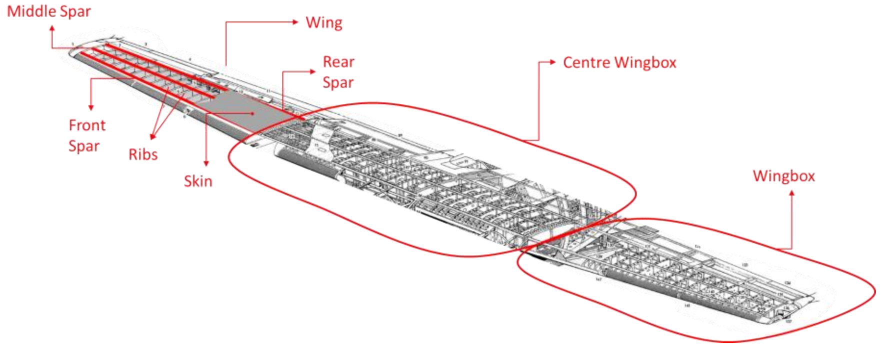
- Definition of structure concept
- Load carrying behaviour: what supports which component
- Load paths – the Stick Model
- Torsion box
- Stiffened panel
- Sandwich
- Major interfaces

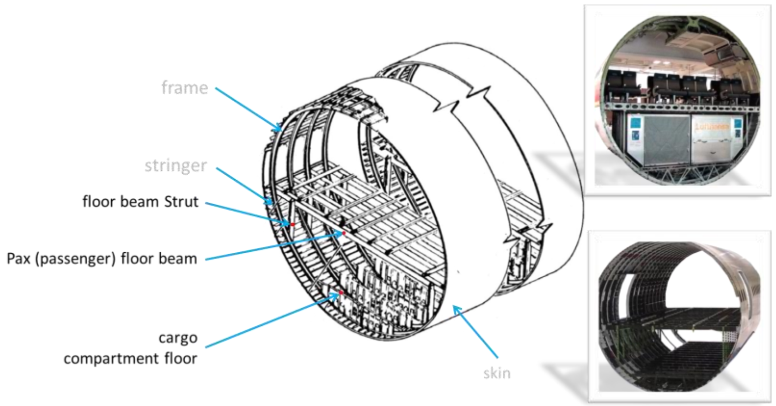
Aerospace Structure Elements - Recap

Aircraft Structures









Aerospace Structure Concept

What is a structure concept?

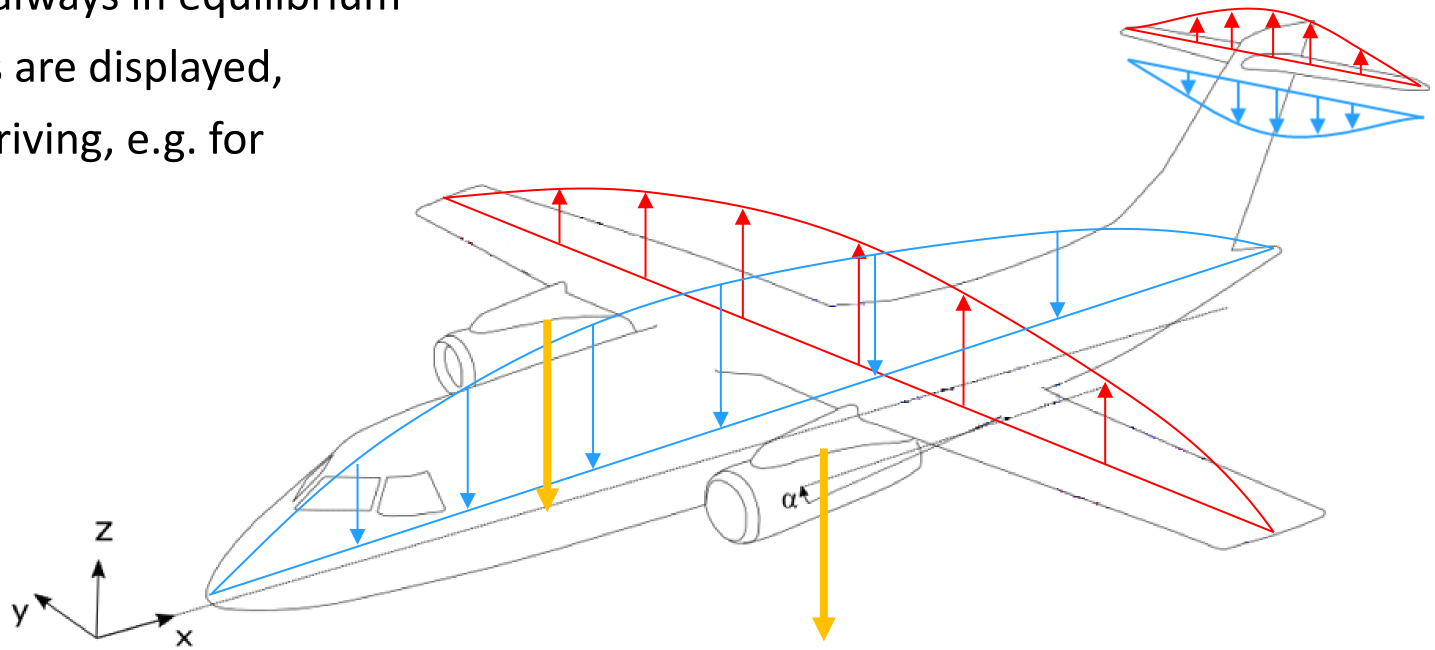
The structure concept is an umbrella term covering

- The load paths along the structure
- The position of load carrying elements:
  - Skin, Stringers, Spars, Frames, Ribs, Longerons, etc.
- Interfaces between the different components
- If relevant – material selection
- If relevant – constructive details related to the manufacturing technology

Load Paths

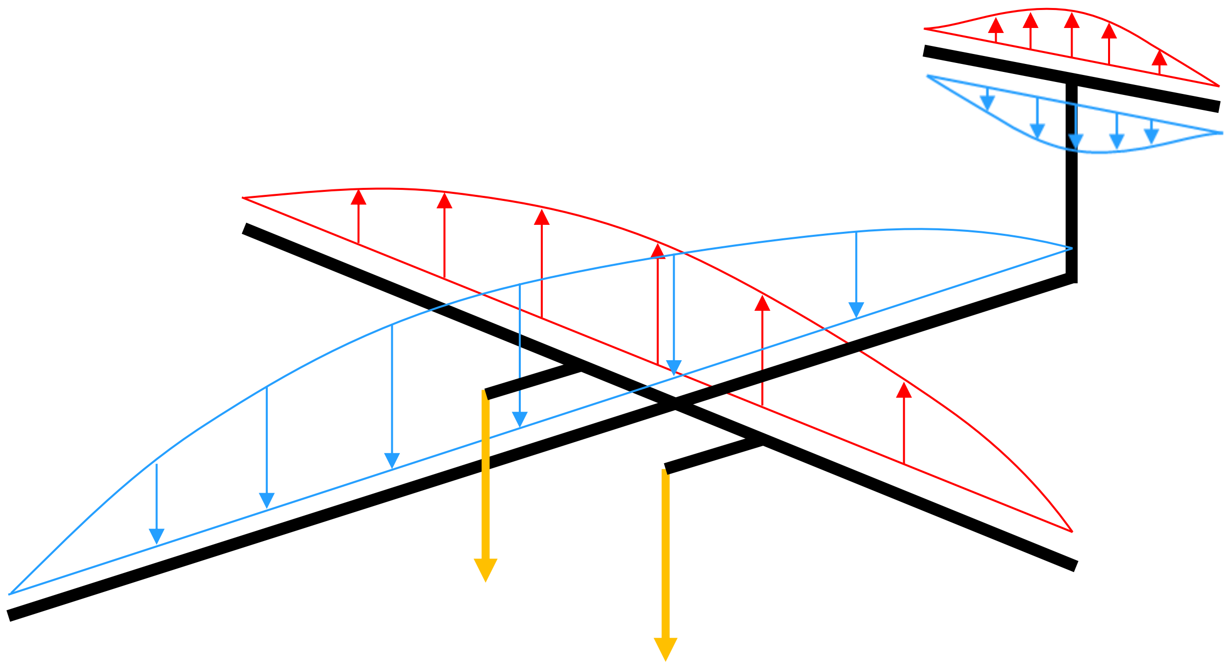
Aerospace Structure Concept – Load Paths

- The load paths along an aerospace structure (aircraft, launcher, …) are determined by the external loads
  - The external loads are represented by the Net Forces
- Net Forces = sum of all external loads, mainly aerodynamic and inertia
  - The net forces for a full system are always in equilibrium
  - In the figure only symmetrical loads are displayed,
- Unsymmetrical loads can be design-driving, e.g. for
  - VTP
  - Fuselage (torsion)
  - Outer Wing (aileron, torsion)



Aerospace Structure Concept – Load Paths

- Airframe can be simplified to a beam model, the so-called stick model
- Stick models are beneficial for the global load distribution (external and internal)



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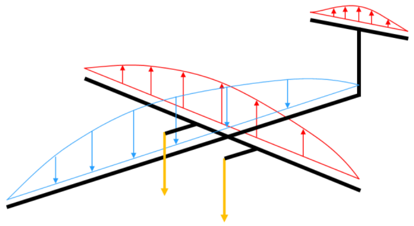
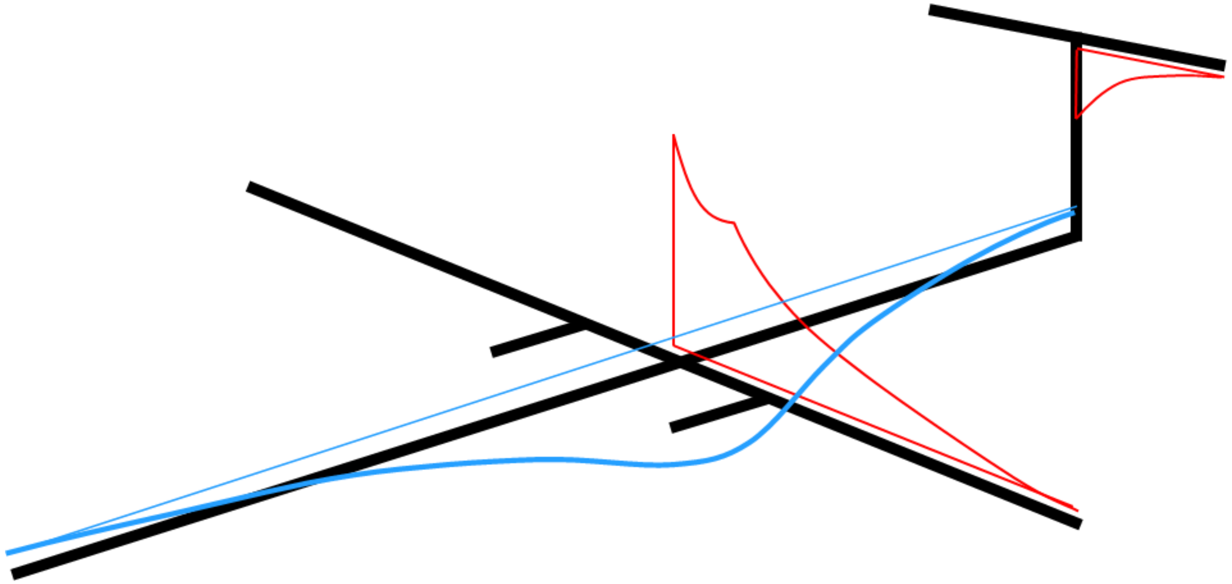
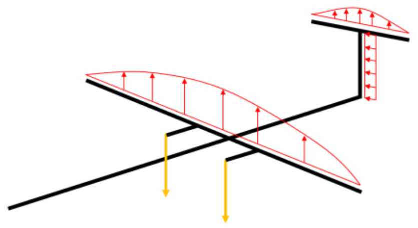
Aerospace Structure Concept – Load Paths



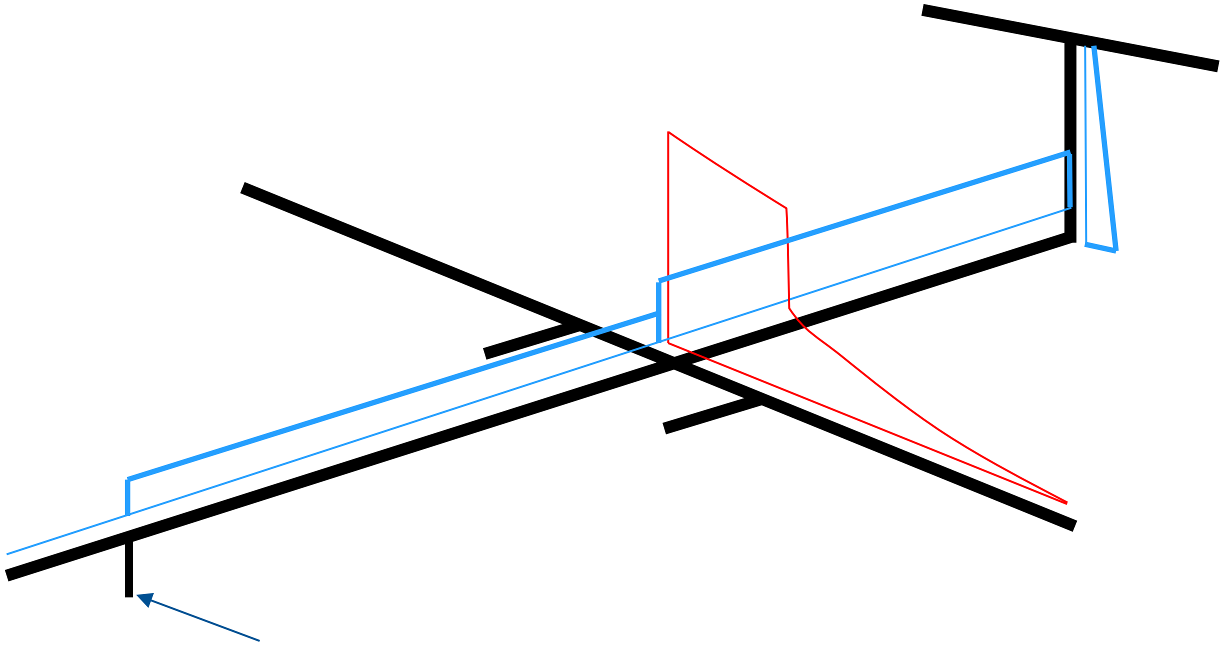
- Internal load distribution (section forces and moments):
  - Bending moments



Aerospace Structure Concept – Load Paths

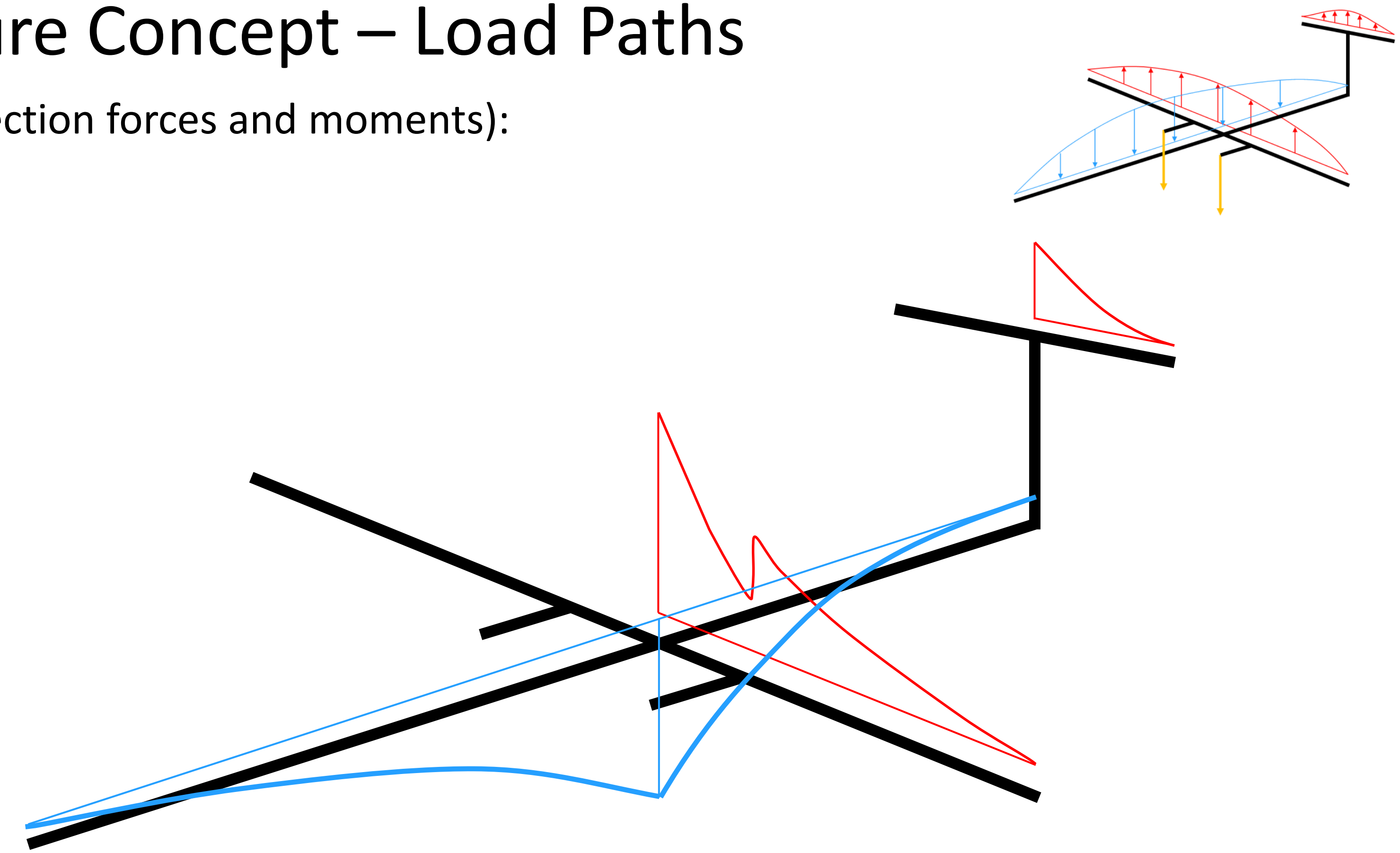


- Internal load distribution (section forces and moments):
  - Torsion moments



Aerospace Structure Concept – Load Paths

- Internal load distribution (section forces and moments):
  - Shear forces



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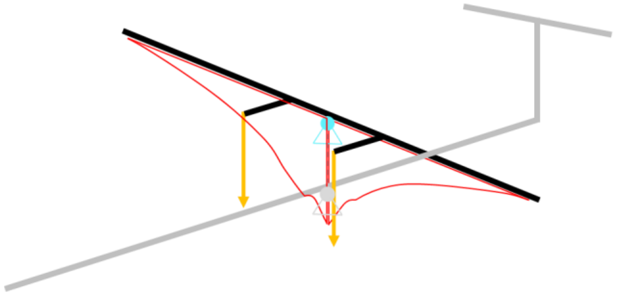
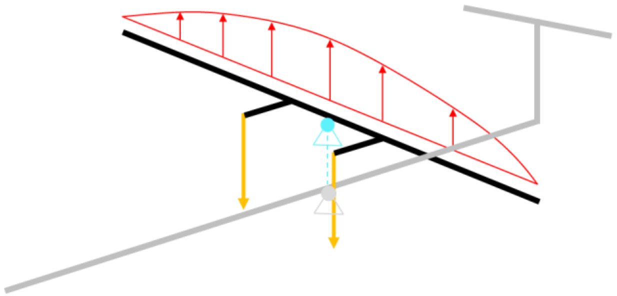
Aerospace Structure Concept – Load Paths

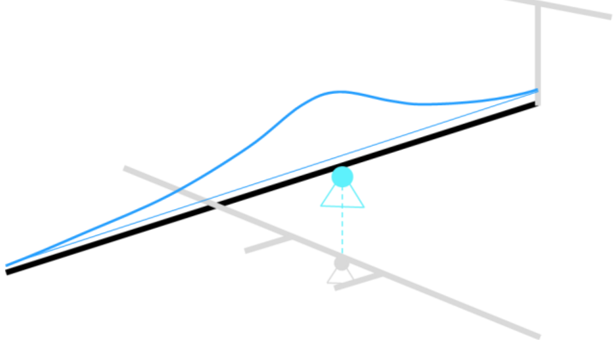
Which component is supporting the other?

- All trimmed conditions i.e., all external loads are in static or dynamic equilibrium!!!
- From wing’s perspective: wing is supported by fuselage





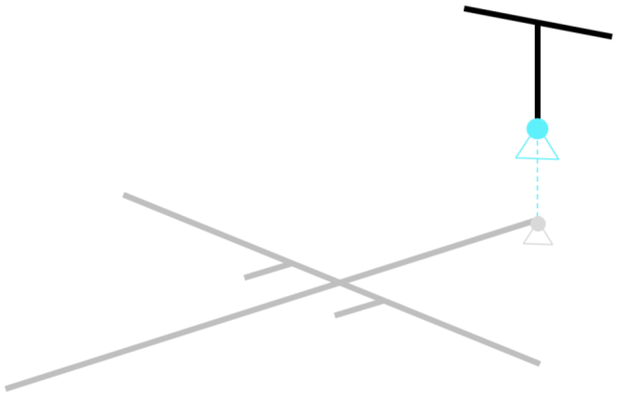
- From fuselage’s perspective: the fuselage is supported by the wing



Aerospace Structure Concept – Load Paths

Which component is supporting the other?

- From VTP’s perspective: VTP is supported by fuselage

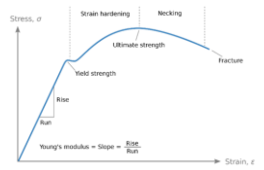


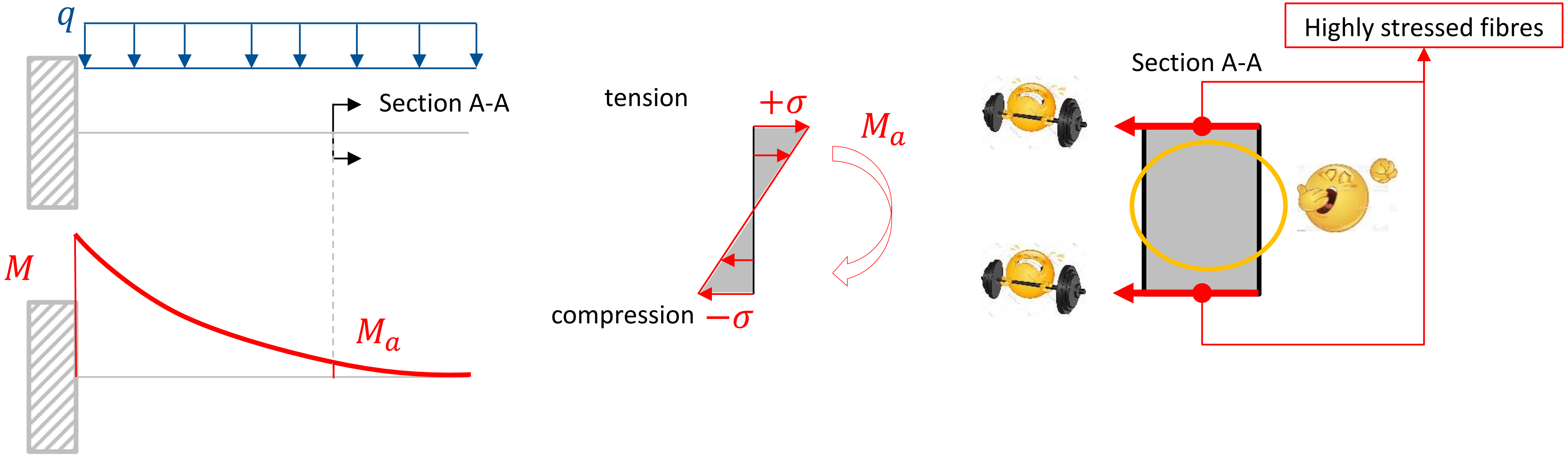
- From HTP’s perspective: HTP is either supported by VTP (T-Tail) or by fuselage (conventional)

Torsion Box, Stiffened Panel, Sandwich

Aerospace Structure Concept – Torsion Box

- The principle of the torsion box is one of the most relevant concepts in (aerospace) structures
- The principle of the torsion box is based on separating the internal forces in order to:
  - Transform bending moments into membrane forces

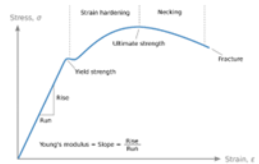


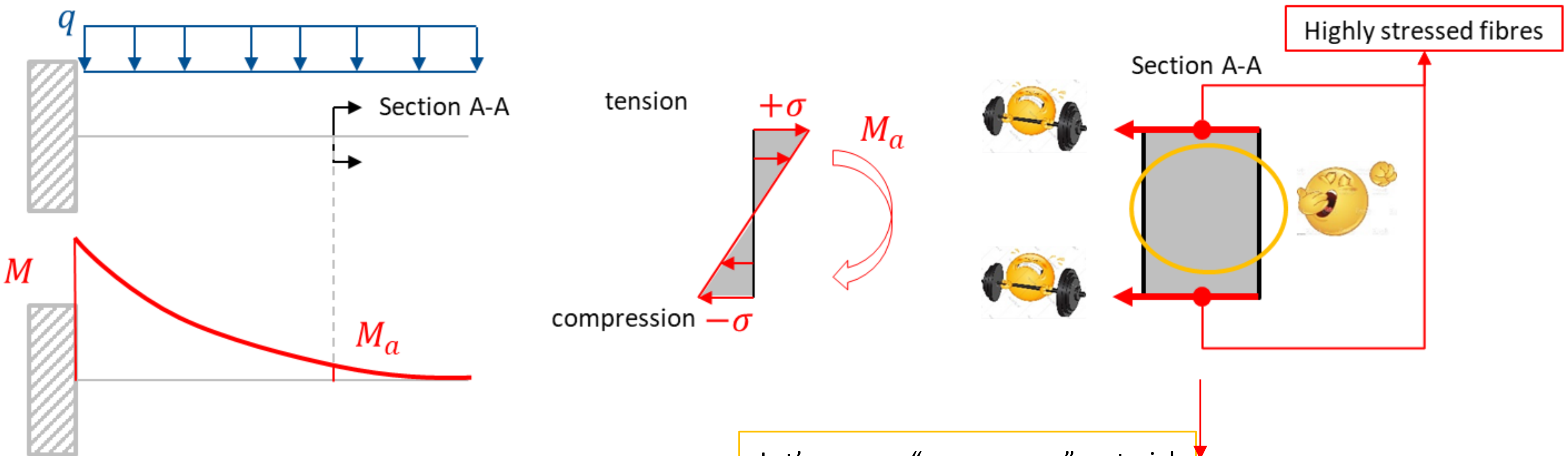


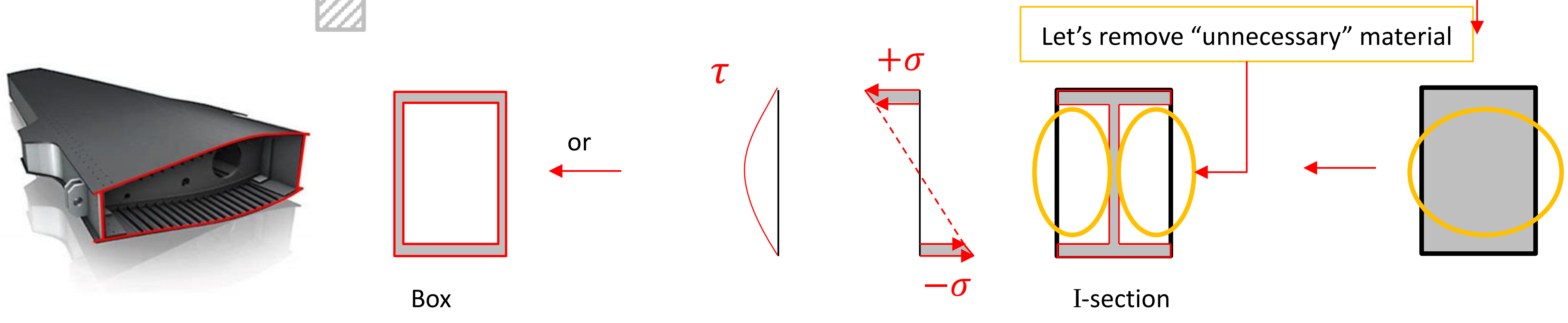
This is the reason why bending stresses are so "painful":
- Material load bearing capacity is not exploited!
- Thus, we need too much material!

Aerospace Structure Concept – Torsion Box

- The principle of separating forces
  - Transform bending into membrane forces





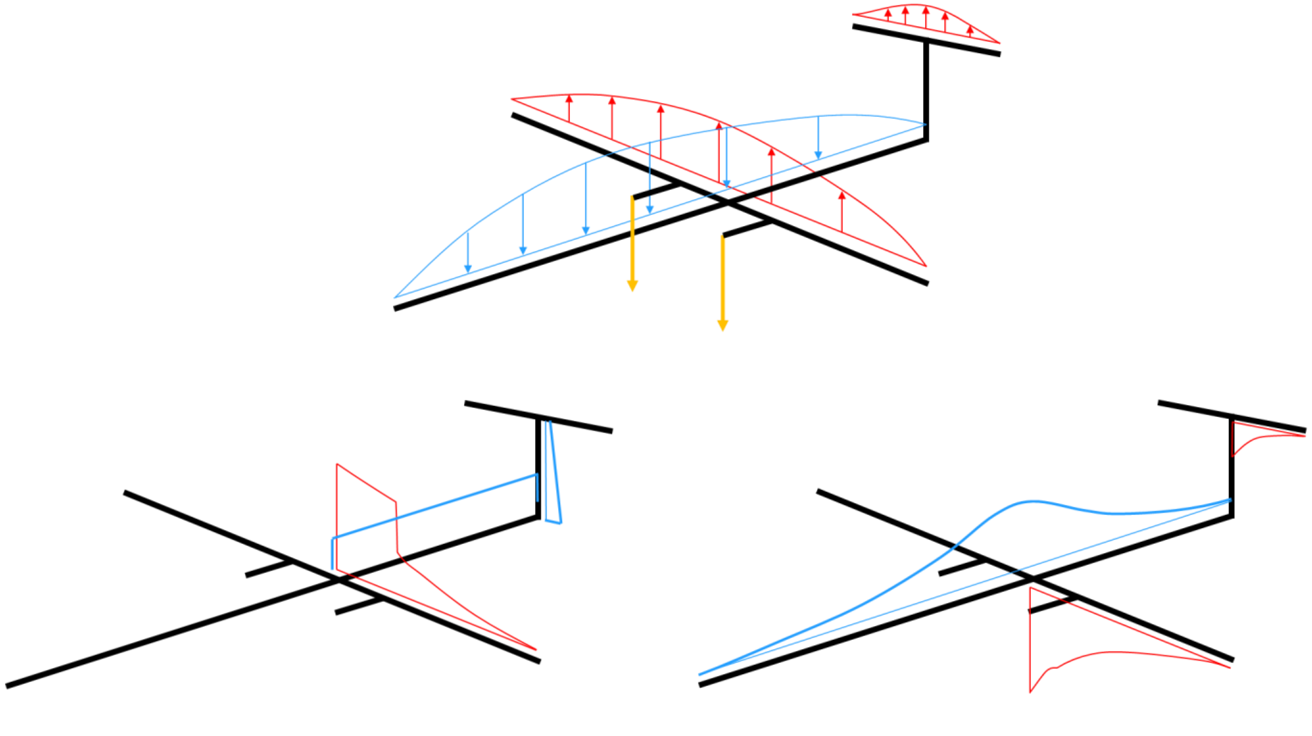


Separate bending stresses into membrane forces:
- tension, compression in the flanges and
- Shear in the web

Aerospace Structure Concept – Torsion Box

The principle of separating forces

- Transform bending into membrane forces



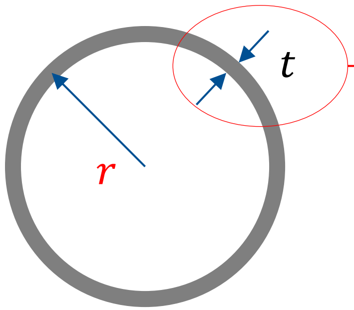
Torsion

Bending Moments

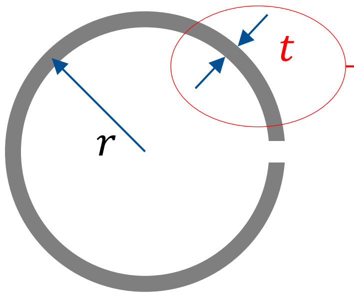
Aerospace Structure Concept – Torsion Box

The principle of closed boxes – the torsion box

- High torsional stiffness



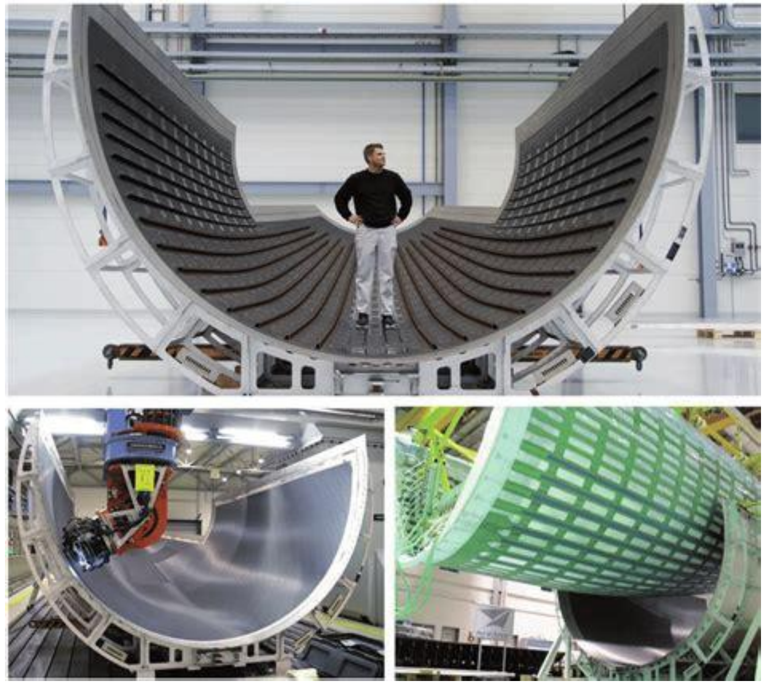
$$I_T = 2\pi\, t\, r^3$$



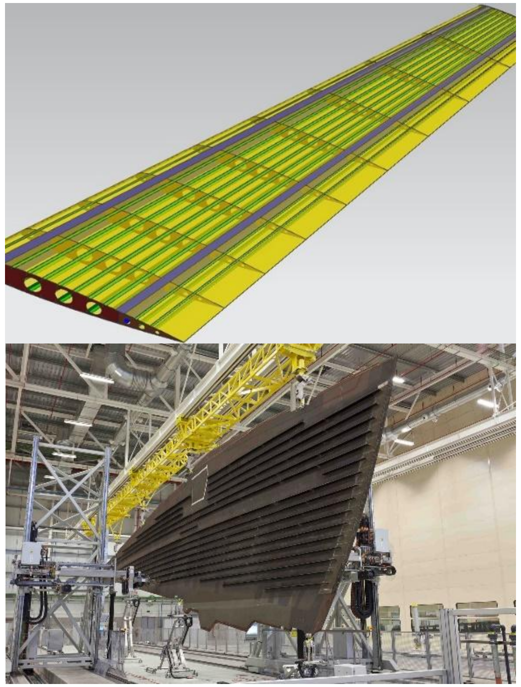
$$I_T = \frac{2}{3}\pi\, r\, t^3$$

Aerospace Structure Concept – Stiffened Panels

- Through transforming the bending stresses (wing, fuselage) into a pair of membrane forces (tension and compression), it is possible to reduce skin thickness significantly (Wing: 2 to 20mm, Fuselage: 2 to 10mm)
- However, the thin skin is prone to buckling. Thus, the need for stiffeners in order to reduce the size of the buckling fields



Premium Aerotec, Stade

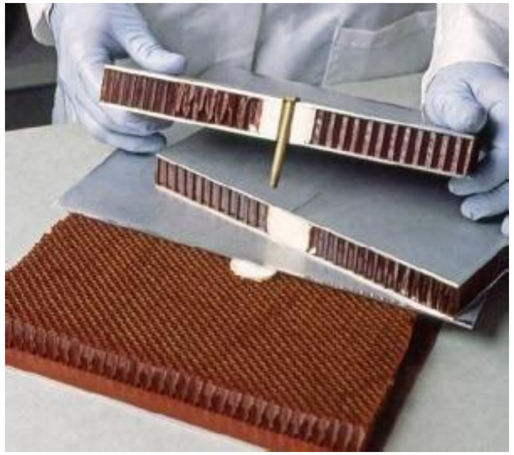


The Stiffened Panels – Influence of buckling field width

Aerospace Structure Concept – Sandwich

- An alternative to stringer-stiffened panels is using sandwich
- Sandwich is made of two thin load carrying skins bonded to a light-weight core
- Load-carrying skins are usually made of carbon composites, but also aluminium
- The core is made of aramid, but also fibreglas or aluminium are possible
- Benefits of sandwich are:
  - High bending stiffness (with low weight), accordingly high critical buckling stress
  - Good damping properties (space applications)
- Drawbacks of sandwich are:
  - Consume too much volume
  - Difficulties to join
  - Cumbersome load introduction
  - Captures moisture

pinterest.com



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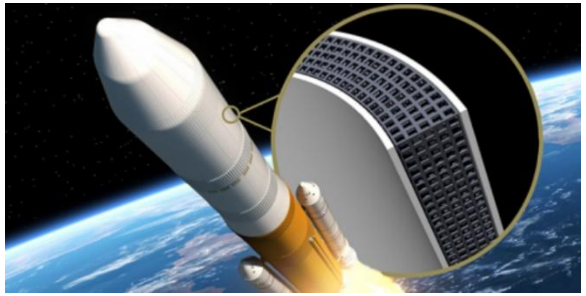


electronics360.globalspec.com

Aerospace Structure Concept – Summary

- Wing (and empennage):
  - the wingbox is the load carrying part
  - Wingbox consists of
    - skin stiffened by stringers
    - Spars connecting the skin covers (top and bottom)
    - Ribs connecting the skin covers (reduce buckling field length for the stringers)
  - Design parameters (for structure concept):
    - Number of spars
    - Stringer pitch
    - Rib pitch
    - Material
    - Manufacturing technology

Aerospace Structure Concept – Summary

- Fuselage:
  - The fuselage consists of
    - skin stiffened by stringers
    - Frames supporting the skin panels (skin and stringers)
    - Longerons for high local loads (longitudinal and transverse)
    - Floors might be also load carrying (especially in military aircraft)
  - Design parameters (for structure concept):
    - Number of frames
    - Stringer pitch
    - Number and location of longerons
    - Material
    - Manufacturing technology

Major Structure Interfaces

Aerospace Structure Concept – Major Interfaces

Overview of major interfaces

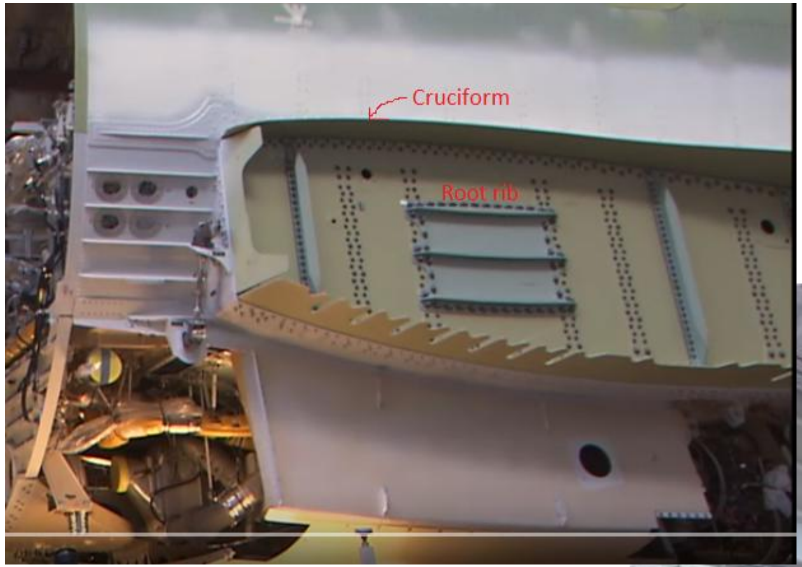
- Wing-to-fuselage
- Empennage-to-fuselage
- Engine
  - to-wing
  - to-fuselage
- Landing gear
  - to-wing
  - to-fuselage

https://www.youtube.com/watch?v=H3YdKBg8ebQ

Aerospace Structure Concept – Major Interfaces

Wing-to-fuselage

- Soft-splice (centre wing box)
- Hard joints



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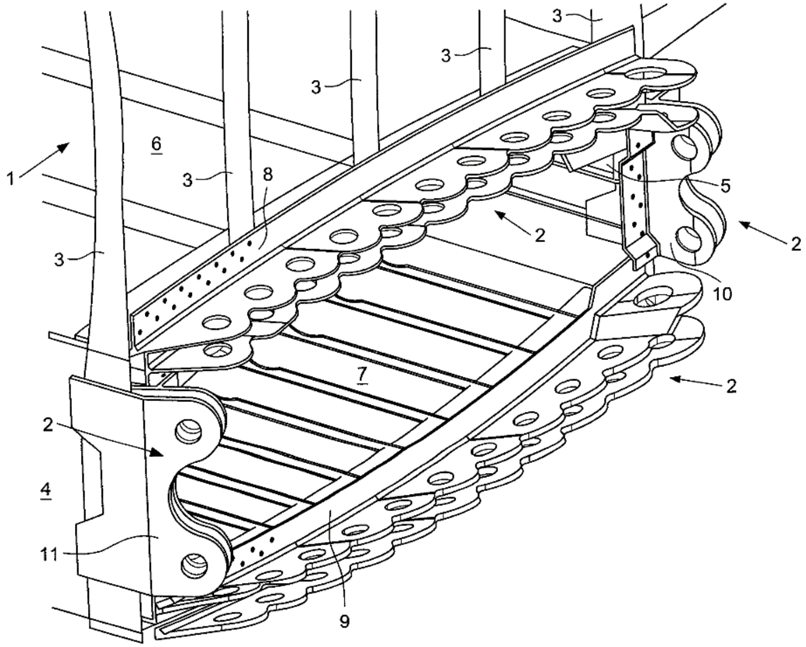
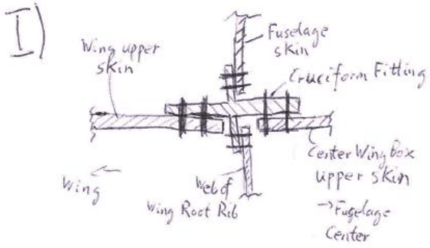




https://www.compositesworld.com/

Patent US8371532 - Aircraft joint - Google Patents

Wing-to-Fuselage interface – Carry-through concept

Wing-to-fuselage: Flugzeugbau (Teil 1) - Die Seite mit der Maus - WDR (wdrmaus.de) (53:00)

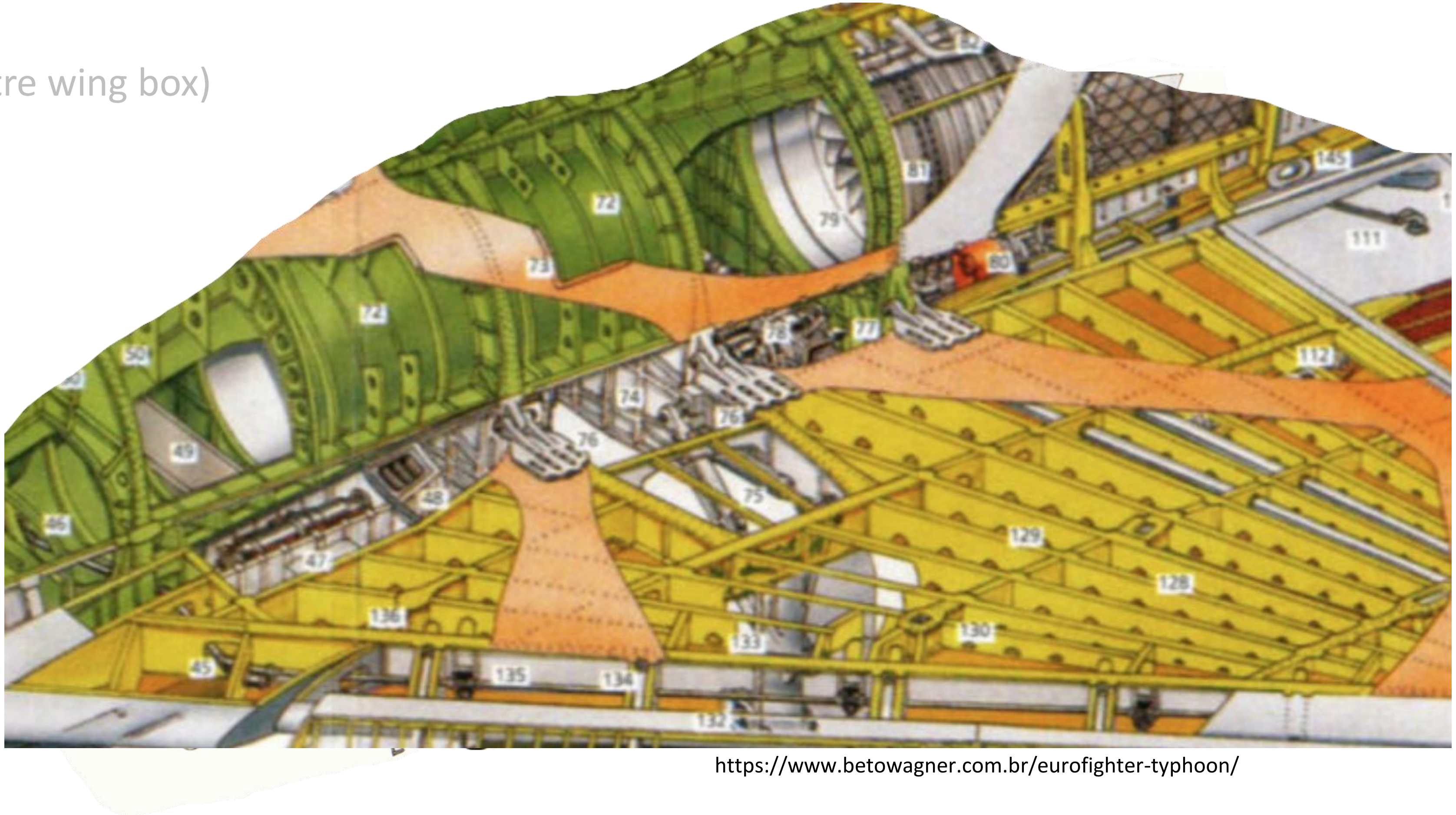
HTP-to-fuselage: Flugzeugbau (Teil 2) - Die Seite mit der Maus - WDR (wdrmaus.de) (5:26 + 15:19)

VTP-to-fuselage: Flugzeugbau (Teil 2) - Die Seite mit der Maus - WDR (wdrmaus.de) (6:16)

Aerospace Structure Concept – Major Interfaces

Wing-to-fuselage

- Soft-splice (centre wing box)
- Hard joints



https://www.betowagner.com.br/eurofighter-typhoon/

Major Interfaces – Hard Joints

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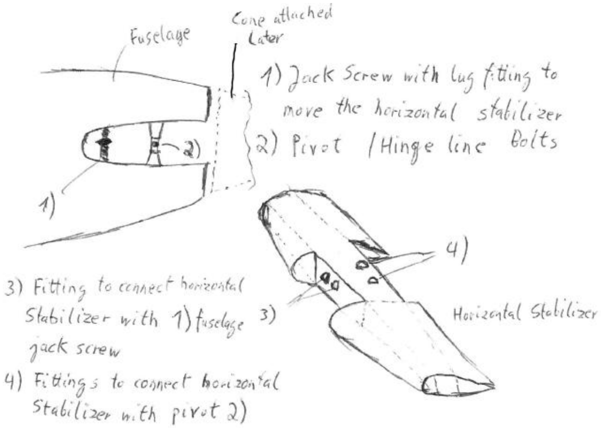
Aerospace Structure Concept – Major Interfaces

HTP-to-fuselage

- Torsion box (housing in fuselage)
- Pivot for all-moveable HTP



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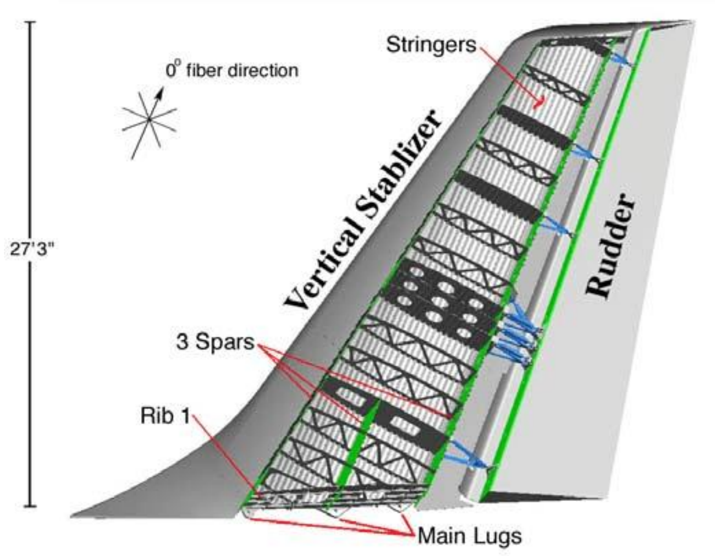
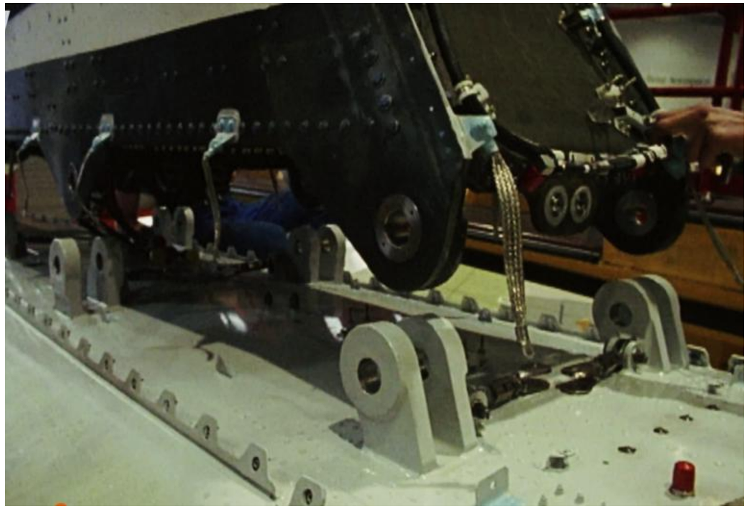
Aerospace Structure Concept – Major Interfaces

VTP-to-fuselage

- Lugs for all 6 degrees of freedom





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