

# Introduction to Aerospace Engineering

Lecture slides



# Structures

## Aircraft & spacecraft shell structures

Faculty of Aerospace Engineering

22-11-2011

# Introduction

## Outline of lectures/lecturer

- 15/11 Material physics & properties / environment
- 22/11 Structures
- 29/11 Loads
- 6/12 Materials & manufacturing
- 13/12 Selection of materials & structures / space
- 20/12 Design & certification / fatigue & durability
  
- 6/1 Manufacturing & joining
  
- Lecturer
  - Name: R.C. Alderliesten (Structural Integrity)
  - Room: NB0.45
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# Learning objectives

Student should be able to...

- Give definition of
  - Airframe
  - Principal structural elements
  - Secondary structural elements
  
- List typical structural elements for aircraft and spacecraft
  
- Explain the function of sheets
- Explain the difference between material stiffness and structural (geometrical) stiffness

# Aircraft & spacecraft structures

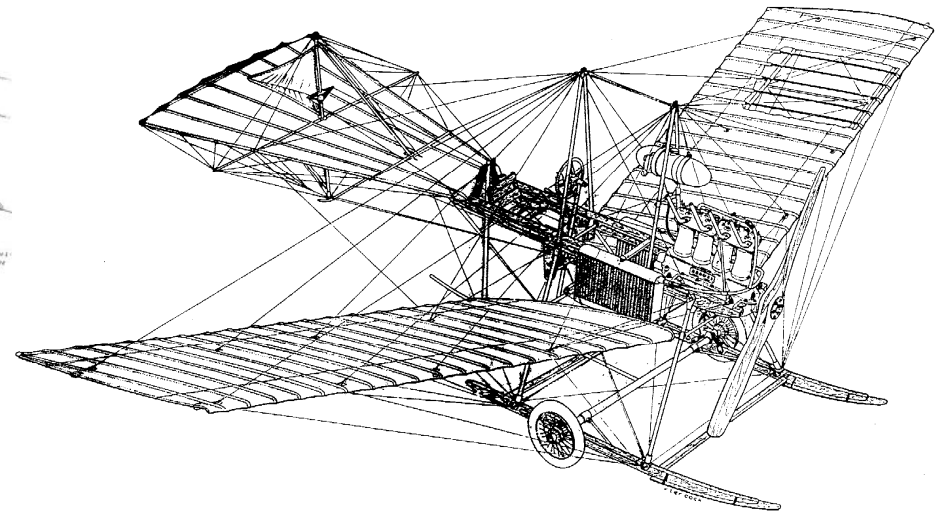
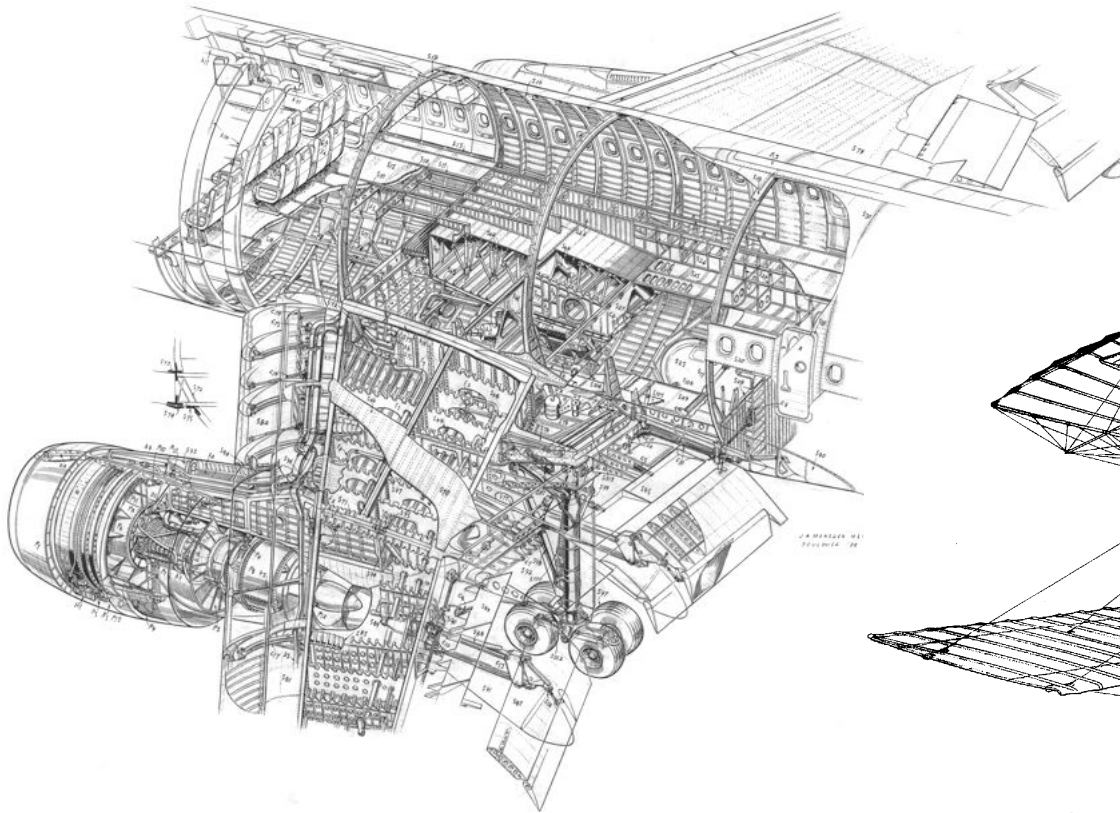
## Definition of airframe

- Aircraft/spacecraft without installed equipment and furnishing
- Consists of load bearing parts: parts that take up forces during
  - normal flight
  - maneuvers
  - take-off
  - Landing, etc.
- Consists of skin and framework (skeleton) that provide aerodynamic shape
- Protects contents from environment

# Aircraft structures

## Examples

- Skin and framework

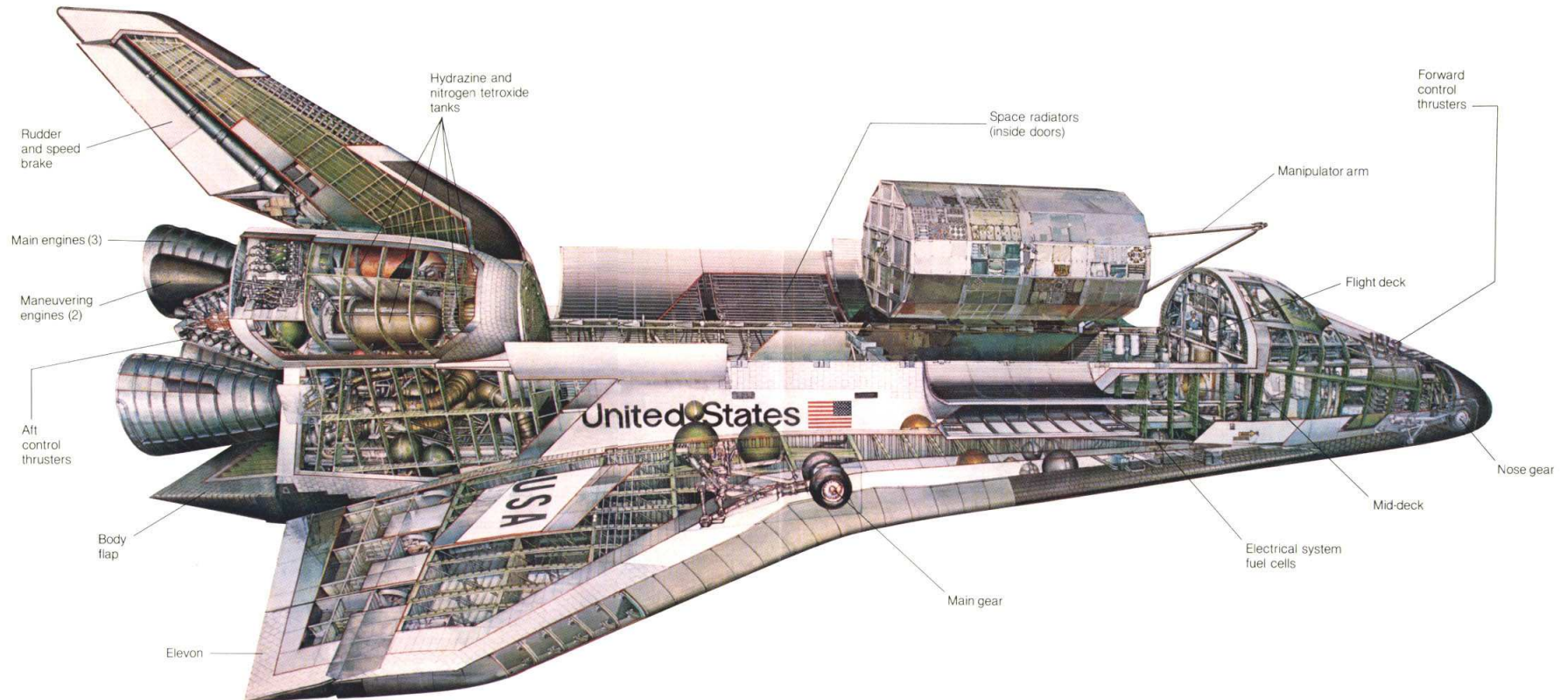




# Spacecraft structures

## Examples

- Skin and framework



# Aircraft & spacecraft structures

## Definition of primary/secondary structure

- Primary structure
  - Critical load bearing structure of an aircraft/spacecraft that in case of severe damage will fail the entire aircraft/spacecraft
- Secondary structure
  - Structural elements of an aircraft/spacecraft that carry only air and inertial loads generated on or in the secondary structure



# Aircraft & spacecraft structures

## Typical elements

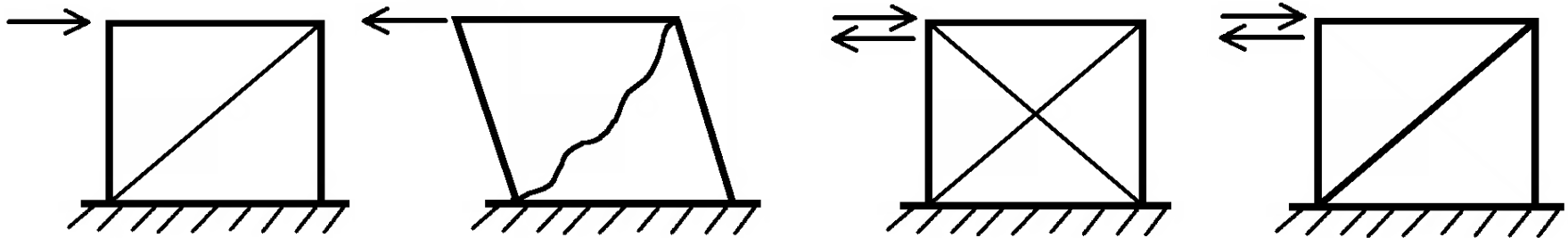
- Fuselage shells
  - Skin
  - Frames
  - Stringers
  - Bulkheads
  - Splices
- Wing structure
  - Wing skin panels
  - Ribs
  - Spars
  - Assembly of spars & skin



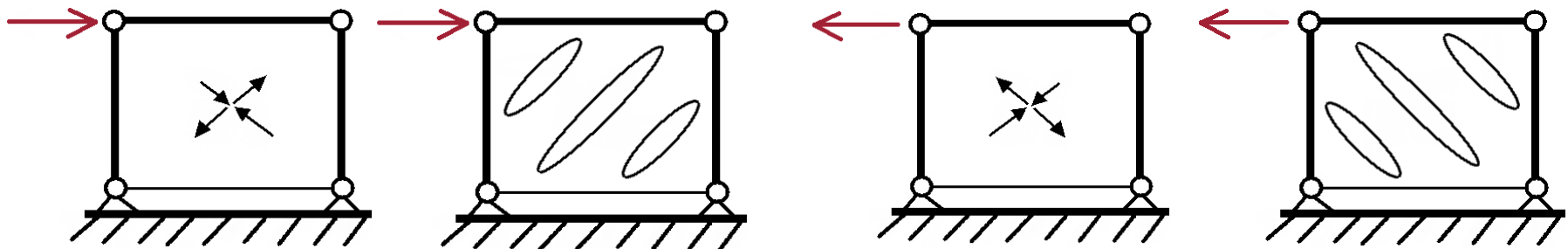
# Shell structures

## Recall: from truss to shell structures

- Function of diagonal elements (tension & compression)



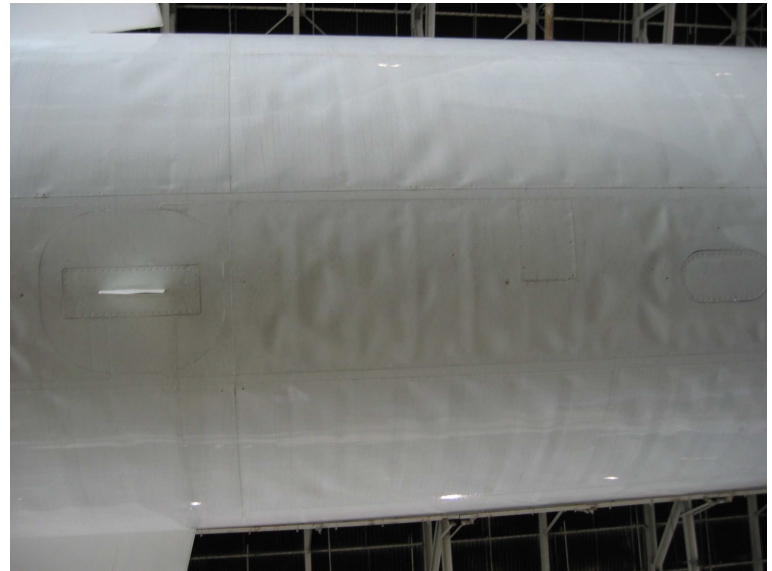
- Replacement by sheet (compression causes buckling)



# Shell structures

## Examples of buckling

- Buckling of sheet



# Shell structures

## Sheet material

- A sheet has more capabilities than reinforcing a structure!

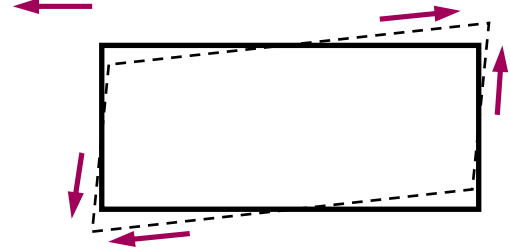
- Tension



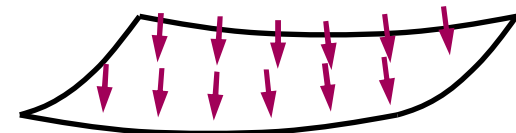
- Compression



- Diagonal function: shear



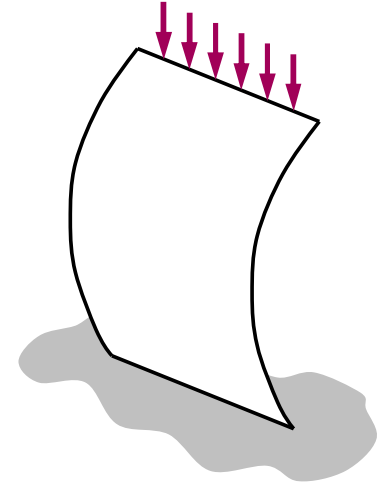
- Sealing function (air tight, fuel tight)



# Shell structures

## Stiffness of sheet material

- A sheet in compression bends out
  - Sheet in tension is not a problem



# Shell structures

## Example of folding/corrugating sheet

- Junker 52 - 1932

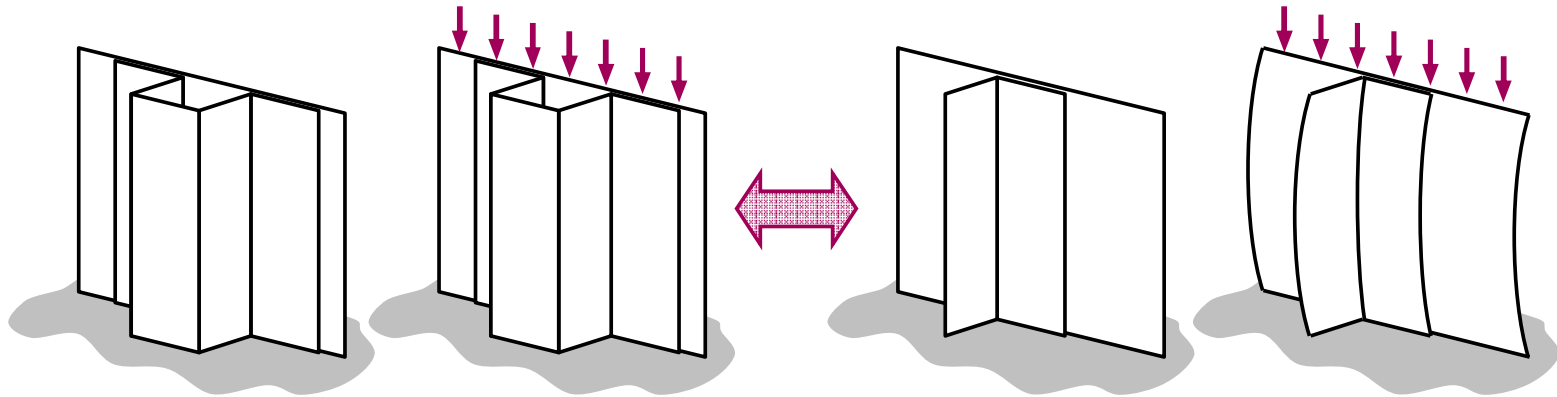




# Shell structures

## Selection of stiffening configuration

- Comparison of stiffener geometry



- Stiffening spacing



# Shell structures

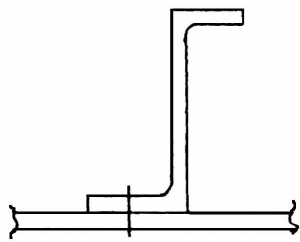
## Stiffener geometry

- Preferred shape depends on type of load

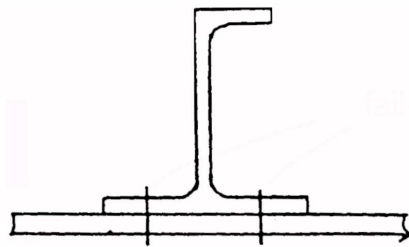


# Shell structures

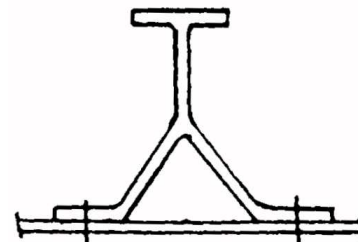
## Stiffener geometry



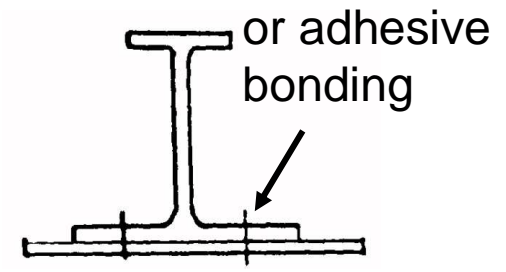
Z-stringer



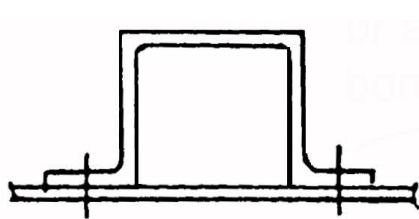
J-stringer



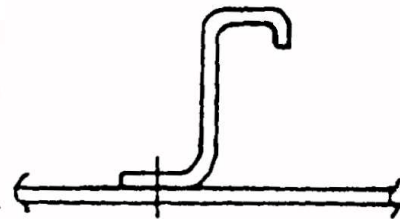
Y-stringer



I-stringer

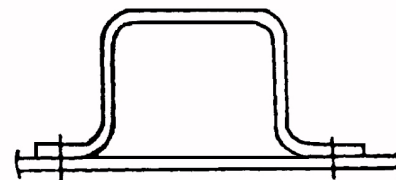


hat-stringer



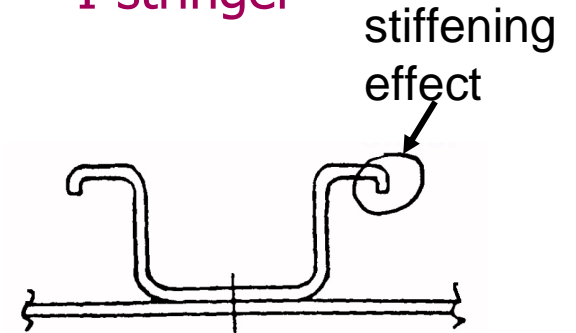
Z-stringer

(Lower wing)



hat-stringer

(Upper wing)

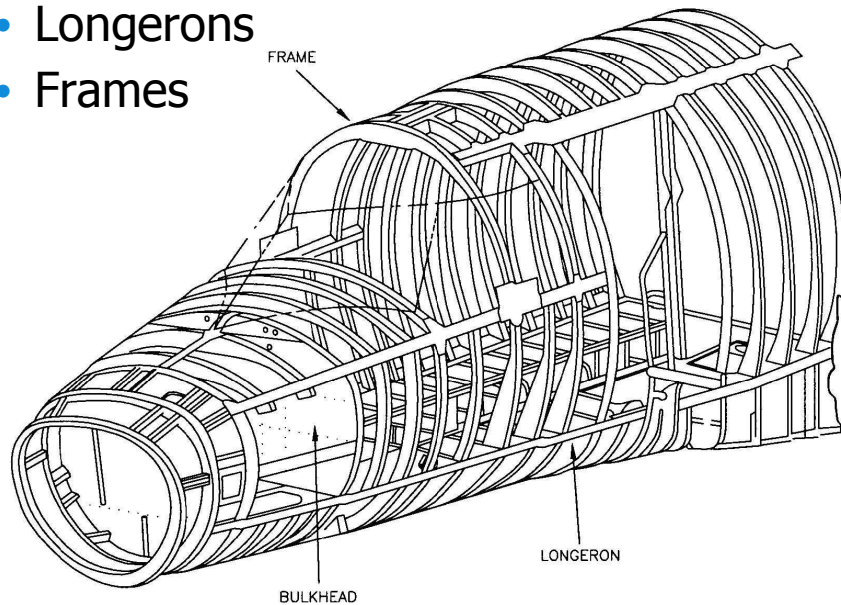


hat-stringer

# Shell structures

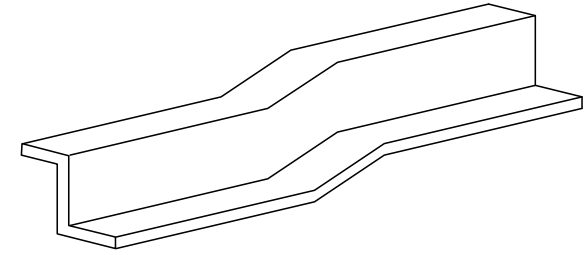
## Stiffener geometry

- Sheet geometrically reinforced by stiffeners
- Example stiffeners
  - Stringers
  - Longerons
  - Frames

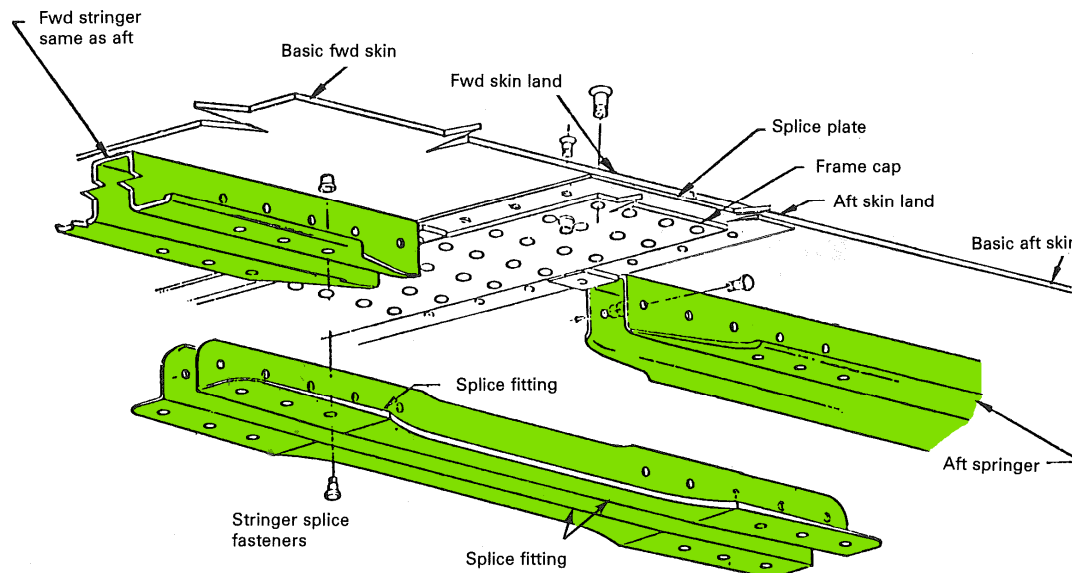


# Shell structures

## Stiffener intersections



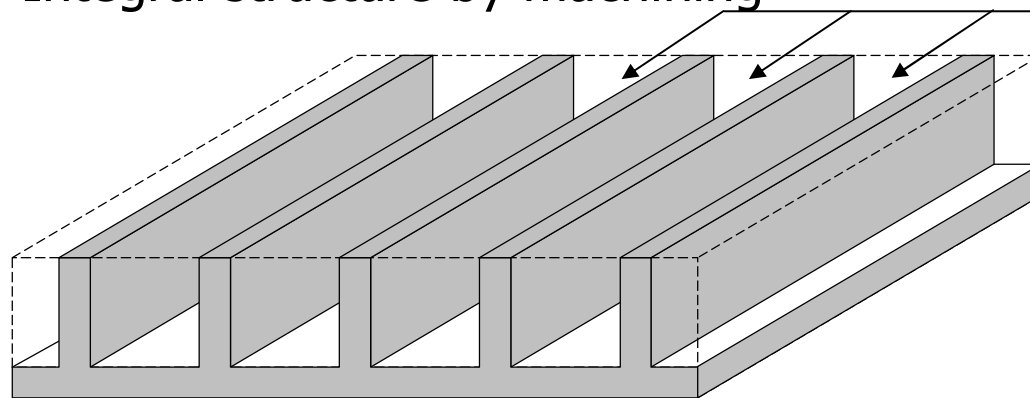
- Stringers in combination with thickness steps (jogging)
  - Butt-joints
  - Doublers
- Intersection of stiffening elements



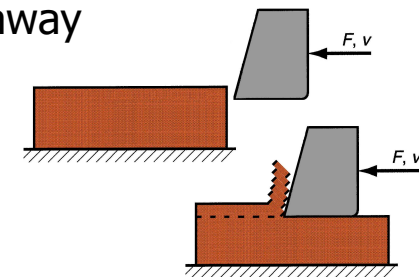
# Shell structures

## Other stiffening concepts

- Integral structure by machining

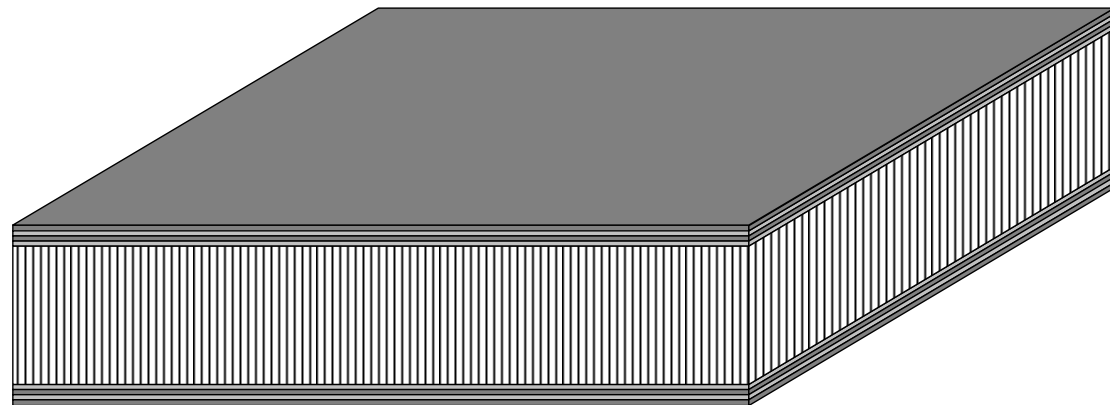


Extra material  
milled away



- Sandwich structure

- Skin {  
face sheet  
core  
face sheet

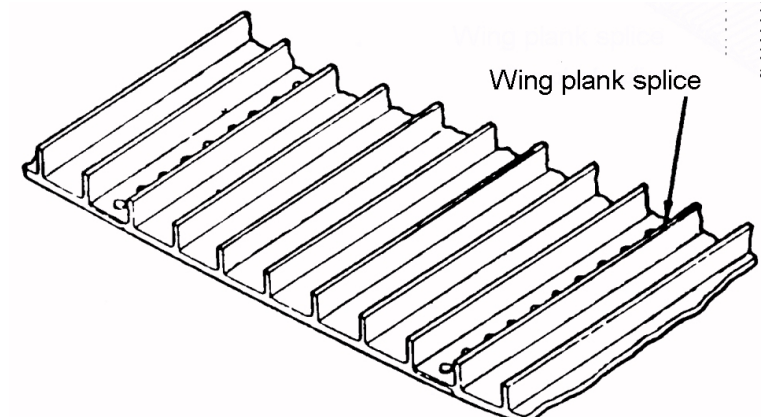
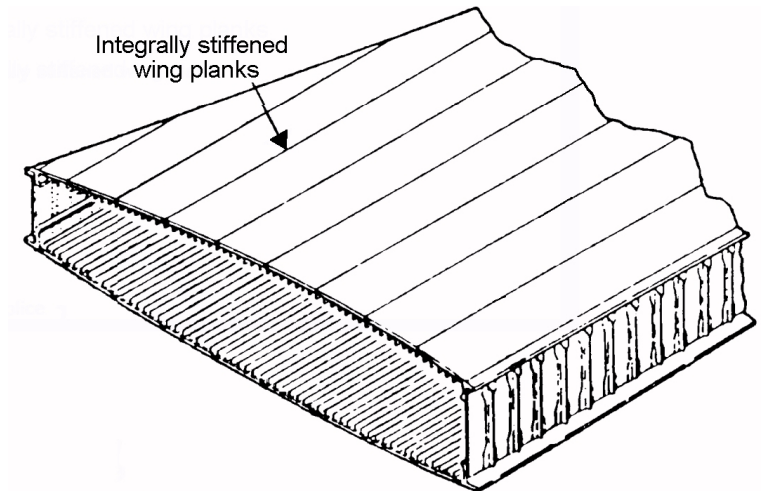




# Shell structures

## Other stiffening concepts

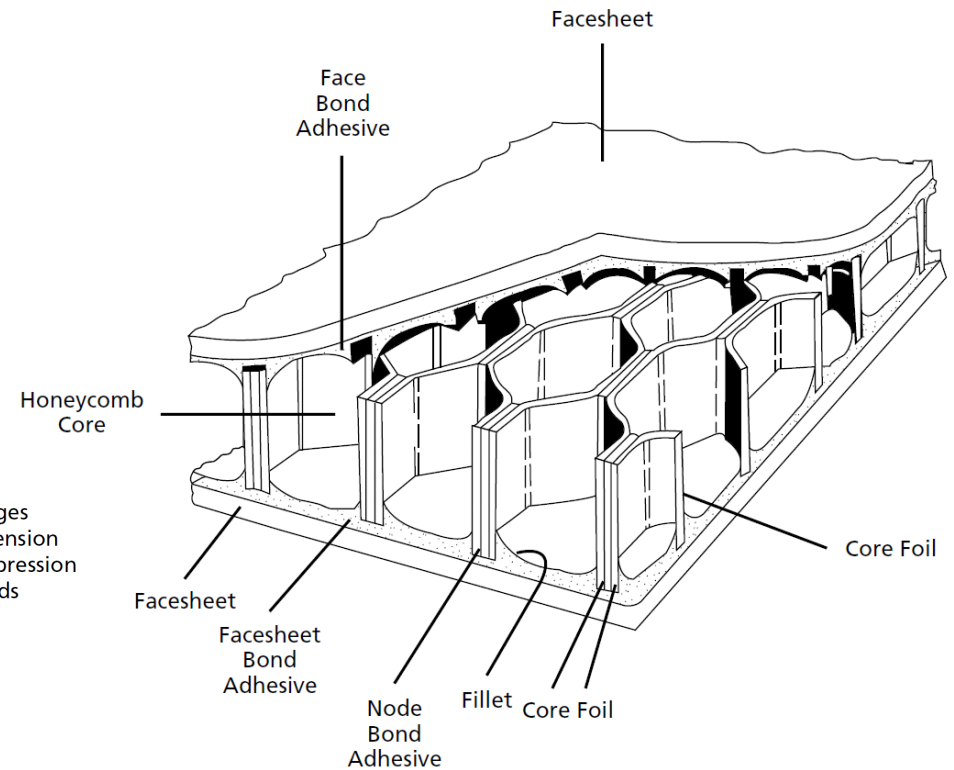
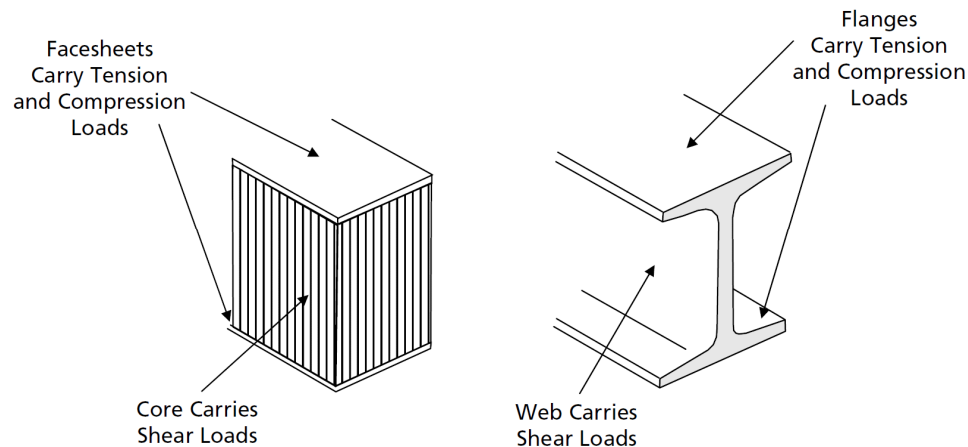
- Integral structure by machining
  - low cost
  - low part count
  - simple blade stiffening
  - thickness continuously adaptable
  
- lot of scrap (90%)
- rapid crack growth
- thick skin  $\Rightarrow$  large aircraft



# Monocoque structures

## Stiffening concept

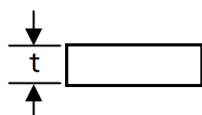
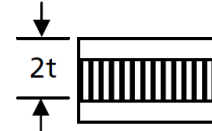
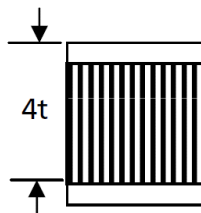
- Sandwich structure
  - No stringers needed
  - Smooth structure
- Difficult to repair
- Difficult to join



# Monocoque structures

## Stiffening concept

- Sandwich structure
  - No stringers needed
  - Smooth structure
- Difficult to repair
- Difficult to join

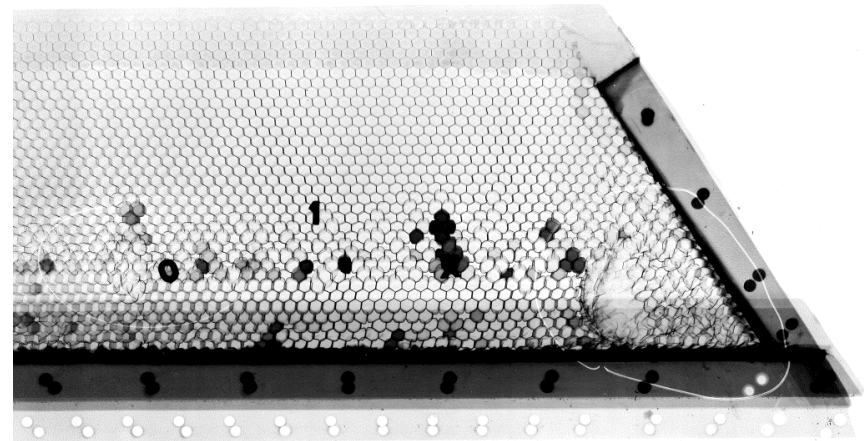
	Solid Material	Sandwich Construction	Thicker Sandwich
Bending Stiffness	 1.0	 7.0	 37.0
Flexural Strength	1.0	3.5	9.2
Weight	1.0	1.03	1.06

- Excellent structural concept, however..
  - complex and expensive details
  - corrosion (metal) and delamination (composites) problems

# Monocoque structures

## Stiffening concept

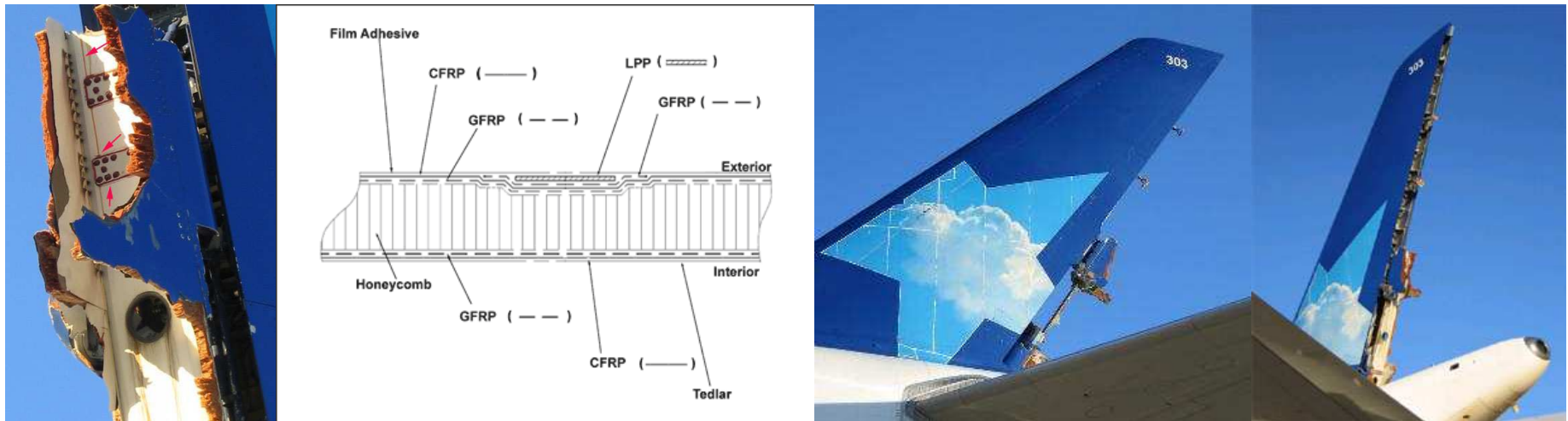
- Sandwich: Excellent structural concept, however..
  - Corrosion (metal) and delamination (composites) problems
- 1970s: Bréguet Atlantic
- Problem: Moisture ingress in honeycomb → corrosion



# Monocoque structures

## Stiffening concept

- Sandwich: Excellent structural concept, however..
  - Corrosion (metal) and delamination (composites) problems
- March 6, 2005: Airbus A310-308 - Air Transat Flight 961
- Problem: In-flight separation of composite rudder



# Summary

## Aircraft & spacecraft structures

- Shell structures
  - provide function as diagonal element
  - Can be geometrically stiffened
- Stiffeners
  - Have different shapes depending on load and manufacturing
  - Can be attached to skin sheet or milled from thick plate
- Sandwich panels
  - Face sheets carry tension/compression loads
  - Core carries the shear load