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Aerospace Structures

Chapter 1.
Structural description of the aircraft

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Index

CHAPTER 1. Structural description of the aircraft

Structural components of aircraft

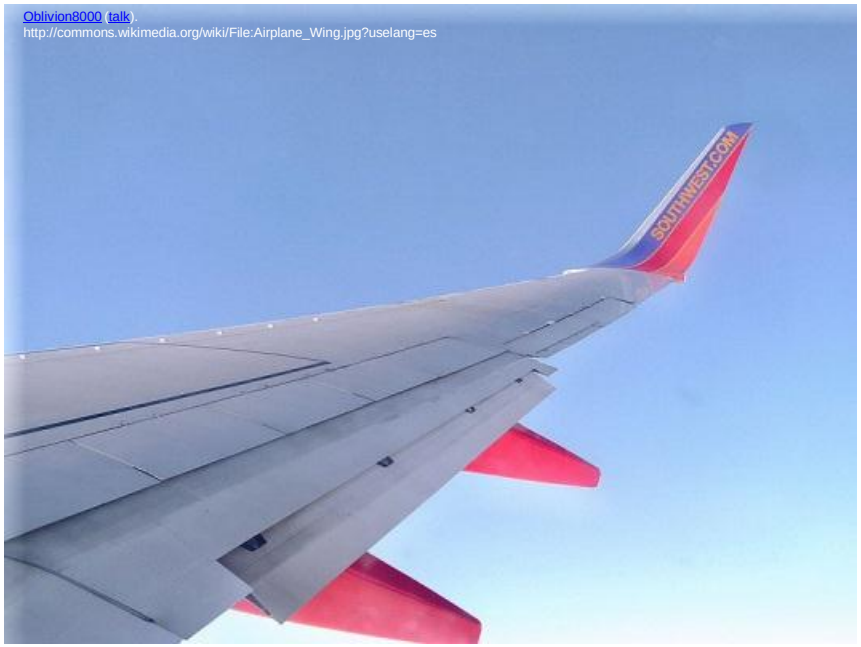
Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Wing structure

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Wing structure

Wing function



Oblivion8000 (talk).
http://commons.wikimedia.org/wiki/File:Airplane_Wing.jpg?uselang=es

The function of the wing is to produce lift

Main loads applied on the wing:

- ❑ Aerodynamic loads
- ❑ Weight

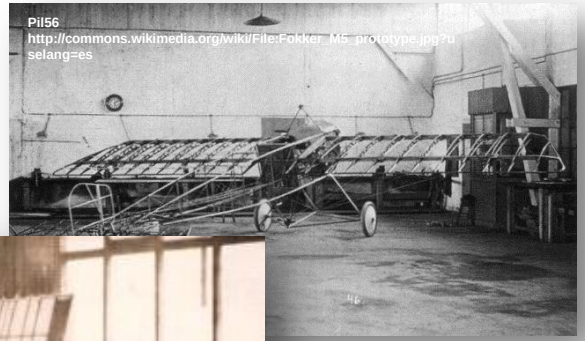
A wing works as a beam able to support the internal forces (Shear, bending and torsional moments)

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Wing structure

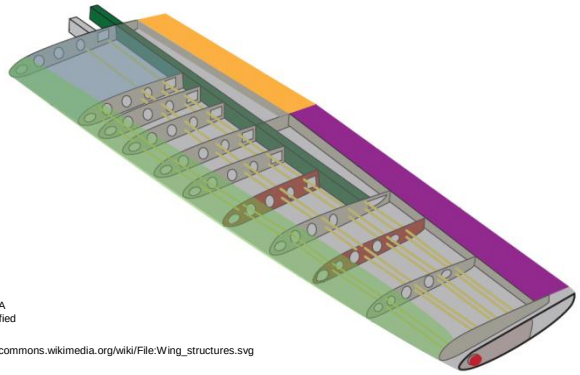
Structures types

Truss-type construction



Seattle Municipal Archives
http://commons.wikimedia.org/wiki/File:Women_making_airplane_wings_c._1910s.jpg?uselang=es

Stressed-skin construction



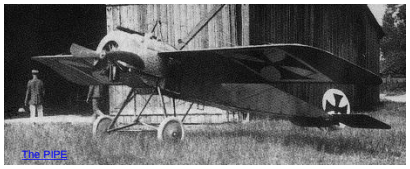
NASA
Modified

http://commons.wikimedia.org/wiki/File:Wing_structures.svg

russavia

http://commons.wikimedia.org/wiki/Category:BAE_Hawk_T1/T2_(Royal_Air_Force)?uselang=es#mediaviewer/File:Hawk_-_RIAT_2011_(6122004254).jpg

Early wing structures



The PIPE

http://commons.wikimedia.org/wiki/File:Fokker_M5K-MG_E5-15.jpg?uselang=es

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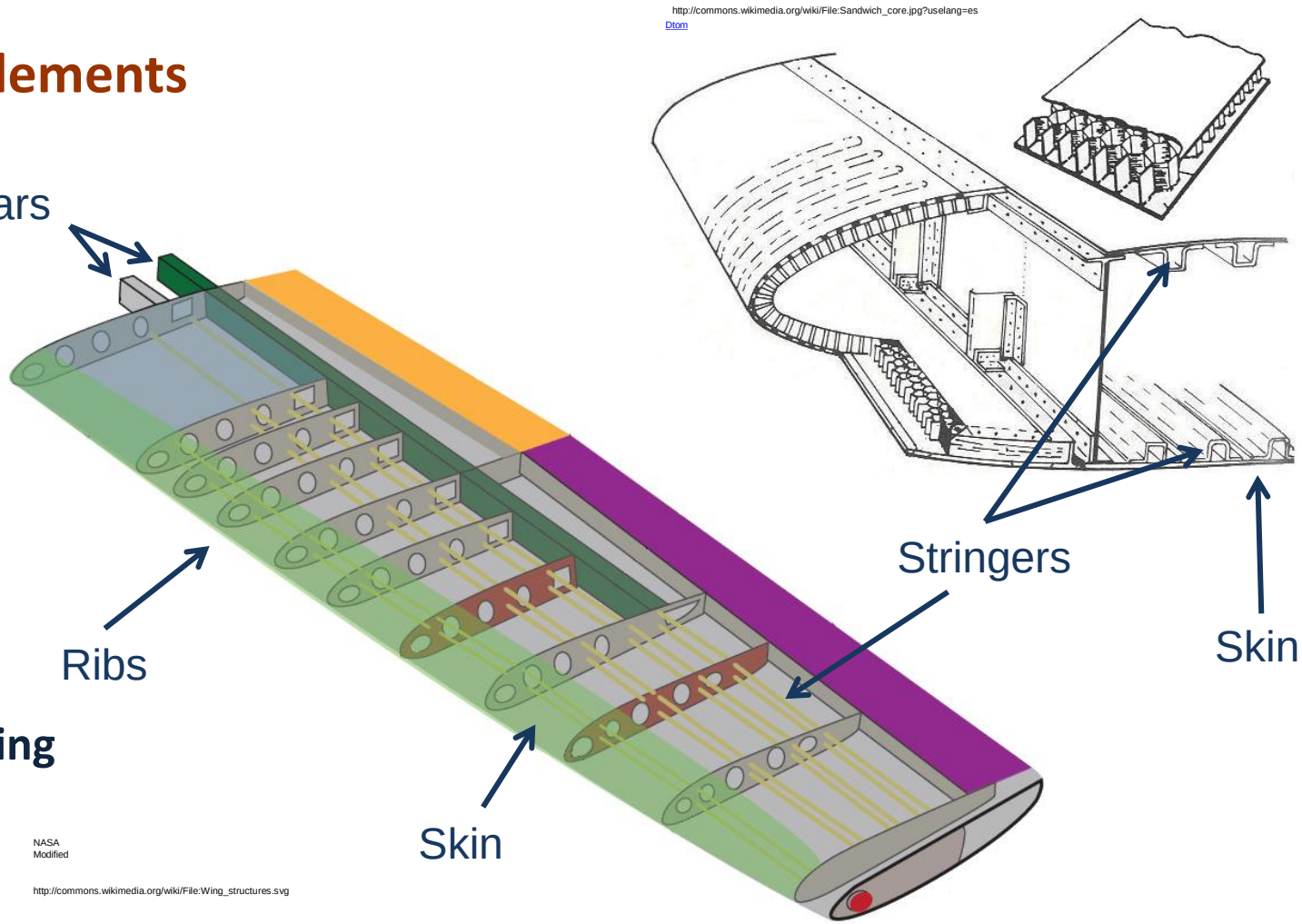
Wing structure

- **Wing elements**



Principal structural elements of the wing

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

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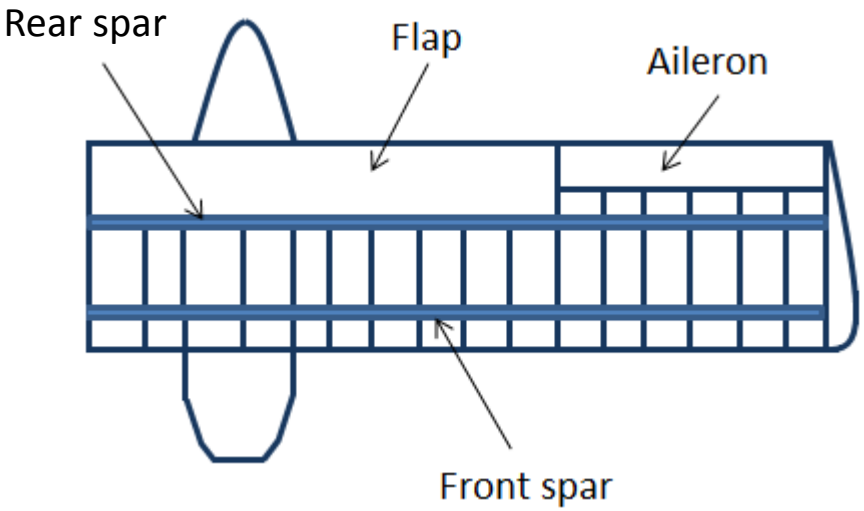
Wing structure

- **Spars**



Torsion box structure: 2-3 spar

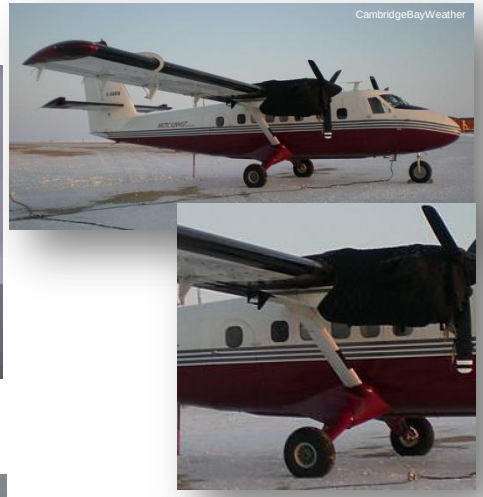
Front spar: 15-30% chord
Rear spar: 65-75% chord

Semicantilever wings

Some aircraft have external struts for wing bracing

bus227
http://commons.wikimedia.org/wiki/File:FlyingWires.JPG

http://upload.wikimedia.org/wikipedia/commons/d/d7/Arctic_Sunwest_Twin_Otter.jpg?uselang=es



Credit: NASA Langley/Sean Smith
http://www.nasa.gov/centers/langley/multimedia/iotw-tdt-wing_prt.htm

Boeing Aerodynamic Efficiency Improvement Joined Wing

Boeing SUGAR Volt concept

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

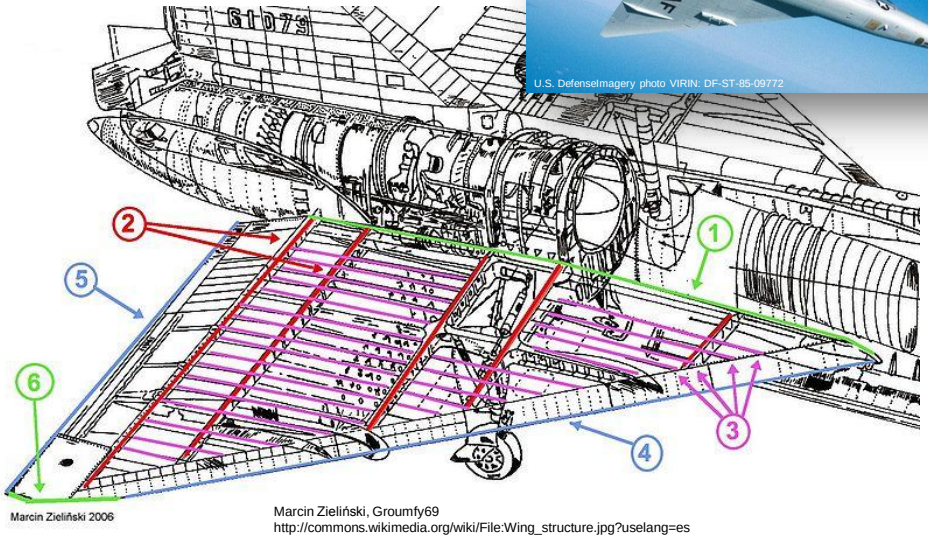
Wing structure

- **Spars**

Convair F-106A Delta Dart

http://commons.wikimedia.org/wiki/File:Delta-Dart-DF-ST-85-09772.JPEG?uselang=es

U.S. DefenseImagery photo VIRIN: DF-ST-85-09772



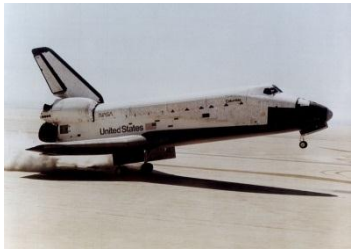
Marcin Zieliński 2006

Marcin Zieliński, Groumfy69
http://commons.wikimedia.org/wiki/File:Wing_structure.jpg?uselang=es

Torsion box structure: multispar
Parallel spars

NASA
http://commons.wikimedia.org/wiki/File:Shuttle_Left_Wing_Cutaway_Diagram.jpg?uselang=es
http://www.nasa.gov/columbia/home/COL_wing_diagrams.html

(1) Wing root
(2) Spars
(3) Ribs
(4) Leading edge
(5) Trailing edge
(6) Wing tip



NASA Photo ID: S81-30746
http://commons.wikimedia.org/wiki/File:Columbia_landing_on_Rogers_dry_lake.triddle.jpg

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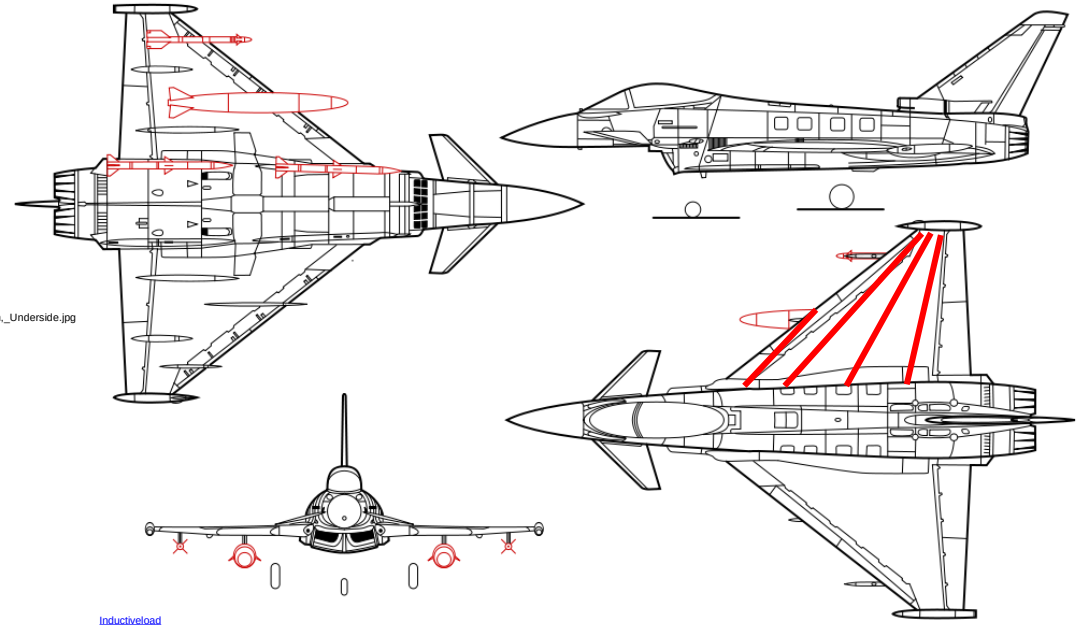
Wing structure

- **Spars**

tMH
ttp://commons.wikimedia.org/wiki/Category:Eurofighter_Typhoon?uselang=es#mediaviewer/File:Eurofighter_Typhoon,_Underside.jpg

Eurofigther

Torsion box structure: multispar
Converging spars



Inductiveload

http://commons.wikimedia.org/wiki/File:Eurofighter_Typhoon_line_drawing.svg?uselang=es

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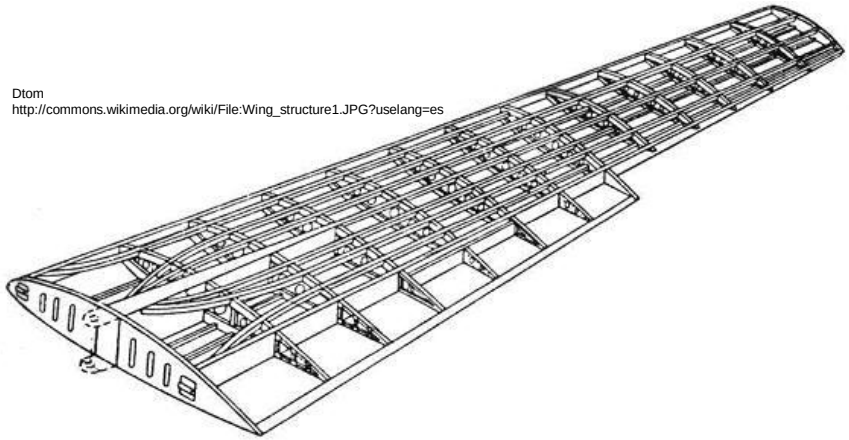
Wing structure

- **Spars**

Types of spar construction



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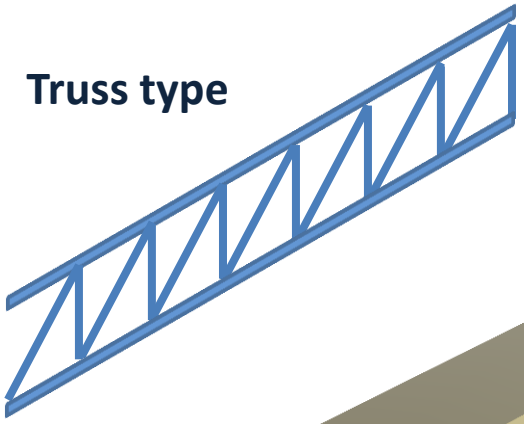
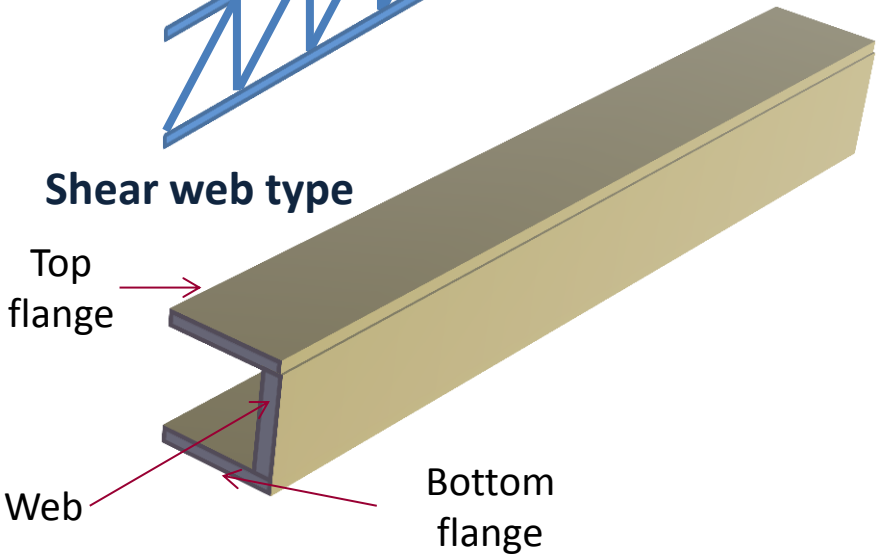
http://commons.wikimedia.org/wiki/File:Wing_structure1.JPG?uselang=es

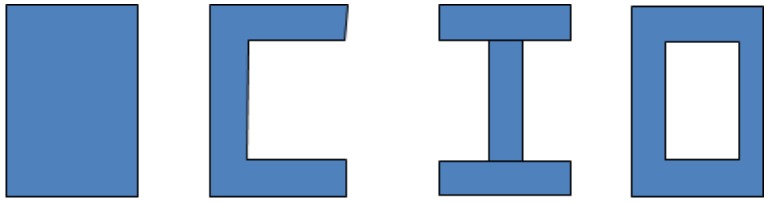
Truss type



Shear web type



Cross-section geometries



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Wing structure

- **Ribs**

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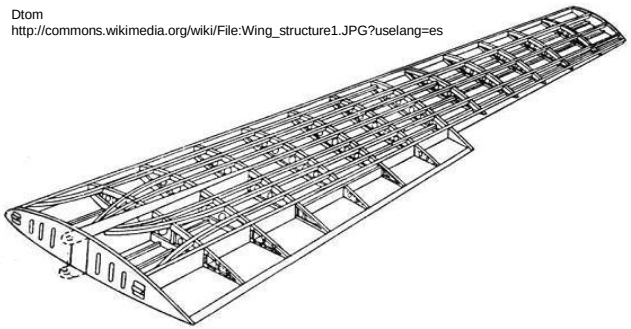
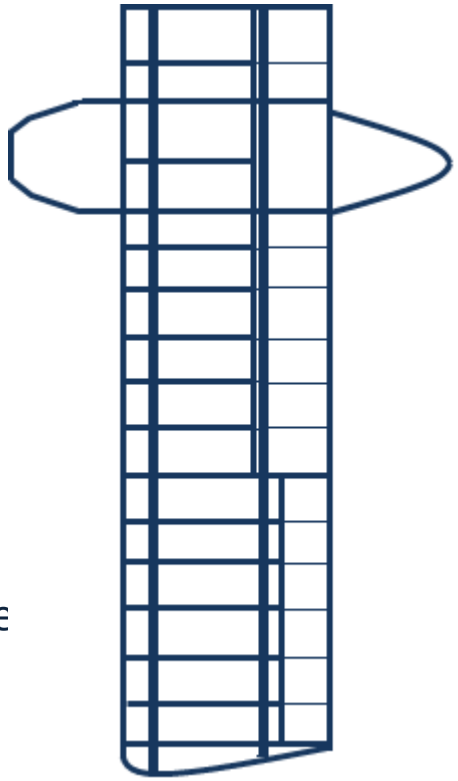
http://commons.wikimedia.org/wiki/File:Wing_structure1.JPG?uselang=es





http://commons.wikimedia.org/wiki/File:Canadair_CL-215-1A10_CL-215-I_AN0786306.jpg?uselang=es
Photo: Pedro Aragão

The wing ribs determine the shape and thickness of the wing

Ribs types

-Shear web ribs
- Truss ribs

The rib spacing is selected after a optimization process (skin+stringer+ribs)

Rib are to be located at each aileron and flap hinge.

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Wing structure

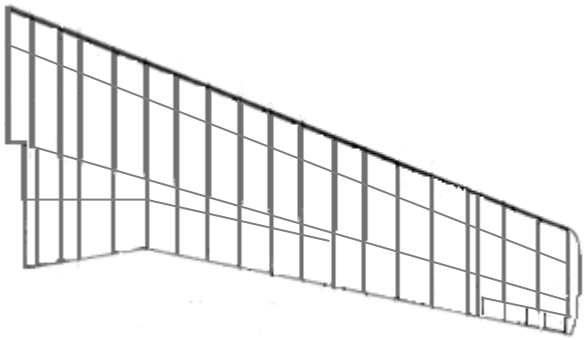
- **Ribs arrangement**

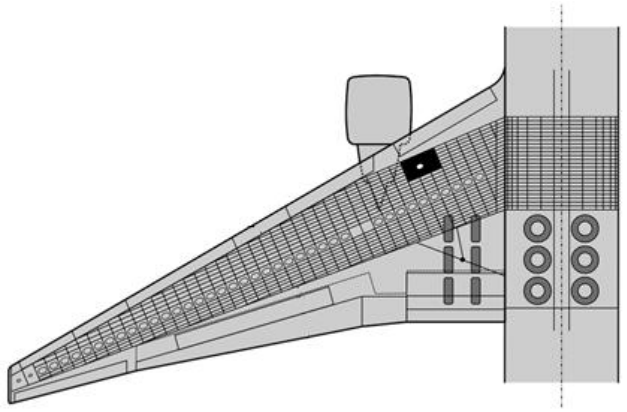
http://commons.wikimedia.org/wiki/File:Aerospatiale_SE-210_Caravelle_10B3_Super_B,_Sterling_Airways_AN0018394.jpg?uselang=es

Aerospatiale Caravelle

http://commons.wikimedia.org/wiki/Boeing_767#mediaviewer/File:LOT_Polish_Airlines,_Boeing_767-25D_ER,_Mississauga_(295649204).jpg

Boeing 767





Tosaka
http://commons.wikimedia.org/wiki/File:Jetliner%27s_wing_structure_(B-777).PNG

Wing ribs parallel to the flight path

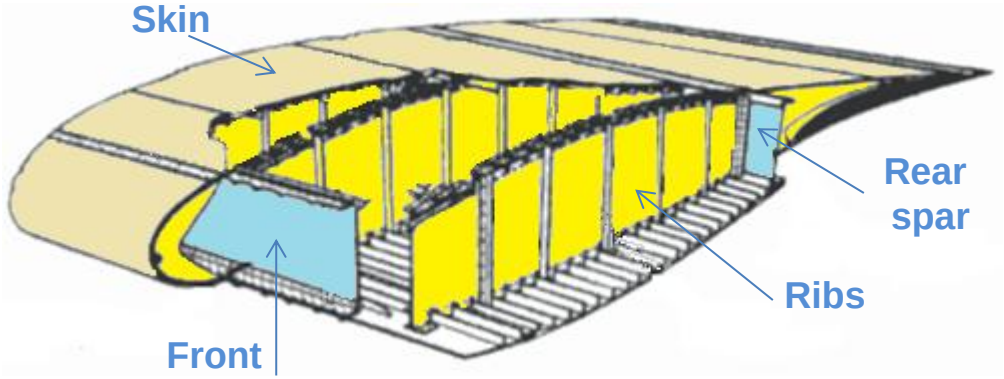
Rib perpendicular to the spars

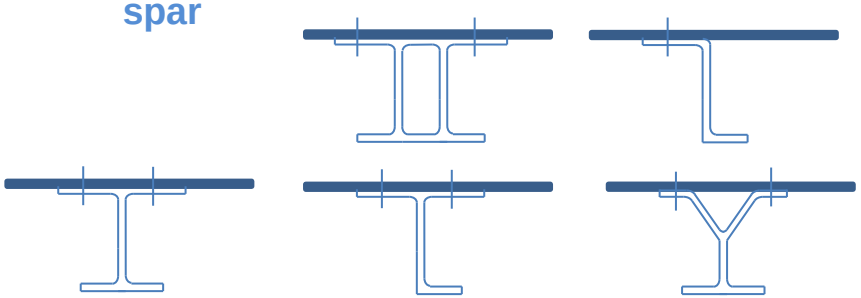
Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Wing structure

Skin

50-70% of the structural weight of the wing





Typical wing skin-stringer panels

It transmits aerodynamic forces to the longitudinal and transverse members

In some designs the spar caps resist the bending stresses, in other skin is the bending-load resistant element

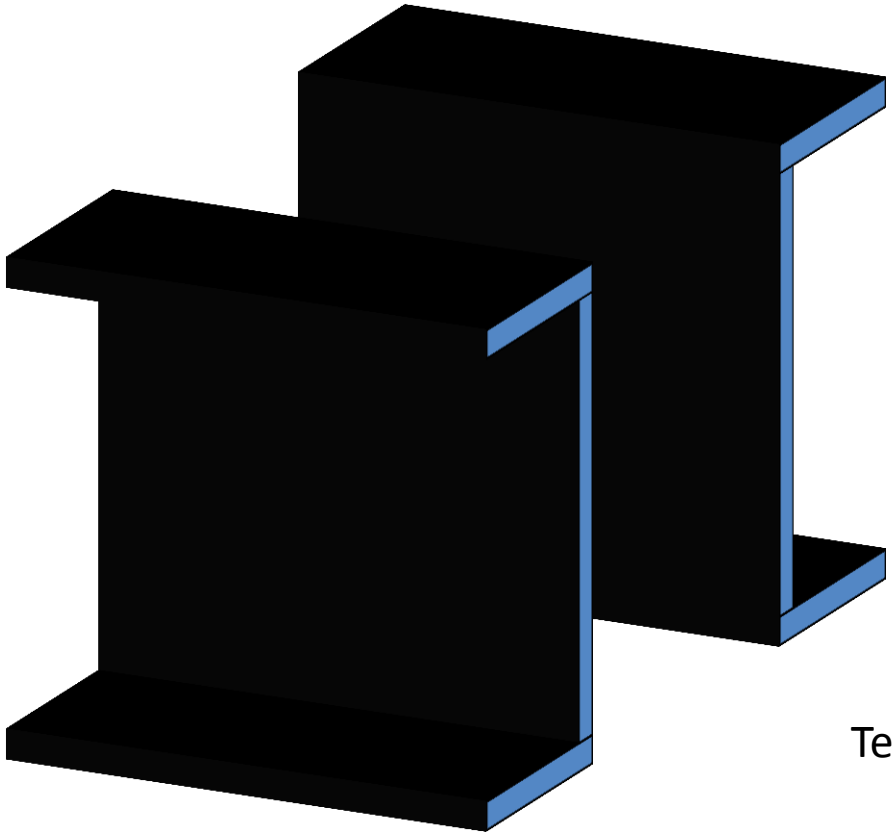
Integrally stiffened panels

Wing skins are machined from a thick plate to obtain the skin-stringer geometry

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Wing structure

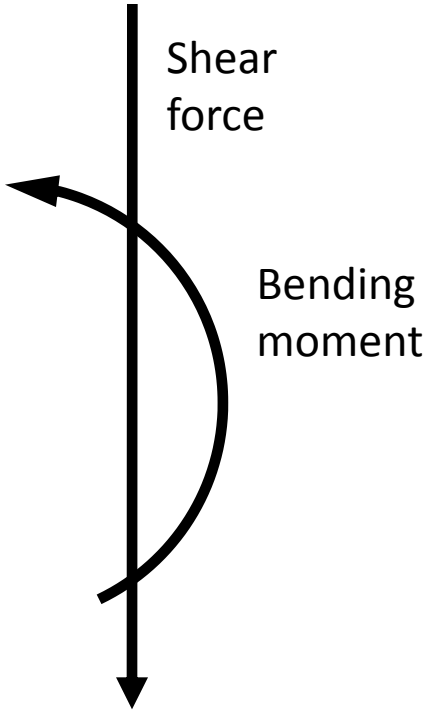
- **Wing box structure**



Compression

Shear

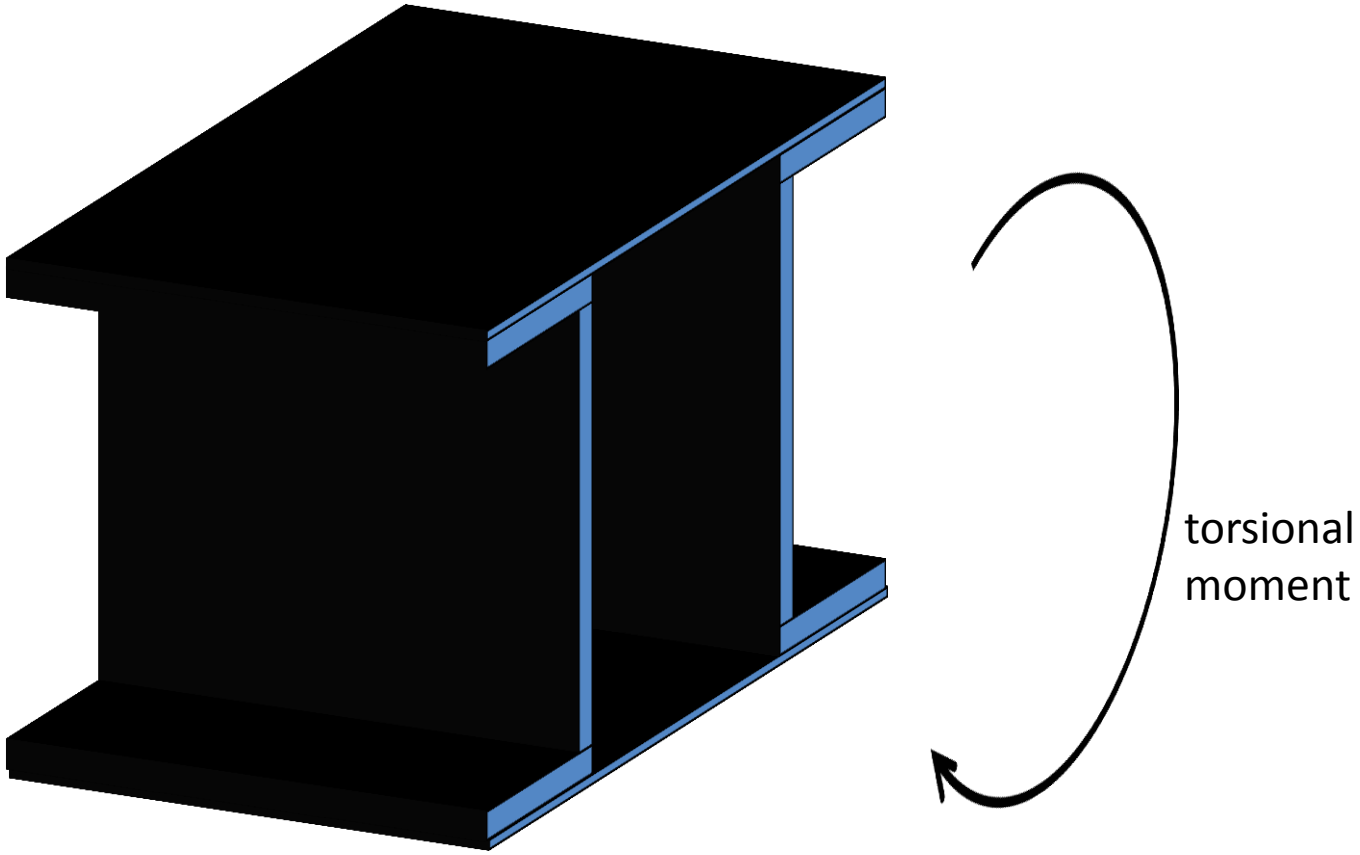
Tension



Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Wing structure

- **Wing box structure**



Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

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Fuselage structure

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

- **Fuselage functions**

The fuselage function is to carry the payload and support many the aircraft system. Thy connect the other structural element (wing and empennage)

Loads on the fuselage:

- ❑ Wing reactions
- ❑ Landing gear reactions
- ❑ Internal pressure

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

Fuselage types

Non stressed-skin structures

- Truss fuselage (1)
- Geodetic fuselage (2)

Stressed-skin Structures

- Corrugated (3)
- Monocoque fuselage (4)
- Semi-Monocoque fuselage (5)

Blériot XI

http://commons.wikimedia.org/wiki/Bl%C3%A9riot_XI?uselang=es#mediaviewer/File:Bleriot_XI_Thulin_2.jpg

Vickers Wellington

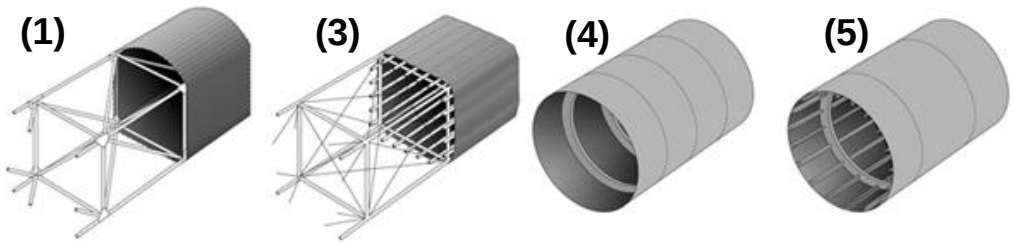
http://commons.wikimedia.org/wiki/File:Vickers_Wellington_Mk2.jpg

Ford Trimotor

http://commons.wikimedia.org/wiki/File:Ford_Trimotor_EAA.jpg?uselang=es

Rutan VariEze

http://commons.wikimedia.org/wiki/Category:Rutan_VariEze#mediaviewer/File:VariEze_in_flight.jpg



Author: Tosaka
http://commons.wikimedia.org/wiki/File:Airframe_(4_types).PNG?uselang=es

Airbus A350

http://commons.wikimedia.org/wiki/Airbus_A350#mediaviewer/File:A350_First_Flight_-_Low_pass_03.jpg

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

- **Fuselage types**

Truss fuselage

http://commons.wikimedia.org/wiki/File:Sopwith_Camel_taking_off,_Masterton,_New_Zealand,_April_2009.jpg?usela

Sopwith Camel, 1917

Most of the early aircraft used this kind of construction

The diagonal elements can be bars or wires

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

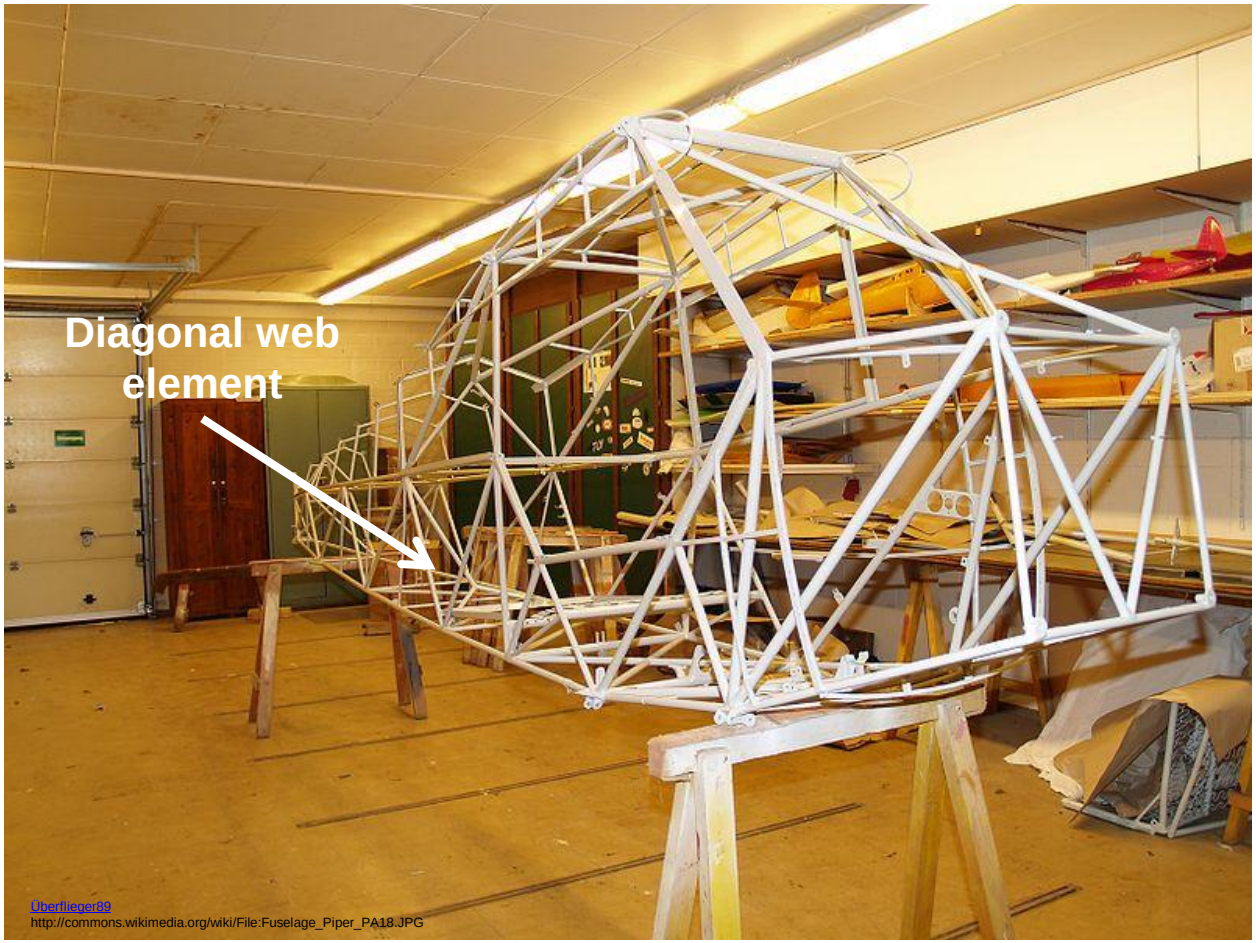
❑ Fuselage types

Truss fuselage

http://commons.wikimedia.org/wiki/Category:Super_18_Model_S18#mediaviewer/File:Super18-Super18-180.jpg
Photo: FlugKerl2

Piper PA-18

This type of structures are still used in small aircraft



Uberflieger89
http://commons.wikimedia.org/wiki/File:Fuselage_Piper_PA18.JPG

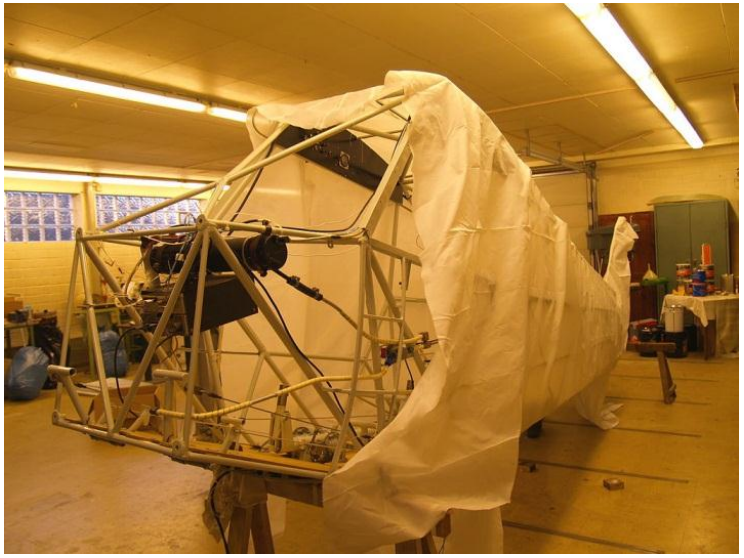
Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

❑ Fuselage types

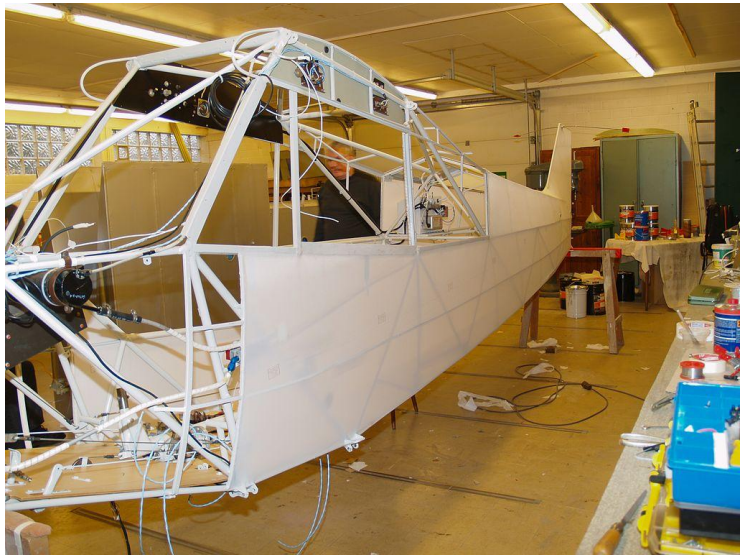
Truss fuselage

Non structural skin



http://commons.wikimedia.org/wiki/Piper_PA-18#mediaviewer/File:L18FuselageCUT.jpg

Überflieger89



http://commons.wikimedia.org/wiki/Piper_PA-18#mediaviewer/File:L18FuselageCT.jpg

Überflieger89

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Fuselage structure

❑ Fuselage types

Geodetic fuselage

Vickers Wellington
1936

Cobatfor
http://commons.wikimedia.org/wiki/File:Vickers_Wellington_Mark_X,_HE239_%27NA-Y%27,_of_No._428_Squadron_RCAF_(April_1943).png?uselang=es

Advantages:
Lightweight structure
High strength
Damage tolerance

Disadvantages:
Complexity

In this type of construction multiple flat strip stringers are wound about the formers in opposite spiral directions

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

❑ Fuselage types

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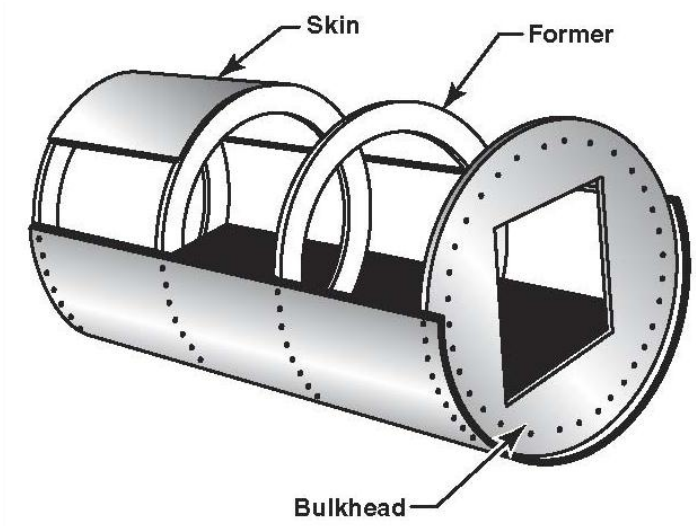
http://commons.wikimedia.org/wiki/File:Chapter_1_img_26.jpg?uselang=es



The skin supports the primary stresses

Deperdussin monoplane racer 1912

First monocoque design

Designed by Louis B`echereau

Monocoque fuselage

Virtually no internal framework

Only transversal elements (former) + skin

Stoddard-Hamilton Glasair III

http://commons.wikimedia.org/wiki/Category:Stoddard-Hamilton_Glasair_III#mediaviewer/File:GlasairIII-Landing.jpg

Used today in small aircrafts with complete composite structure

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

❑ Fuselage types

http://commons.wikimedia.org/wiki/File:Ju-Air_Junkers_Ju-52-3m_HB-HOS_Hahnweide_2011_03.jpg?uselang=es

Junkers Ju-52/3m
1932

http://commons.wikimedia.org/wiki/File:Ju52_civil.jpg?uselang=es

Ford Tri-Motor
1926

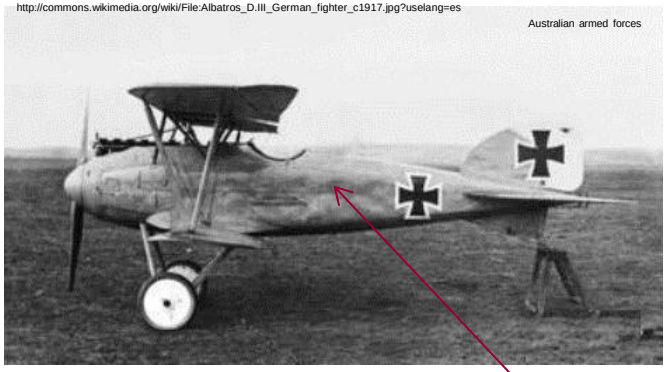
http://commons.wikimedia.org/wiki/File:Ford_Tri-Motor_(EAA)_(340406538).jpg?uselang=es

It had a structure with metallic corrugated skin

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

Fuselage types



Albatros D.III
1916

Streamlined fuselage

Semi-Monocoque fuselage

Longitudinal elements

- Longerons
- Stringers

Transverse element

- Frames
- Bulkheads

Stringer

Frame

Floor support beam

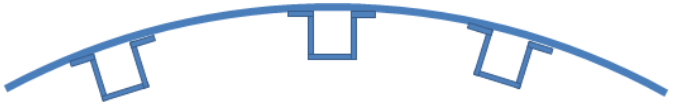
Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

❑ Skin and stringer

The skin carries the shear stresses produce by the internal forces (torque and shear force)

Typical fuselage skin-stringer panels



B-247

C-141
C-5

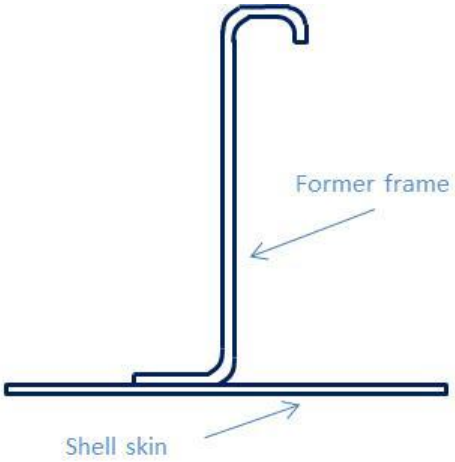
B-707
B-720 DC-10
B-727 Trident
B-737
B-747

L-188 L-1011
CV-880 A300
F-28

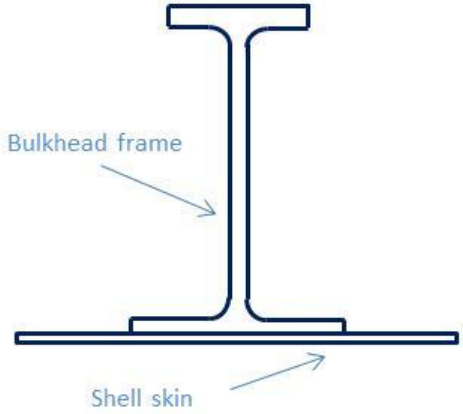
Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

❑ Frames



Former frame



Bulkhead

Author: Kolossos
http://commons.wikimedia.org/wiki/File:Fuselage-747.jpg?uselang=es

Frames function

- ❑ Maintain the shape of the fuselage
- ❑ Increase the buckling strength of the stringer

Distance between frames are around 500 mm

Frame thickness are 75-150 mm

Bibi95
http://commons.wikimedia.org/wiki/File:Exposition_-_Les_100_ans_de_l%27a%C3%A9rospatiale_-_Paris_-_4_Octobre_2008_(2913799759).jpg

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Fuselage structure

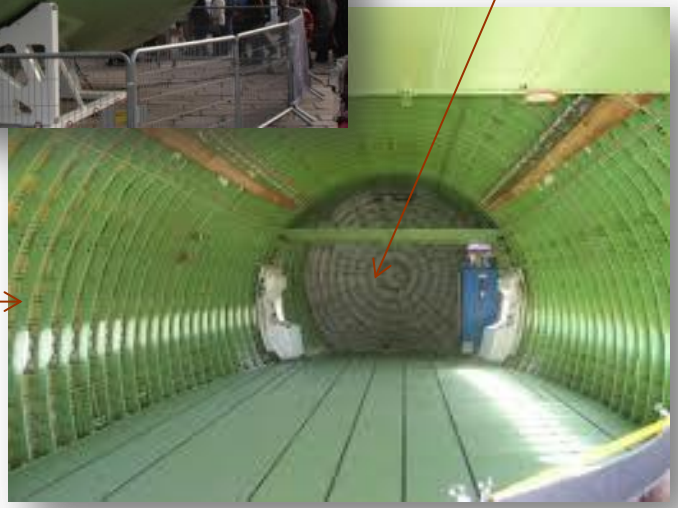
❑ Frames

Bibi95
http://upload.wikimedia.org/wikipedia/commons/1/19/Exposition__Les_100_ans_de_l%27a%C3%A9rospatiale_-_Paris_-_4_Octobre_2008_%282913796295%29.jpg

Front dome

Rear dome

Frames



NASA
http://commons.wikimedia.org/wiki/File:Shuttle_Carrier_Aircraft_interior_bulkhead.jpg

Types of frames

- Former frame
- Bulkhead
- domes

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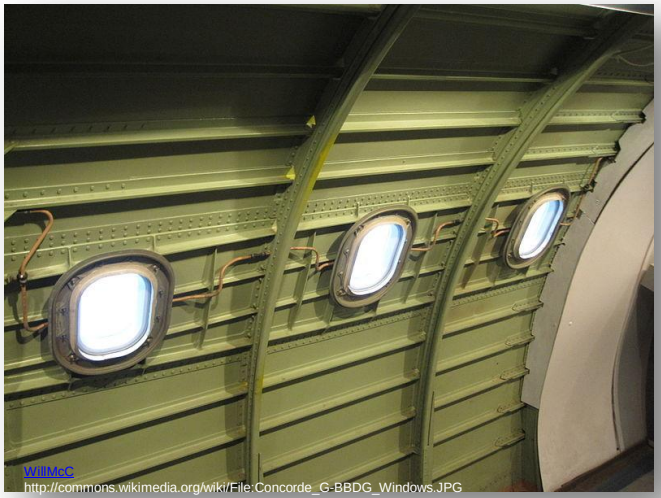
Fuselage structure

❑ Cutout

The fuselage has requirements for opening cut-out such windows, doors, service panels, hatches, bomb bays...



The direct load paths are interrupted and as a result the structure around the cut-out must be reinforced to maintain the required strength

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Stabilizers structure

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Stabilizers structure

❑ Stabilizers

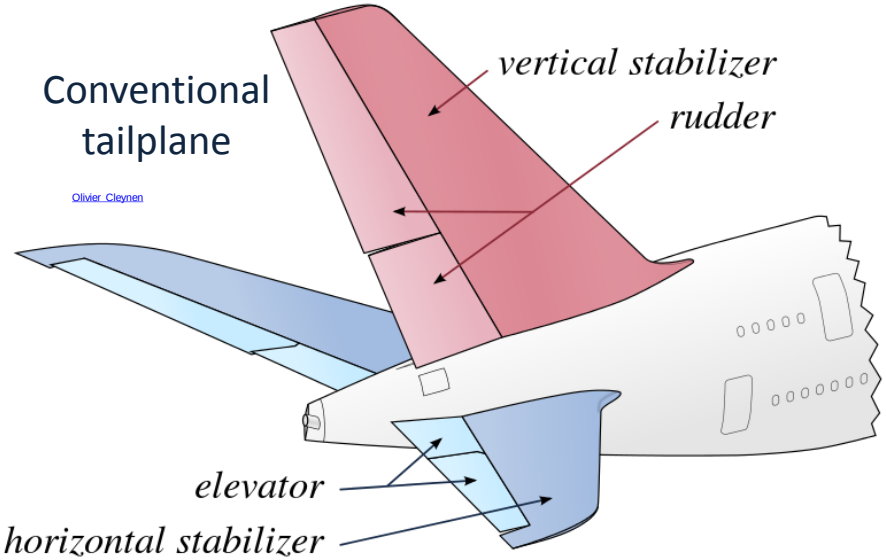
U.S. Air Force photo by Bobbi Zapka
http://commons.wikimedia.org/wiki/File:Global_Hawk_1.jpg

Alternate tailplane: V-tail

http://commons.wikimedia.org/wiki/File:Airbus-H%C3%B6henruder.jpg

Horizontal stabilizer of an Airbus A320

Conventional tailplane



Olivier Cleynen

http://commons.wikimedia.org/wiki/File:Tail_of_a_conventional_aircraft.svg?uselang=es

Stabilizer construction is similar to wing construction.

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Stabilizers structure

❑ Horizontal Stabilizers

http://commons.wikimedia.org/wiki/File:Boeing_707-131B,_Trans_World_Airlines_-_TWA_AN2228670.jpg?uselang=es

Boeing B07

Box construction with spars, closer light rib spacing (less than 250 mm) and skin without stringer

Low cost and high torsional stiffness

Box construction with spar, stronger ribs and skin with stringer

Low weight

http://commons.wikimedia.org/wiki/Lockheed_L-1011#mediaviewer/File:Lockheed.tristar.flying.arp.jpg

Lockheed L-1011

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Stabilizers structure

❑ Horizontal Stabilizers

http://commons.wikimedia.org/wiki/File:F-16_Falcon_Fighting_-_091119-F-7323C-292.jpg?uselang=es

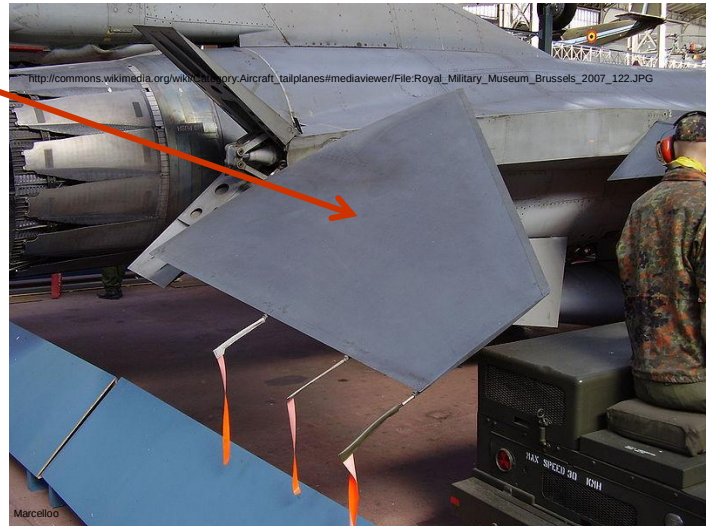
Lockheed Martin F-16

In fighter design, usually no spar + ribs construction is used

Two designs

a) Honeycomb + one spar

b) Corrugation multi-spar



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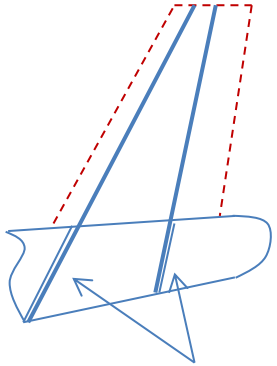
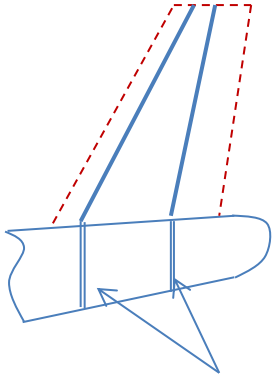
Stabilizers structure

❑ Vertical Stabilizers



Fuselage bulkheads

Tail box front and rear spar terminated at aft fuselage bulkhead



Fuselage bulkheads

Tail box front and rear spar terminated outside of fuselage

http://commons.wikimedia.org/wiki/Category:Aircraft_tails#mediaviewer/File:Airforce_Museum_Berlin-Gatow_322.JPG

Russavia
http://commons.wikimedia.org/wiki/File:N551VL_Gulfstream_G550_G-V-SP_(9489975740).jpg

The span of the t-tail fin is aprox. 1/3 than conventional tail

The vertical stabilizer must be made considerably stronger and stiffer to support the forces generated by the tailplane

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    Chapter 8 Wing Box Structure
    Chapter 11Fuselage

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