# Aerospace Structures

M.Sc. Andrés Camilo Herrera Araujo

# General information

Andres Camilo Herrera Araujo

B.Sc. Aeronautical Engineering

M.Sc. Engineering

andresc.herrera@upb.edu.co

# Introduction

This course involves the concept of aerospace structures through demonstrative methodologies (analytical forms) allowing to the student to have a specific vision on its professional development in the area of aero structures, in addition to a general definition of the aerospace structural components and its nomenclature.

The student must evaluate the processes of reparation, design and analysis of a structure

# Objectives

- To reinforce the basic concepts of aerospace materials and mechanics of materials

- Reforzar conceptos básicos de mecánica de materiales y materiales aeroespaciales


Boeing 777X Fuselage

# Objectives

- To identify technical details, necessary to understanding aerospace structures

- Identificar detalles técnicos necesarios para el entendimiento de una estructura aeroespacial


Airbus A400M

# Objectives

- To understand phenomena that affects aircraft structural design

- Entender los fenómenos que afectan el diseño de una estructura aeroespacial

Boeing 787 production line

# Objectives

- To count with the necessary knowledge in order to start an structural design specialty

- Contar con el conocimiento necesario para iniciar una especialidad en estructuras

Airbus Beluga carrying a satellite

# Objectives

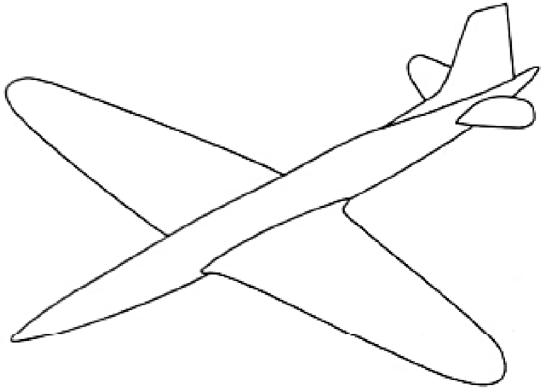
- To understand the basic details about structural airworthiness, the monitoring, and surveillance needed in order to follow regulatory issues

- Comprender los detalles básicos de una estructura aeronavegable, el monitoreo y supervisión necesarios para cumplir con el ente regulador

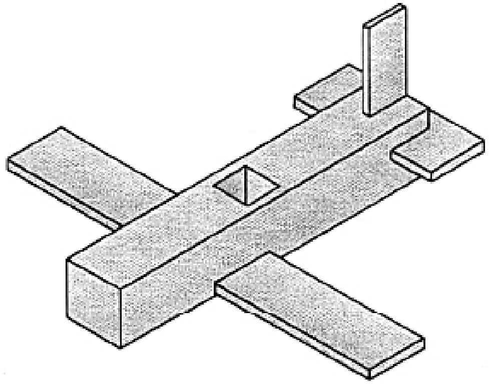

Sheet metal assembly

# Aircraft Configurations

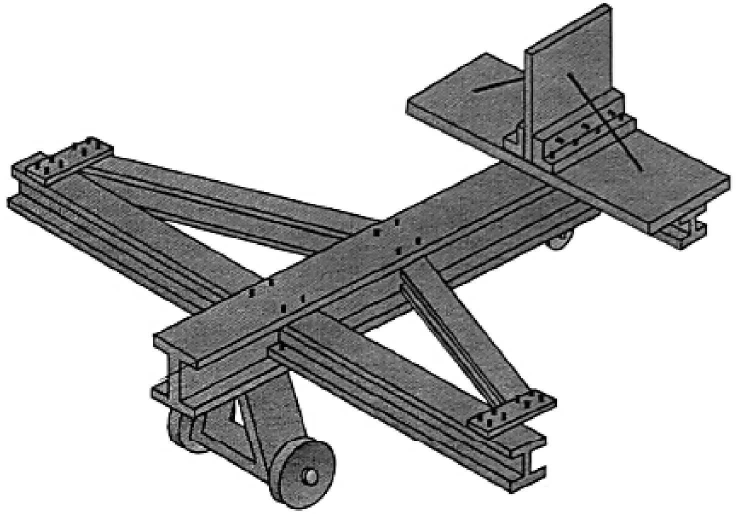
## "Ideal Airplane"



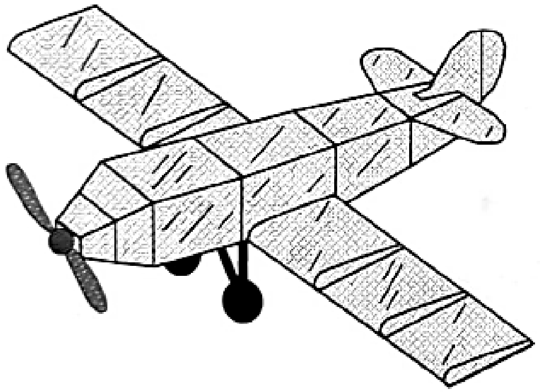
Aerodynamics Group



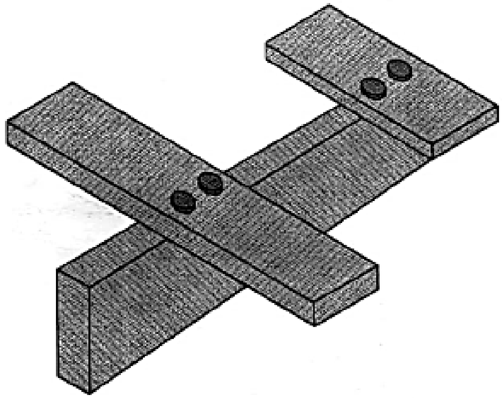
Design Group



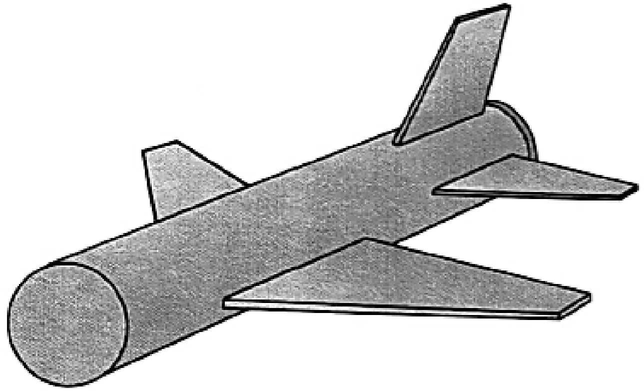
Stress Group



Weight Group



Manufacturing Group



Payload Group

# Schedule

**Unit 1**: History and context (1 weeks)

**Unit 2**: Review of aircraft structural sections and materials (2 weeks)

**Unit 3**: External loads (5 weeks)

**Unit 4**: Internal loads (5 weeks)

**Unit 5**: Repairs (3 weeks)

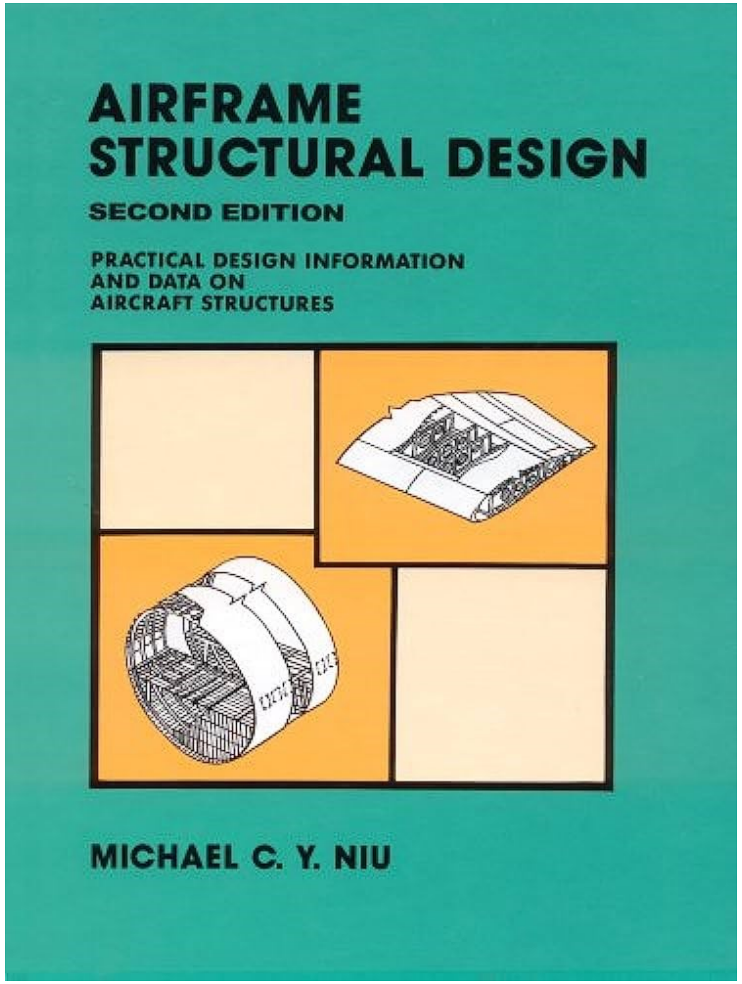
# Evaluation

- Presentation 10%
- Midterm 1 : 25% general (Feb 21*)
- Midterm 2: 25% external and internal loads (Mar 28*)
- Final Exam: 30% (May 19*)
- Final Project: 10% (repair case) (May 15 & 16*)

* Tentative dates

# References

- **Niu C (1988). Airframe structural design practical design information and data on aircraft structures. Conmilit Press**
- **Niu C (2011). Airframe stress analysis and sizing. Conmilit Press**
- **TH Megson. Aircraft Structures for engineering students**
- John Cutler (2005). Understanding aircraft structures. Blackwell Publishing
- R C Alderliesten (2018). Introduction to Aerospace Structures and Materials



# Agreements

- Please participate
- Respect your classmates
- You have learned some basic principles and techniques, and you will understand some other ones
- We can’t learn everything in one semester

# Structures

¿What are the structures for?

¿What are the challenges of designing for light weight structures?

¿Are the aeronautical and aerospace structures the same?

¿What are your thoughts on the future of aerospace engineering?

# Parts of interest

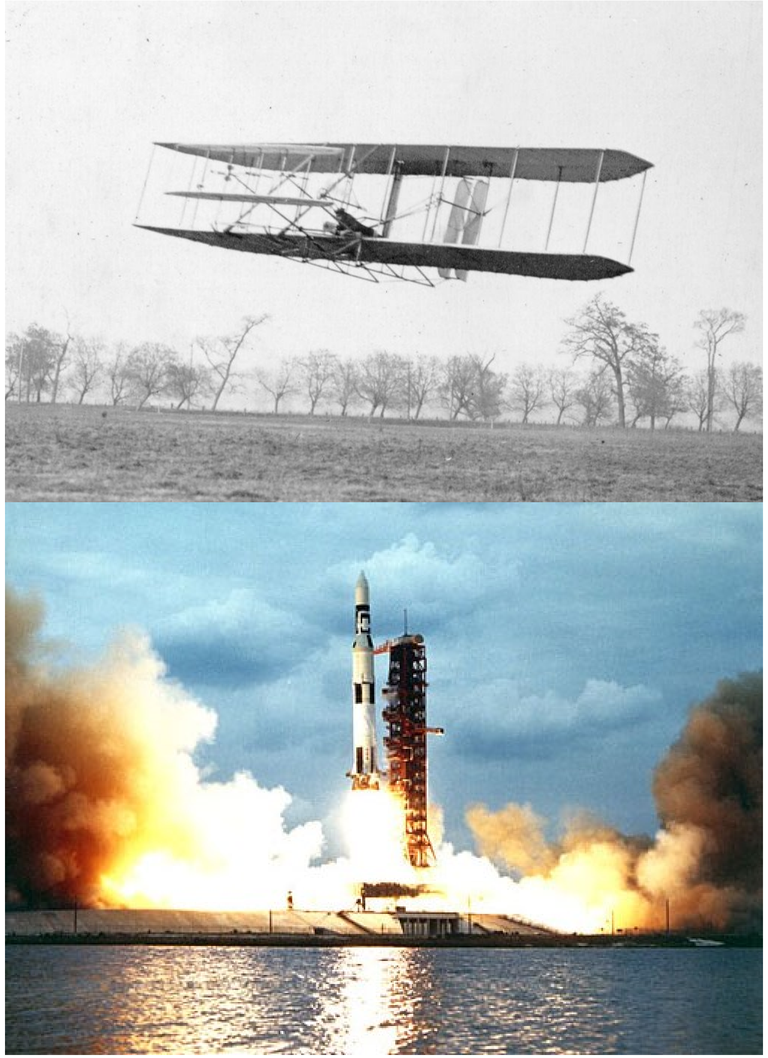
- Fuselage
- Empennage
- Wings
- Aerodynamic surfaces

**Mostly primary structures**

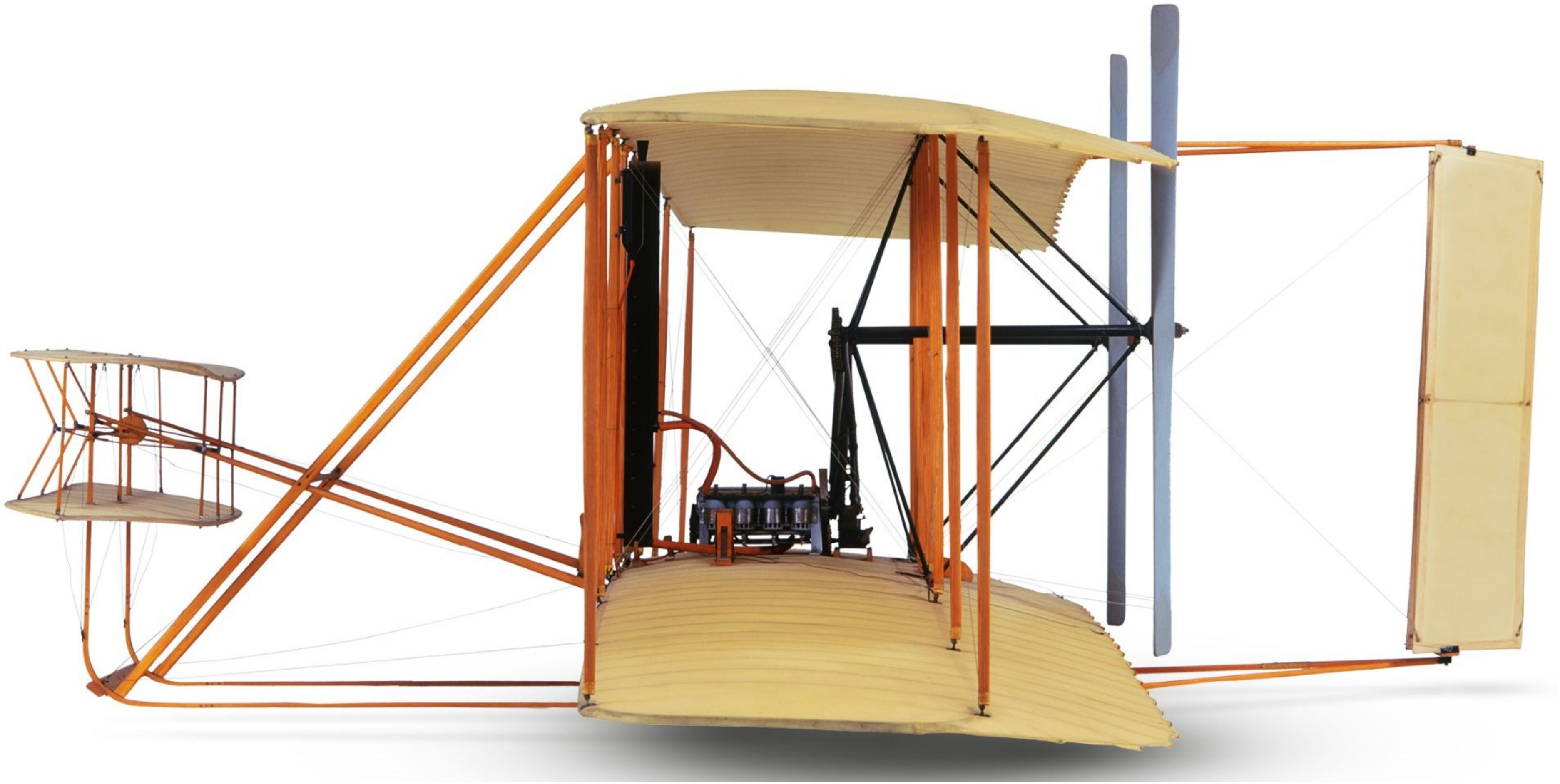
# Why studying aerospace structures

- Aircrafts have considerably changed since 1900's.

- A review of the aerospace structures development since the Wright Brothers Flyer to the NASA's Apollo 11 is a **large but important task**.



# Why studying aerospace structures

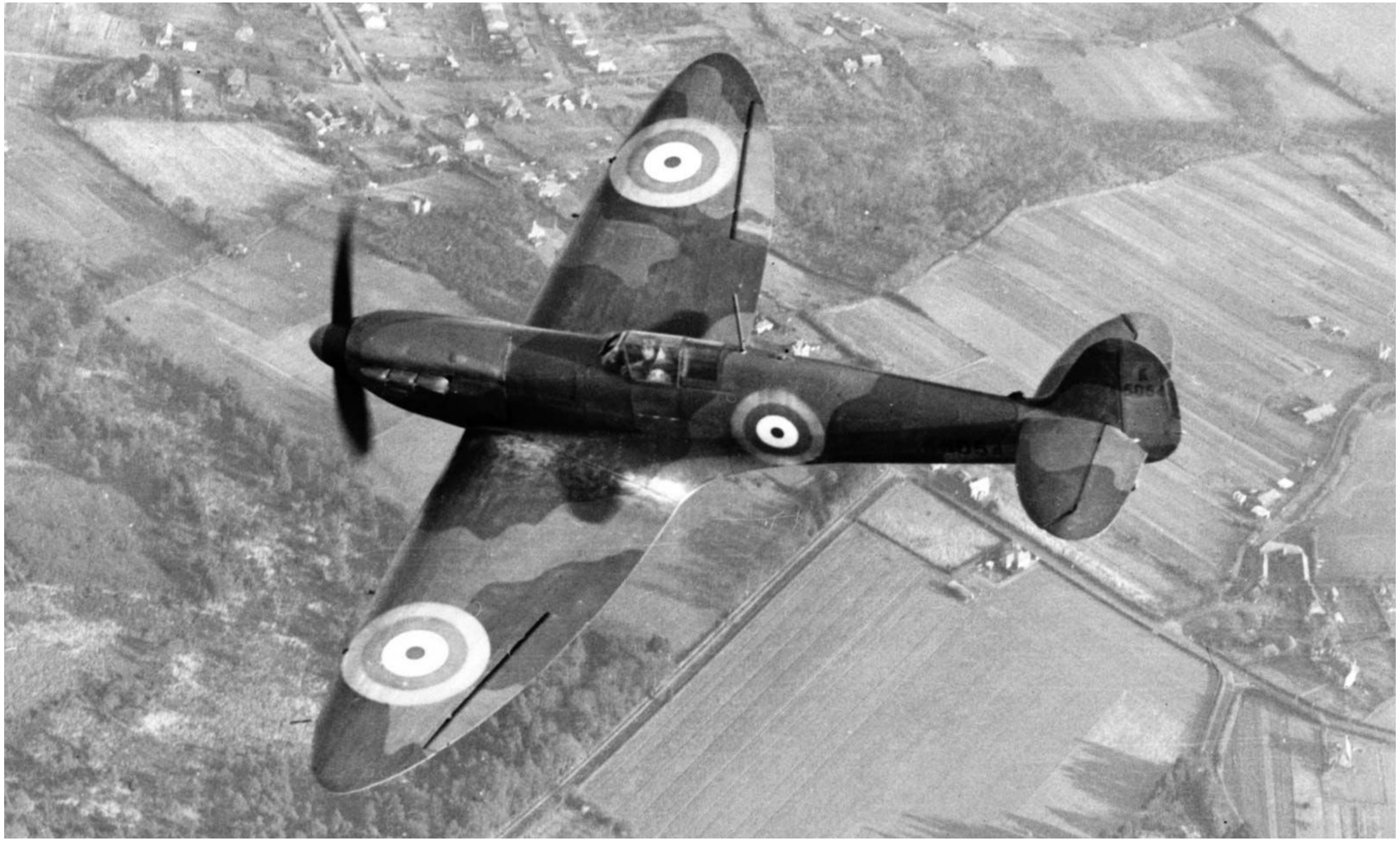


Wright Brothers Flyer

# Why studying aerospace structures

Albatros D.Va 1917

# Why studying aerospace structures



Supermarine Spitfire 1938

# Why studying aerospace structures


Douglas DC-3

# Why studying aerospace structures

Sikorsky R-4

# Why studying aerospace structures


North American F-86 Sabre

# Why studying aerospace structures

Saturn V

Lunar lander – Apollo 11

# Why studying aerospace structures


Boeing 727

# Why studying aerospace structures


Boeing 787-8


Airbus A350-900

# Why studying aerospace structures

Lockheed Martin F-22 Raptor

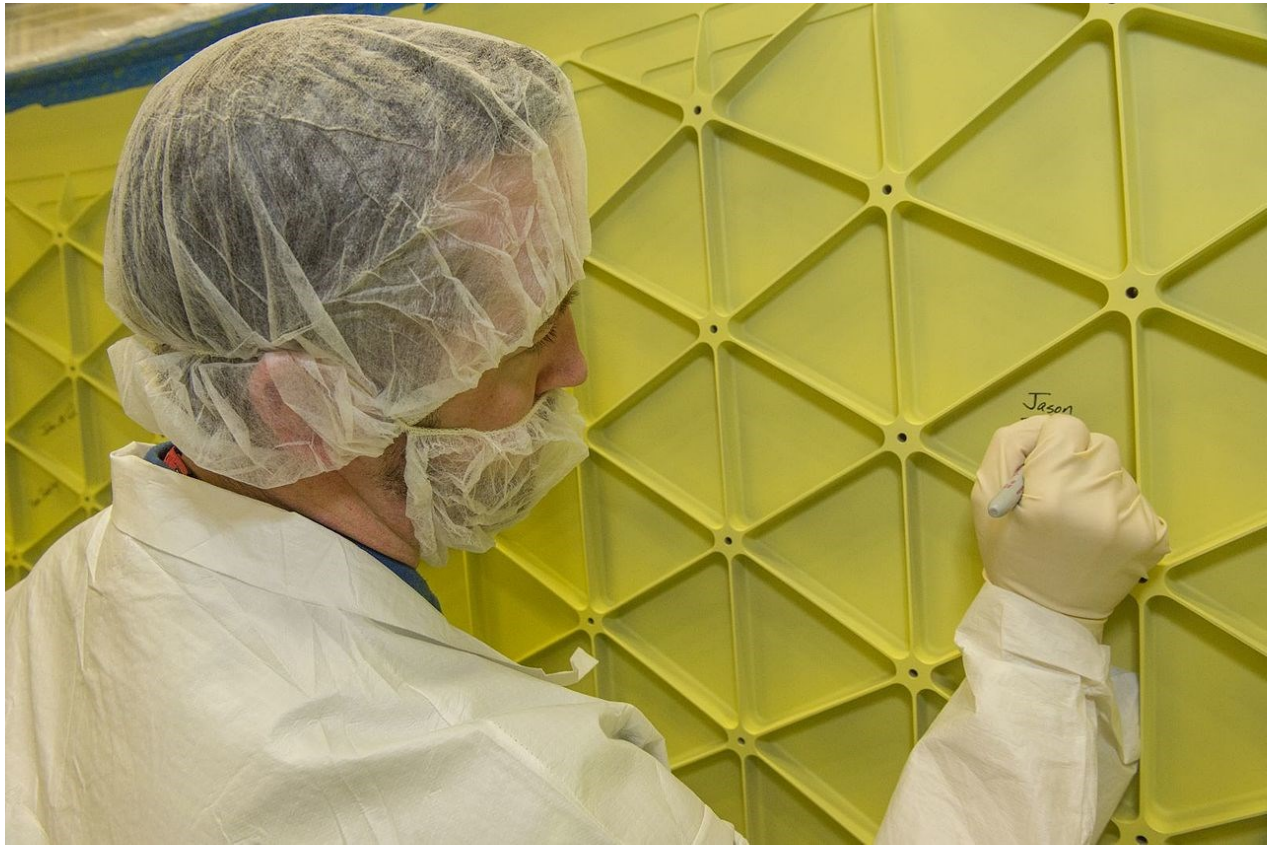
Northrop Grumman B-2 Spirit

# Why studying aerospace structures

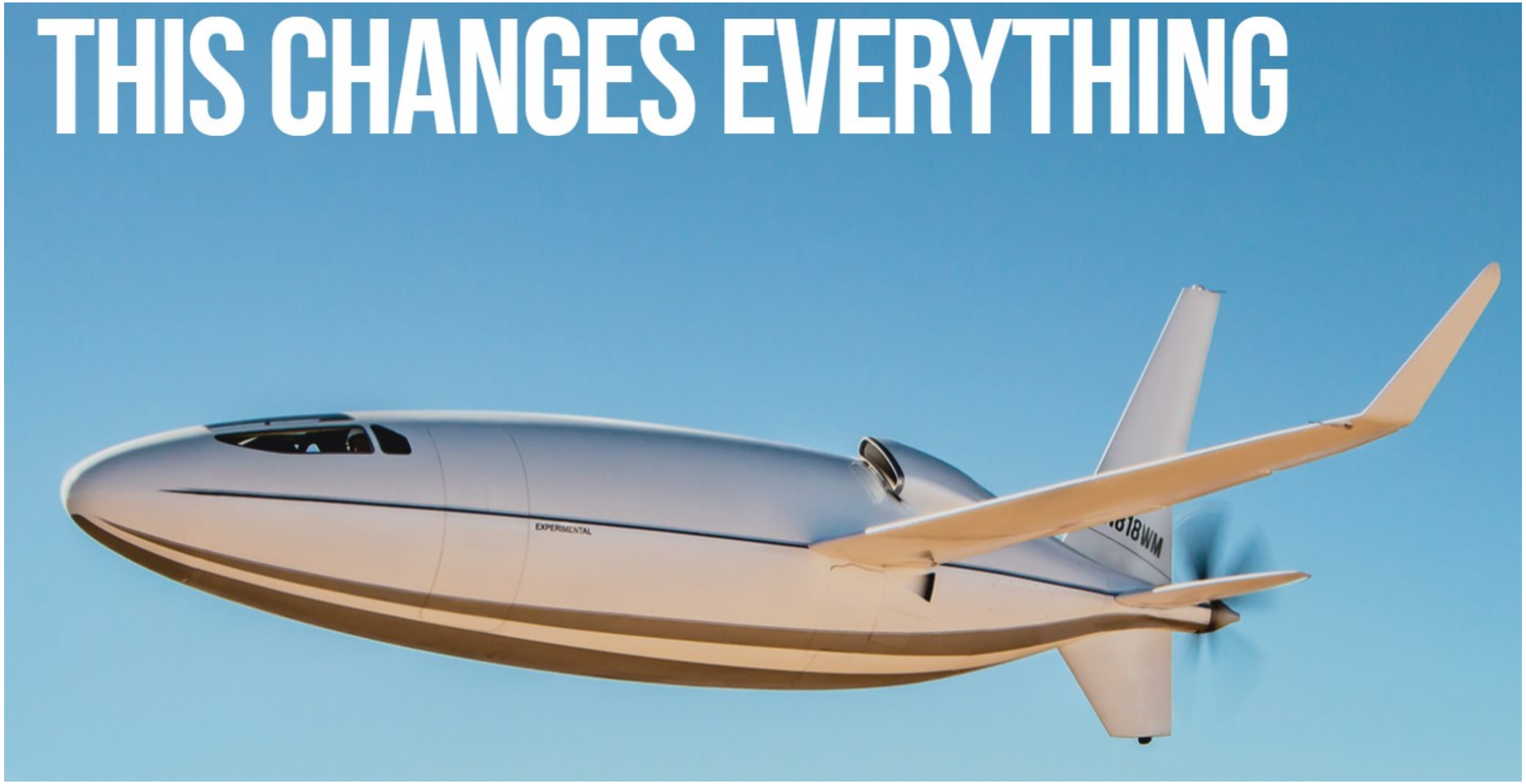
Blue Origin – New Glenn


SpaceX - Starship

# Why studying aerospace structures




# Why studying aerospace structures




https://ottoaviation.com

Celera 500L

# Generalities

An aircraft is a manned or unmanned machine which flies.

**Aircraft categories:**

- Fixed wing, rotary wing aircraft
- Propulsion aircrafts, gliders
- Lighter than air, heavier than air

Depending on characteristics, there may be other distinctions

https://media.tenor.com/kdS4R5BhtbMAAAAd/airplane-fly.gif

# Generalities



# Regulatory

- Federal Aviation Regulation: FAR 23 and FAR 25
- Reglamento Aeronáutico Colombiano: RAC 23 and RAC 25. (LAR 23 LAR 25)
- EASA: CS 23 and CS 25
- Air Transport Association System iSpec 2200, (ATA 100, from 51 to 57)

IATA

AERONÁUTICA CIVIL
Unidad Administrativa Especial

EASA
European Aviation Safety Agency

Code of Federal Regulations
Reader Aids :: Insight Into the eCFR

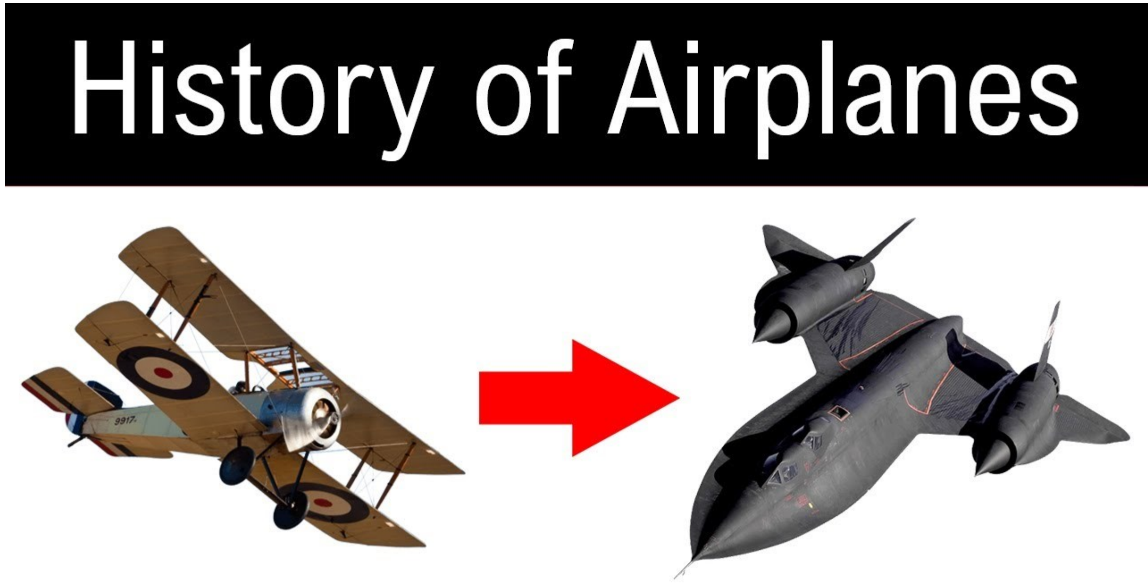
# Aerospace engineering fields

a) Aerodynamics
b) Propulsion
c) Avionics
d) Miscellaneous systems (hydraulics, electronics, **structural**, among others)

# History

State of the art vary among aerospace fields

- Propulsion engines evolved in 14 years from 12 hp to 2000 hp
- By contrast, although materials have evolved, aero structures have not too much



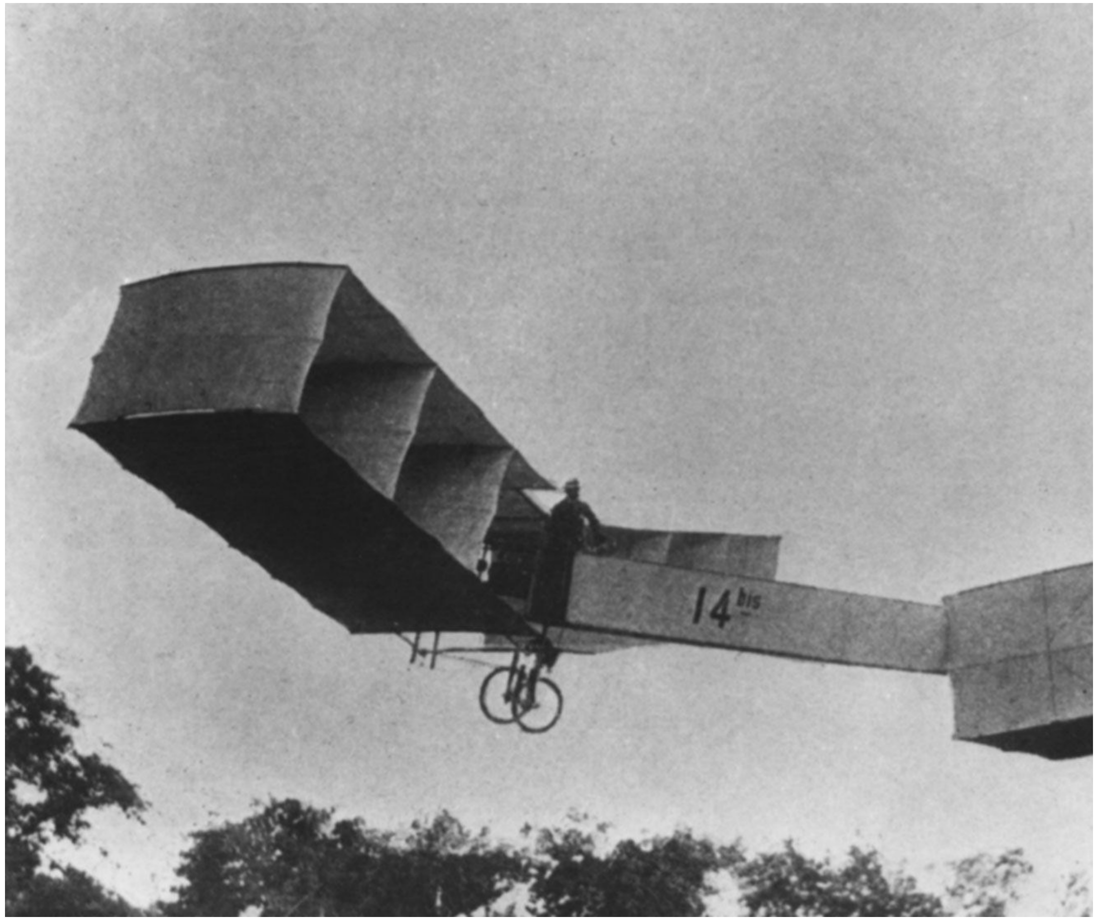
# History

- New material and manufacturing developments carried this evolution

- Since struts to extremely smooth aerodynamic surfaces


# History

During the early years, aircraft structural design relied more on intuition and empirical rules than theoretical principles or analysis



# History

- George Cayley y Otto Lilienthal 1890 ’ are considered the fathers of aviation

- They developed gliders made of timber (willow) and fabric (cotton). A deeply study of bird wings was made

- First tries for implementing stations and control surfaces

# History

Octave Chanute (1890's) aviation pioneer, civil engineer (bridges, railways).

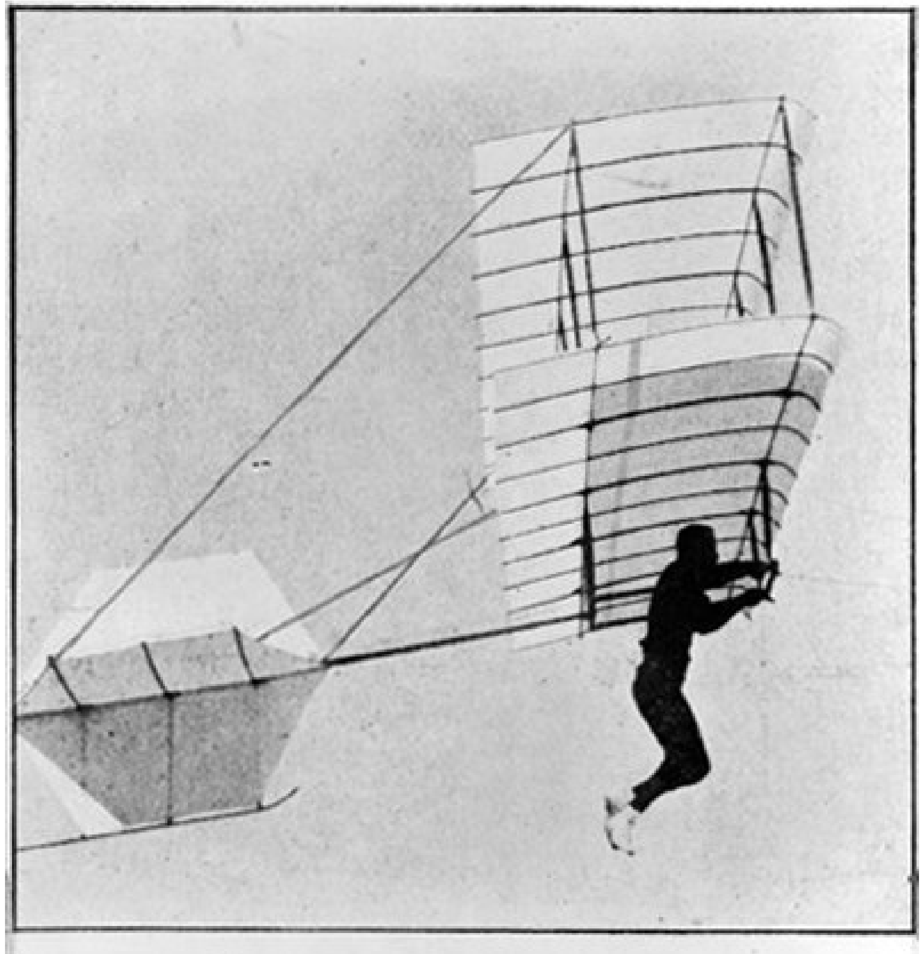
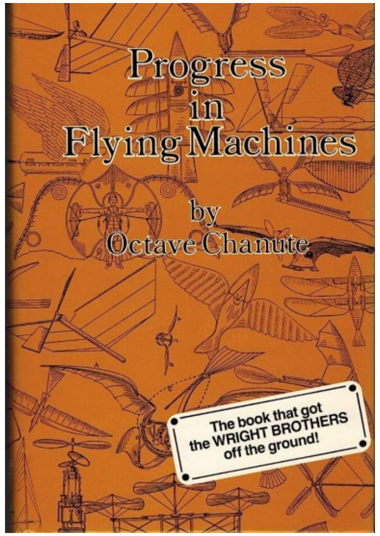


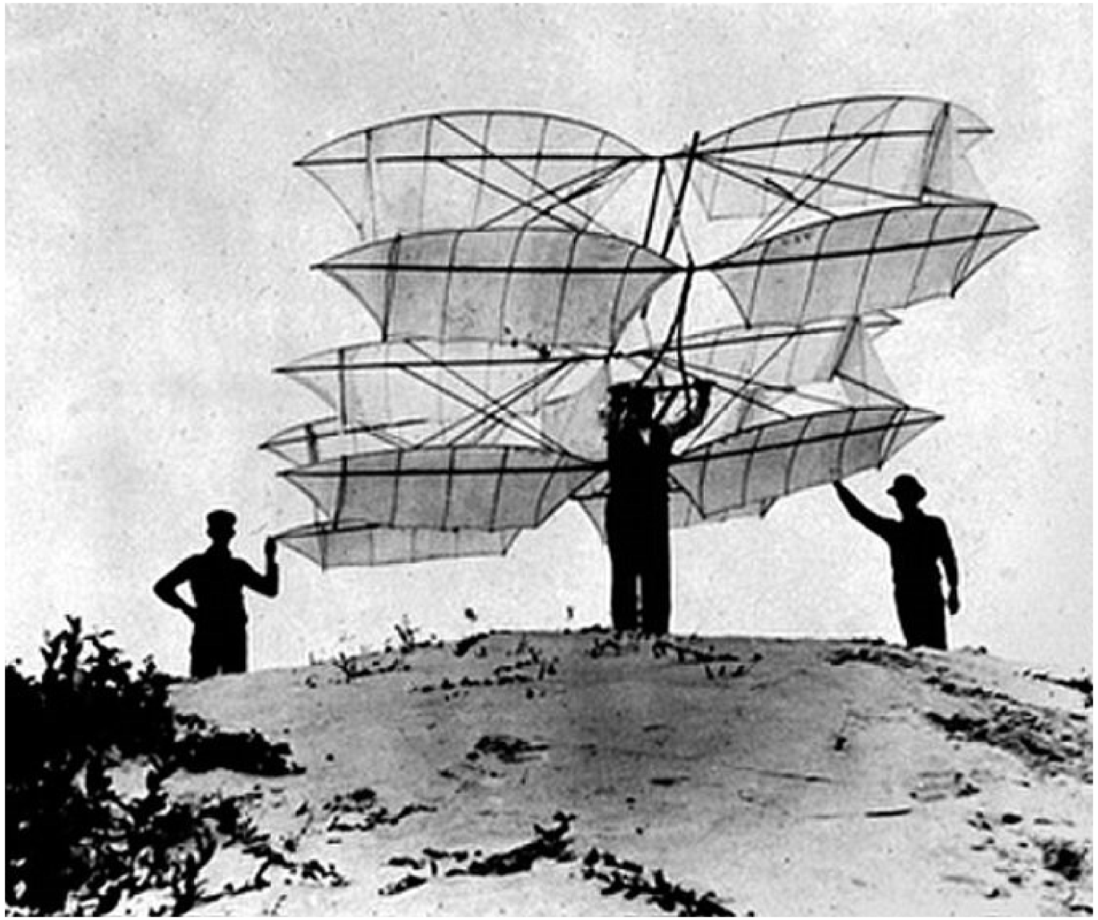
Fig. 39: O. Chanutes Zweidecker im Fluge.

# History

His contribution:

- Progress in Flying Machines (book).
- First biplanes with supports and wires



# History

•Previous knowledge was condensed successfully by Wright Brothers

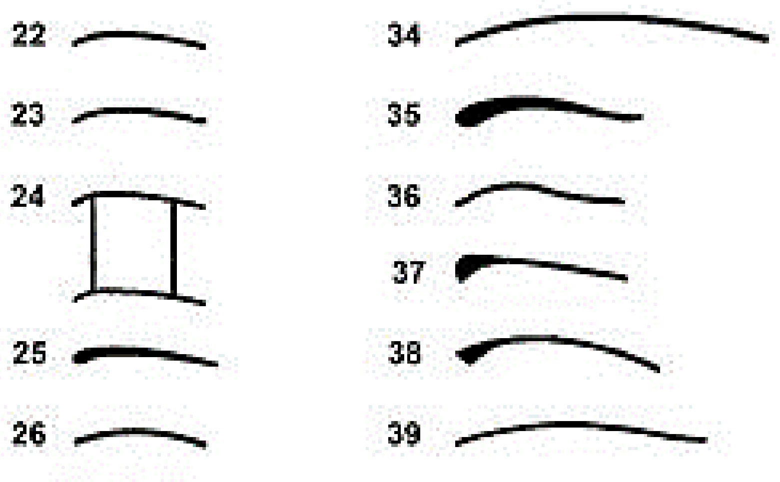
•Aircrafts heavier than air was conceived by Wright Brothers

•Main materials, timber, wires, and fabric Clearly the biplane form wasn't original

December 17th, 1903

# History

The Wrights made preliminary tests on over 200 wing shapes, then thoroughly investigated 57 of the most promising. The foils are made of sheet steel; thicker portions are built up with wax.




https://www.wright-brothers.org/Adventure_Wing/Hangar/1901_Wind_Tunnel/1901_Wind_Tunnel.htm

# History

- If we look in detail, there's no doubt of a complexity design in the wing structural design
- Among two planes, a rectangular frame is formed Wires are used for stability, and avoid the collapse
- The two wings, one above other, creates a lightweight but stiff structure

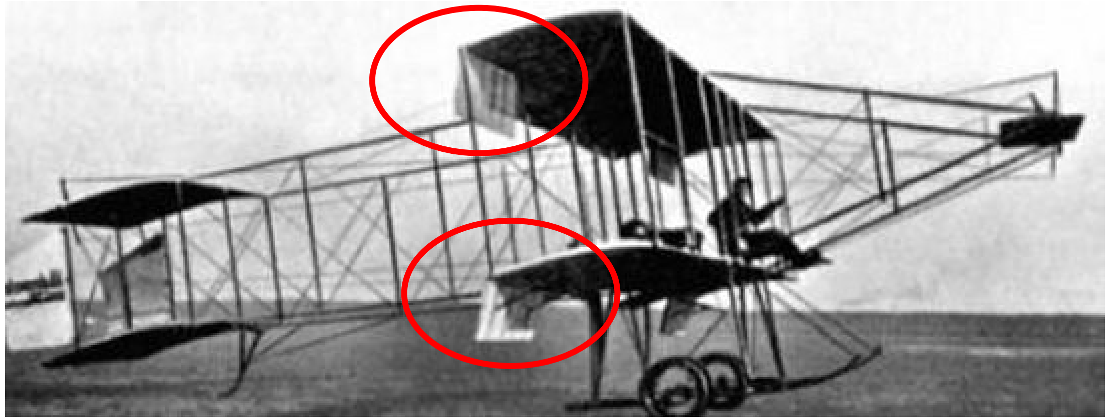
# History

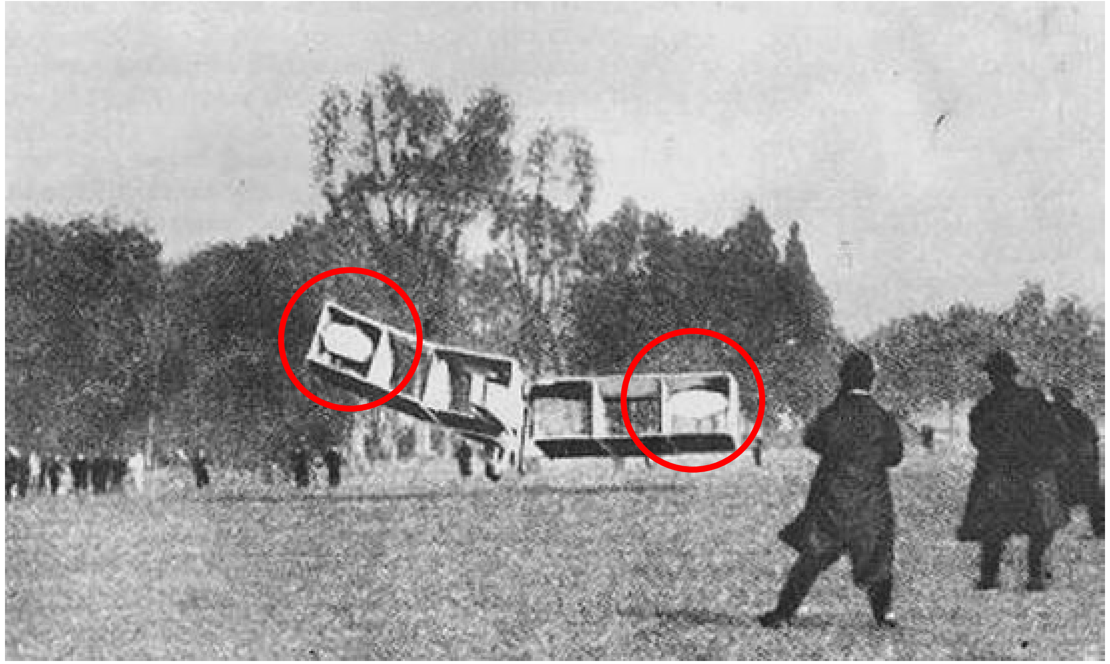
- The Wright Brothers understood structures so well that they arranged the fabric cover for their wings so that the weave was oriented plus or minus 45 degrees with respect to the spars. **This had the effect of resisting in plane shear forces**.

- Wing warping

# History

- Henri Farman 1908 (France) and Santos Dumont
- Used small devices he called ailerons to provide lateral control
- Ailerons replaced a type of control called wing warping in which the pilot could deform the wings asymmetrically to provide roll control



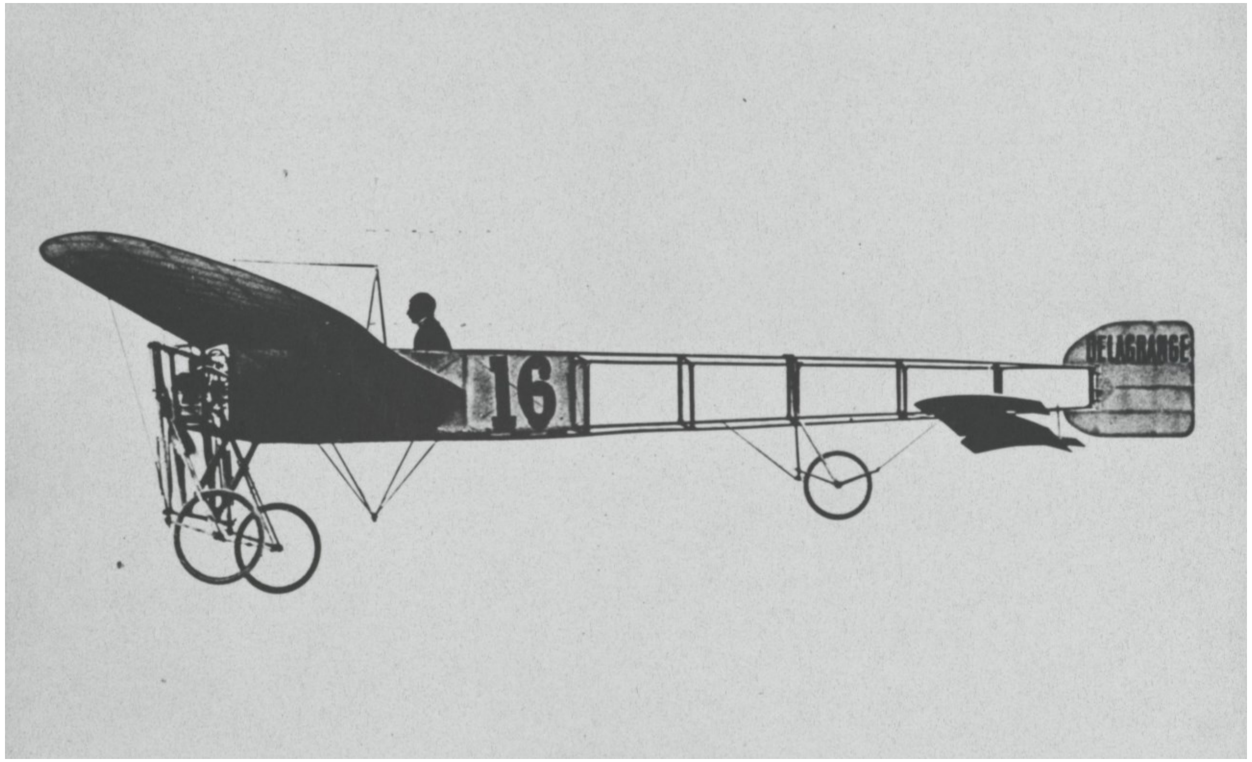


# History

- Monoplane designs began to appear. Louis Bleriot (1909)

- These new monoplane designs had external wire supports attached to the wing and ending in a central post above the fuselage

- English Channel (canal de la mancha)



# Parenthesis in history

- Louis Bechereau (French), 1911.
- He formed the fuselage out of multiple layers of wood to create a streamlined shape
- The wood layers were glued together with their grains running in different directions to strengthen the skin
- Swedish engineer Ruchonnet called the new technique monocoque construction

# Parenthesis in history

This airplane won the Gordon Bennett Cup in 1913 with a speed of 200.8 km/h

# History

- With the beginning of the WWI, engines started to increase in size and power (Axial reciprocating engines)
- Bigger engines, required new structural materials. Loads started to increase
- Therefore, some wood parts were replaced by metallic materials


Thomas-Morse S-4C Scout

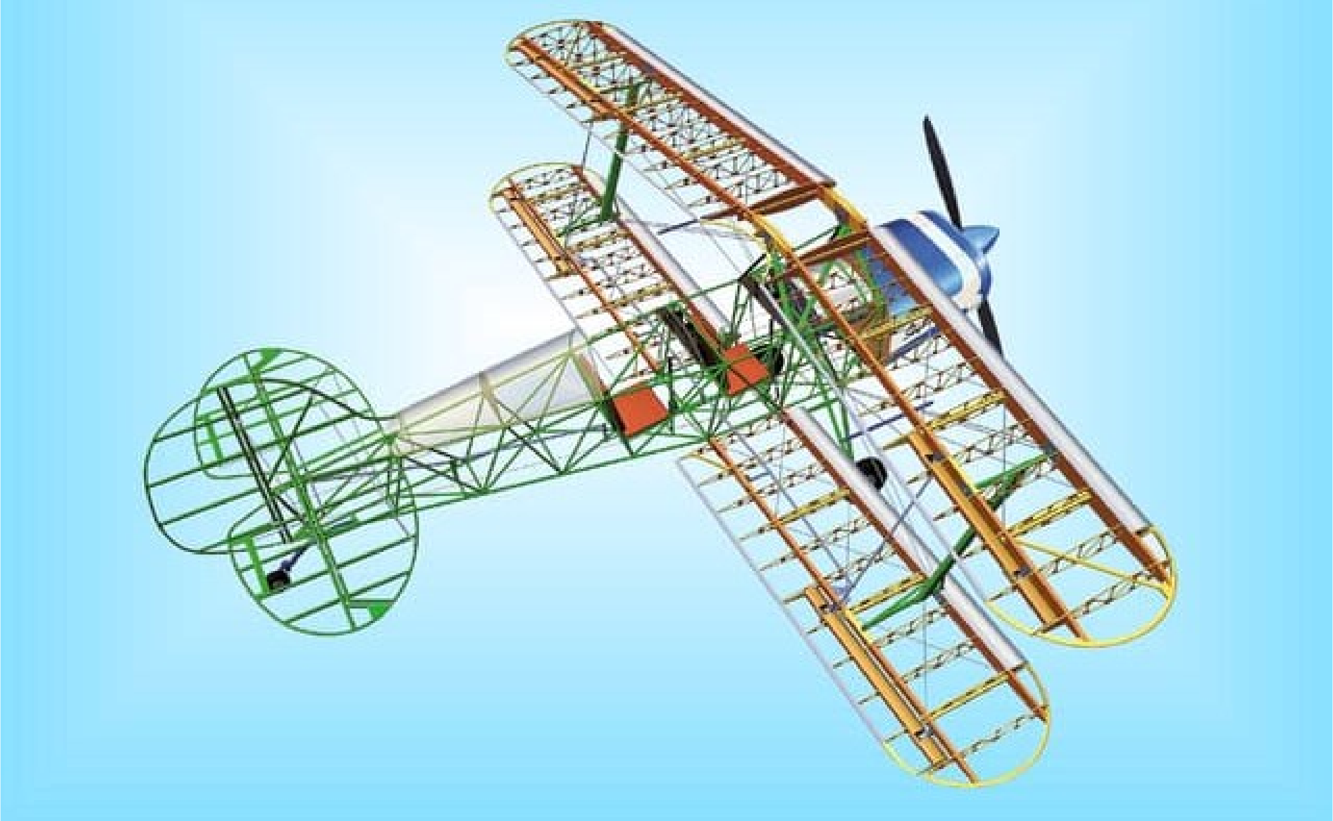
# History

Sopwith Camel F11 UK

# History

- Engineers were encouraged by aerodynamics and propulsion to design more efficient aircrafts in terms of structures

- Trusses started to be a fundamental part of the aero structures

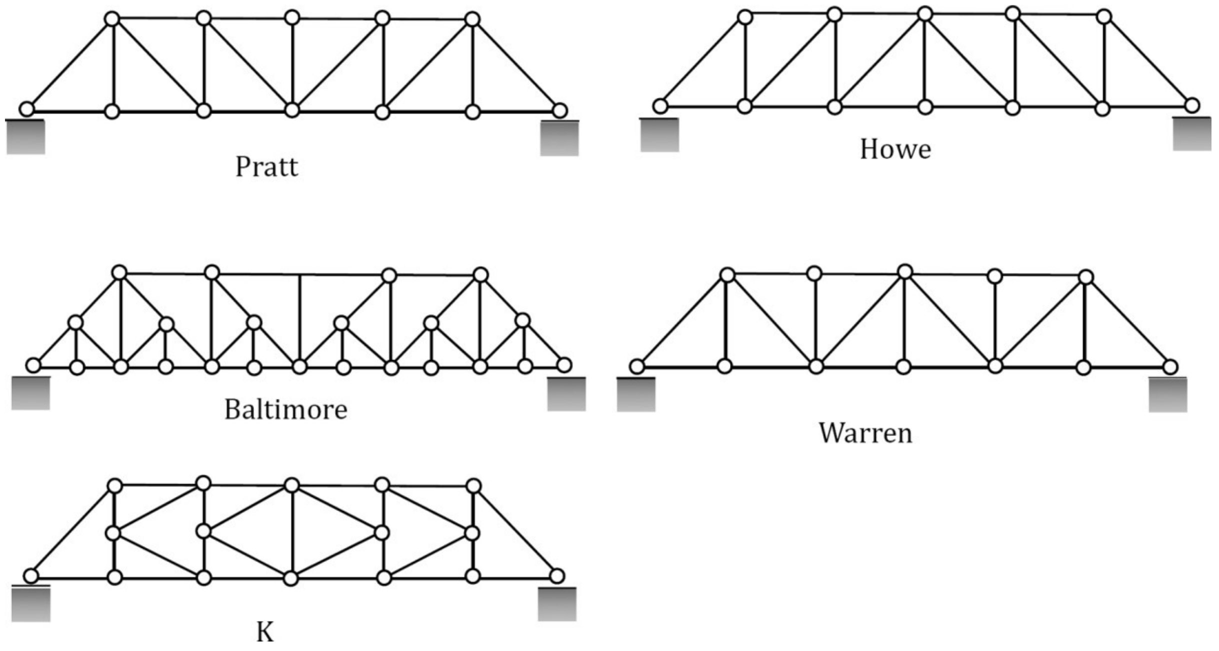


# Trusses

Trusses are structures commonly conceived by two principal elements:

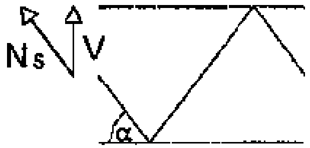
- Parallel elements (longerons)
- diagonal members

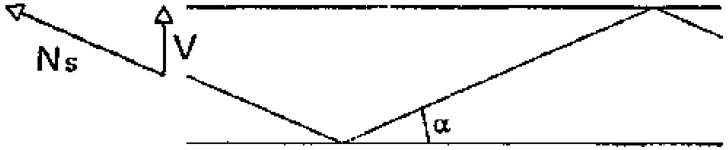
Loads are applied in joints, and are distributed by the structure



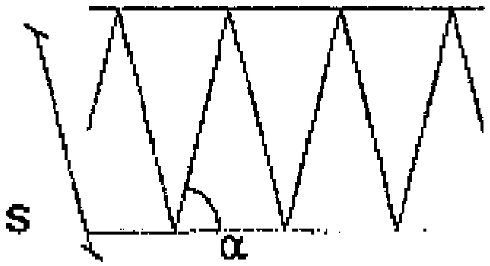
# Trusses

- The larger the slope, larger the load
- The greater the angle is, there will be necessary a large number of elements



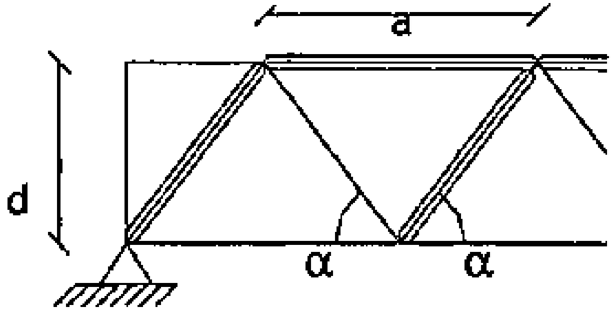
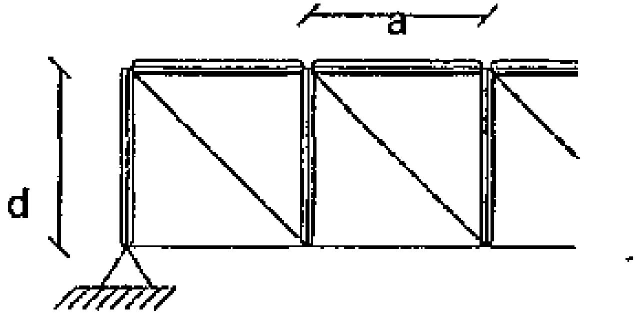




$(N_s \rightarrow \infty \quad \text{cuando } \alpha \rightarrow 0)$

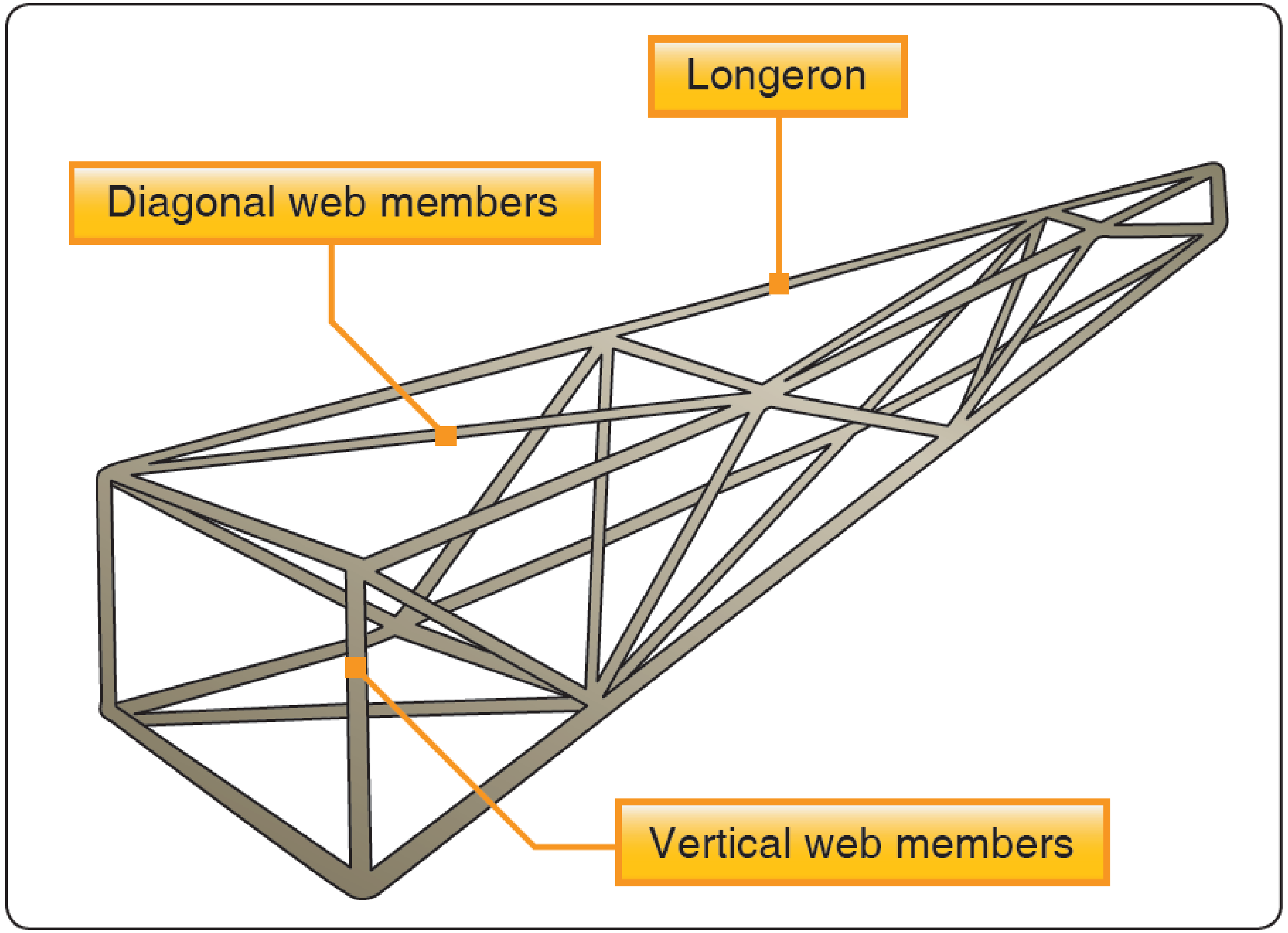



$(\text{cuando } \alpha \rightarrow 0 \quad \sum S_i \rightarrow \infty)$

# Trusses (Optimal values)

| | | | ÓPTIMO | RAZONABLE |
|---|---|---|---|---|
| Triangulación simétrica |   | | $\alpha = 45^o$<br>$a = 2d$ | $45^o \leq \alpha \leq 60^o$<br>$2d \geq a \geq d$ |
| Montantes y diagonales |   | | $a = \sqrt{2}d$ | $2d \geq a \geq d$ |

# Trusses (aircraft structure)

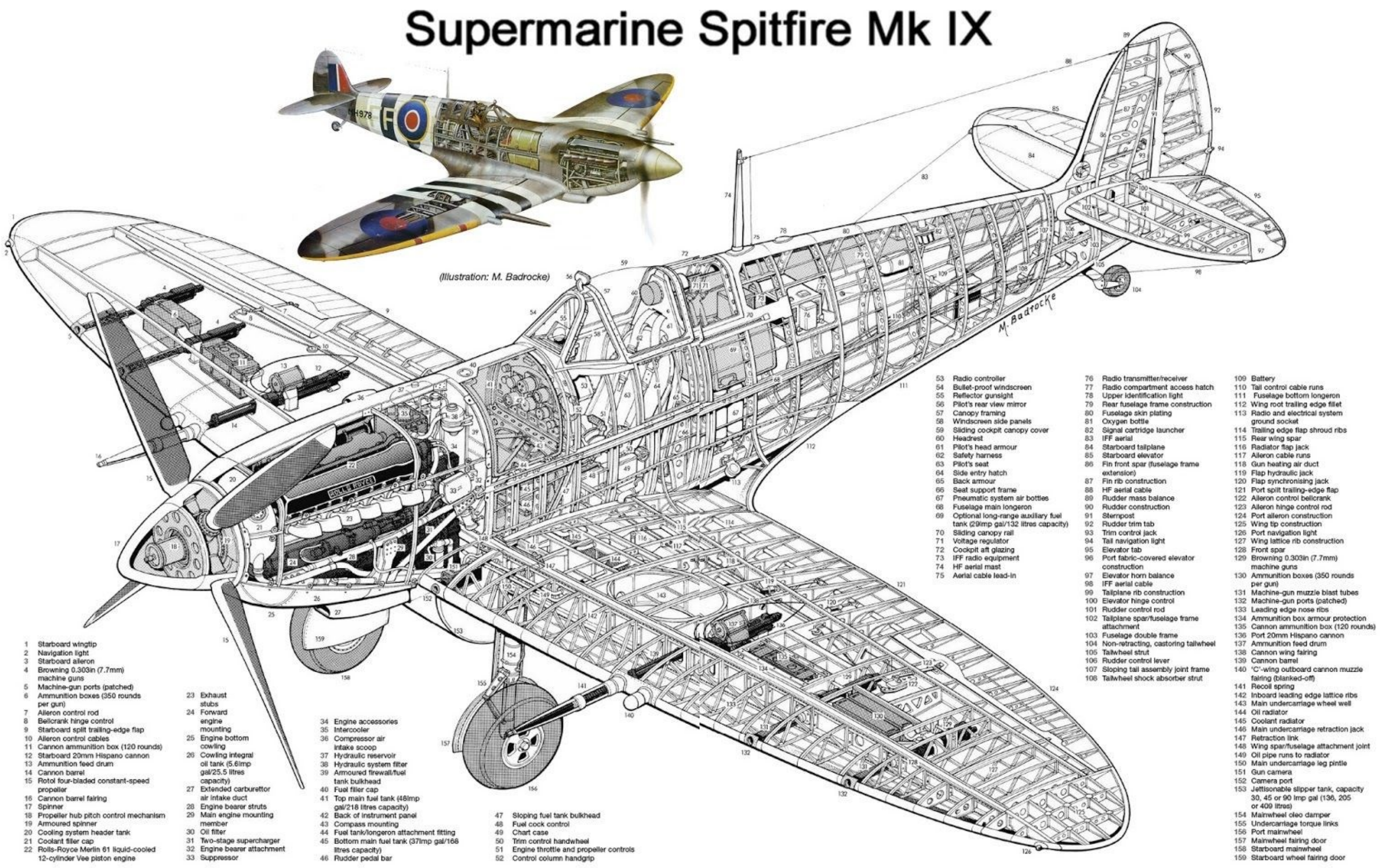



# WWI structures

Post WWI, the development is focused on monoplane aircrafts

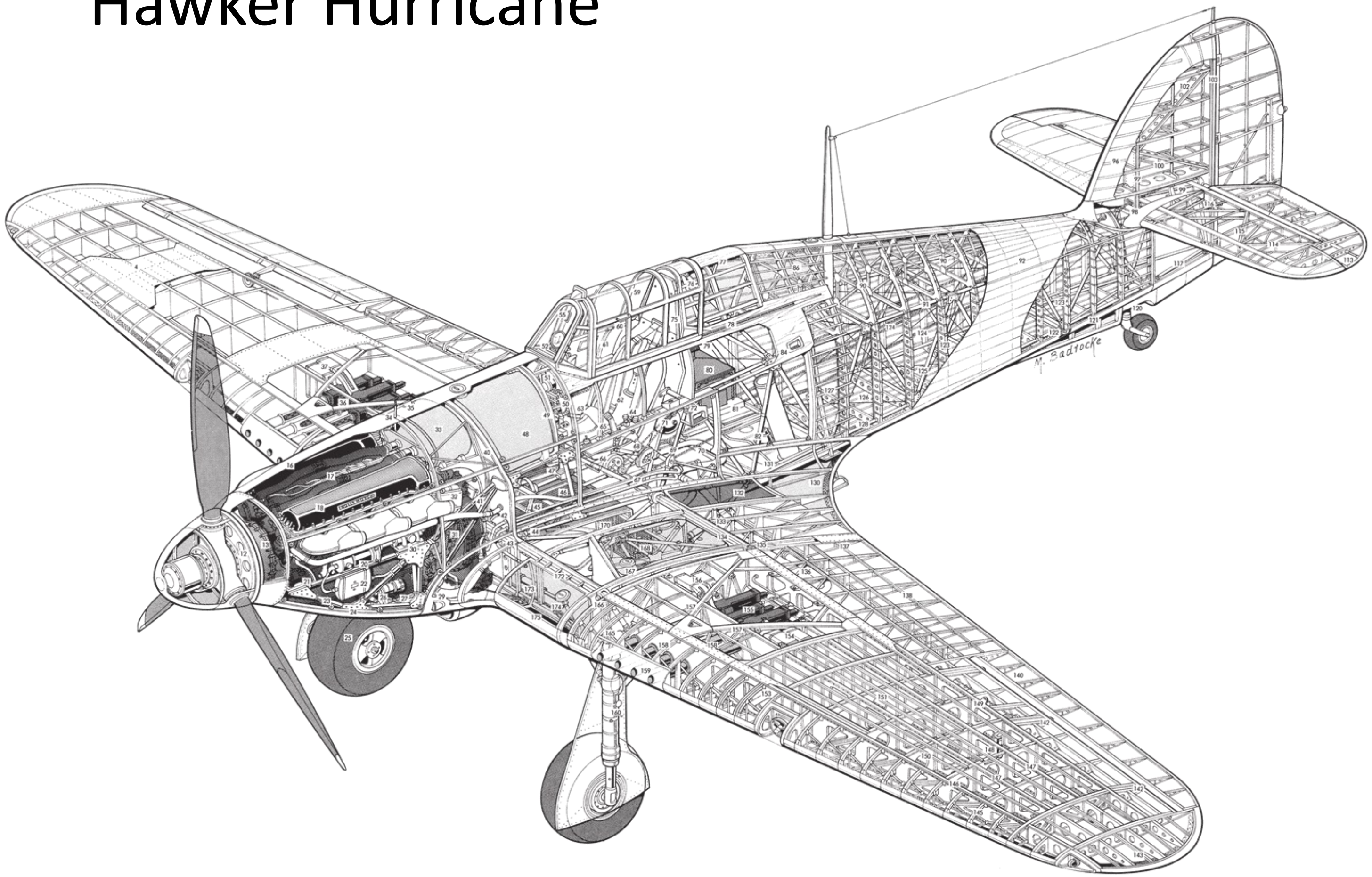

Spirit of St. Luis

# WWII structures



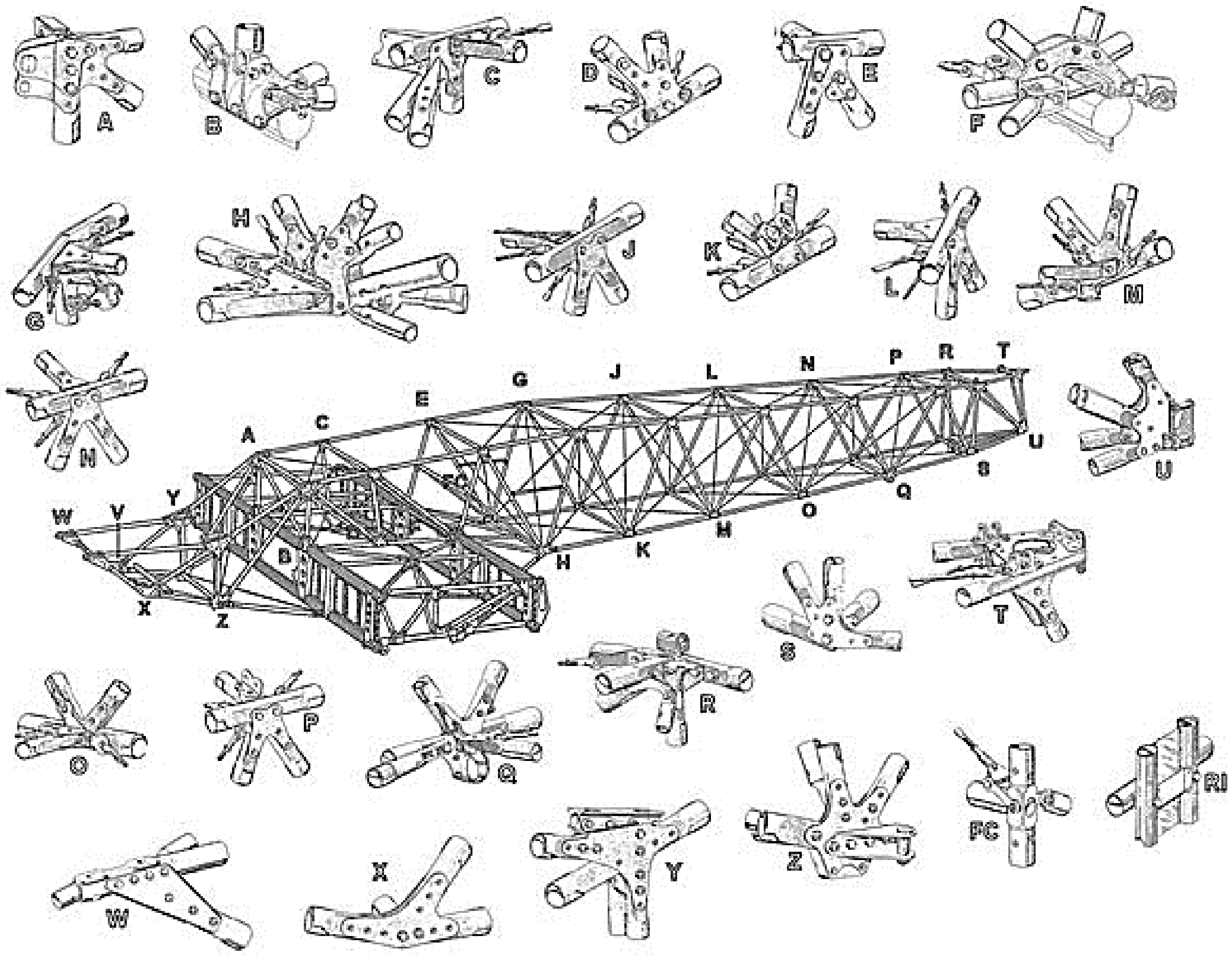
# WWII structures

Hawker Hurricane

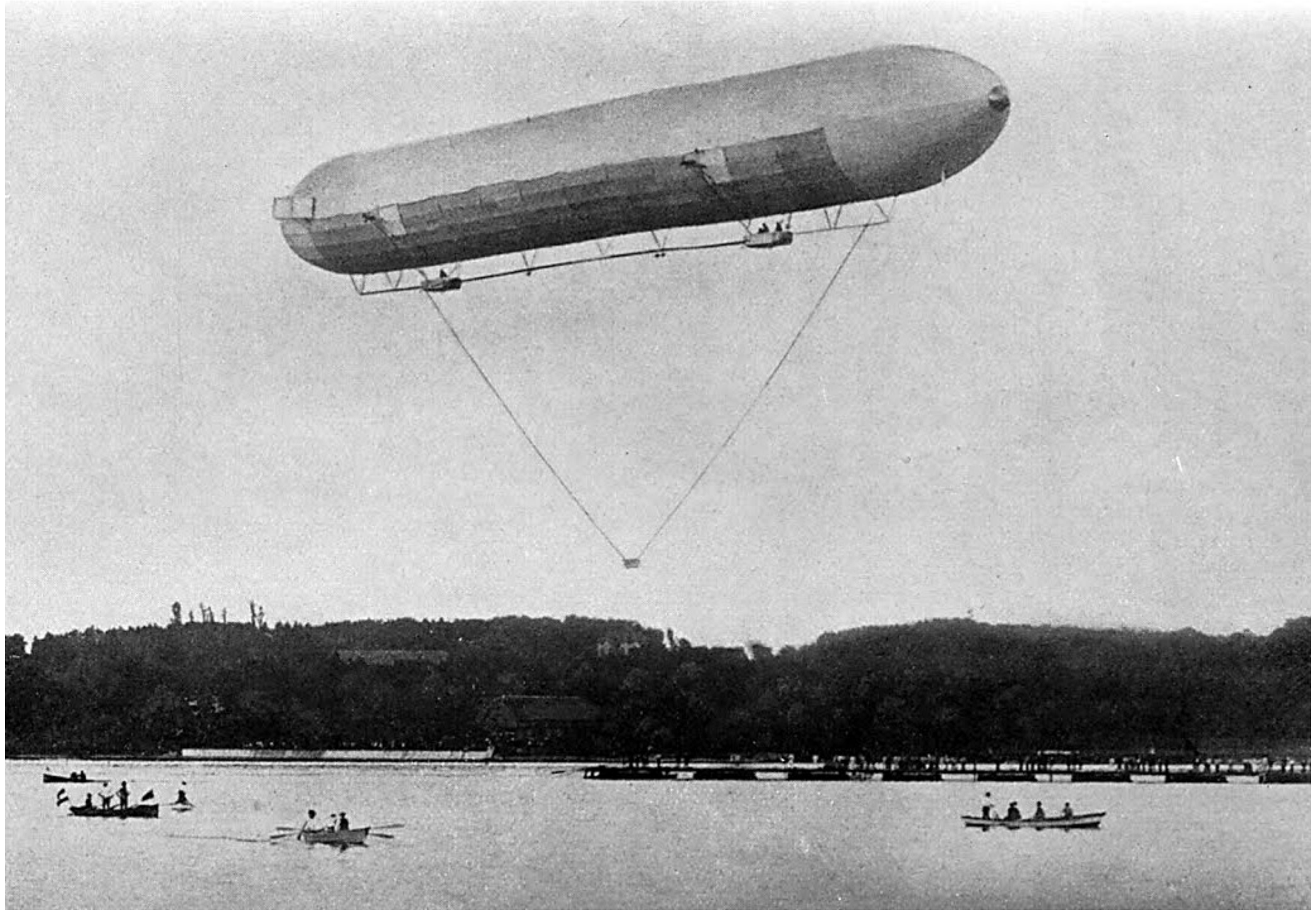


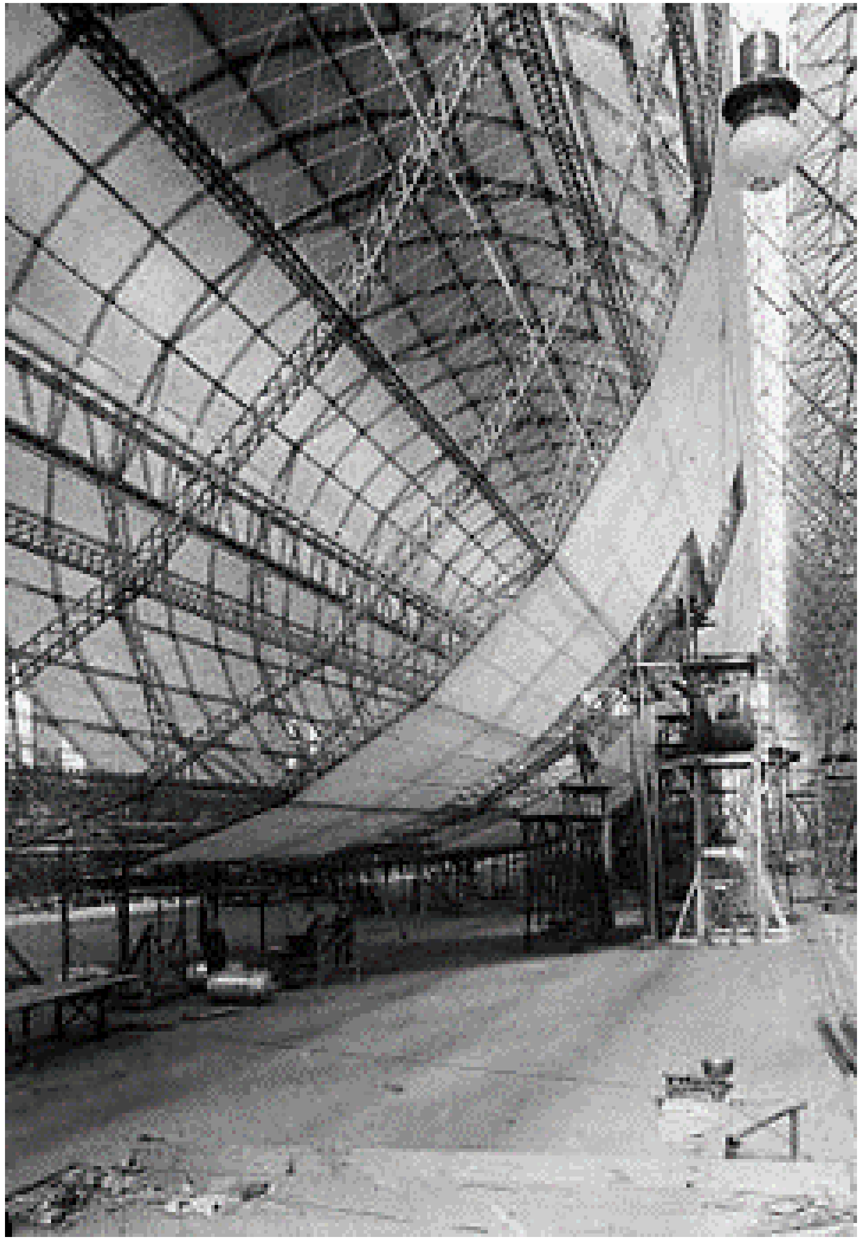
# WWII structures

# WWII structures

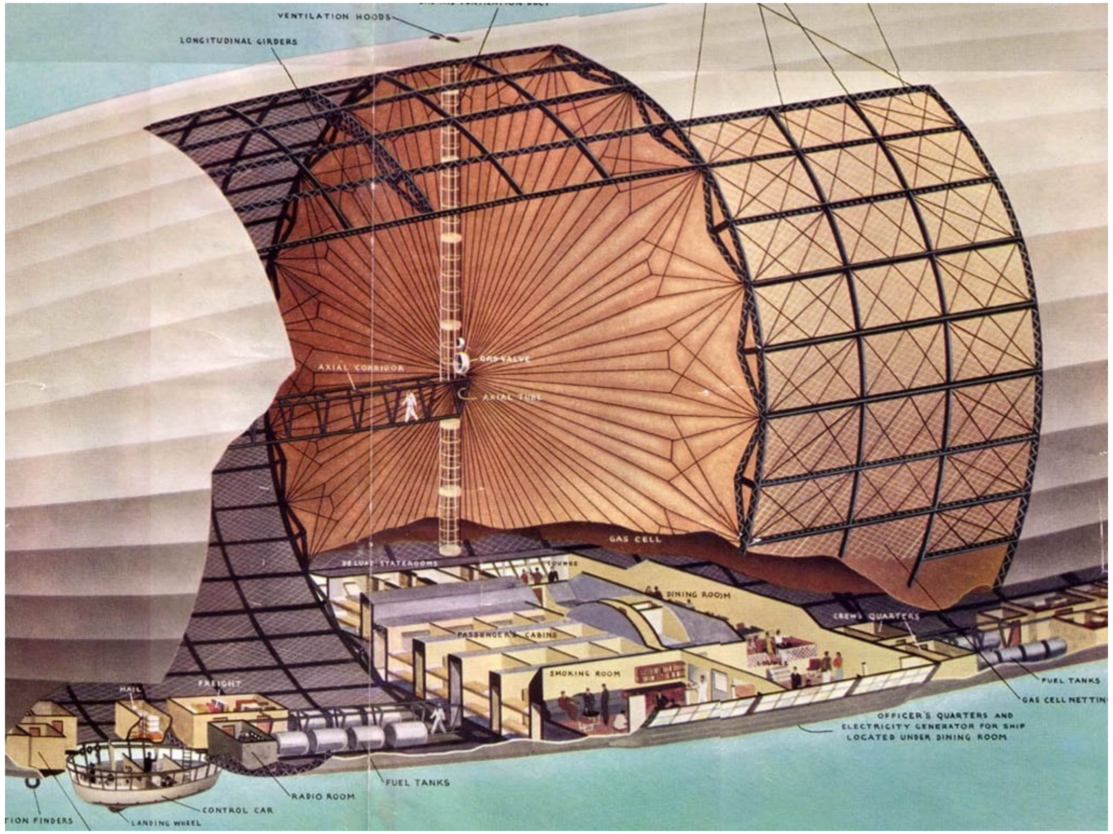


# LZ 1 Zeppelin

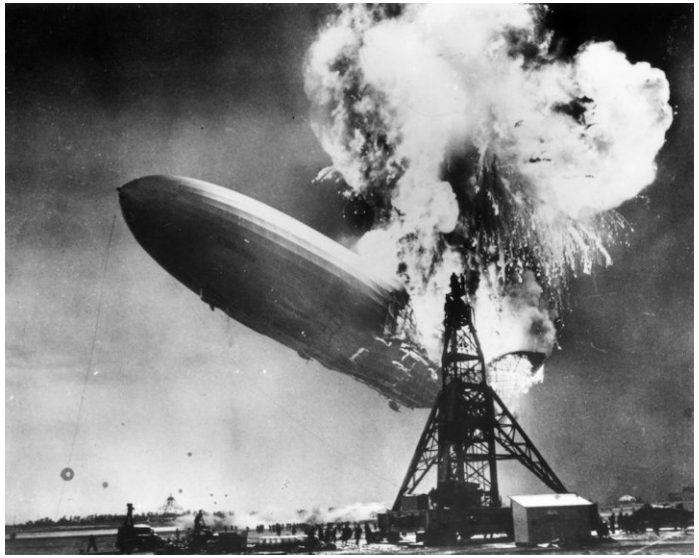




# LZ 129 Hindenburg

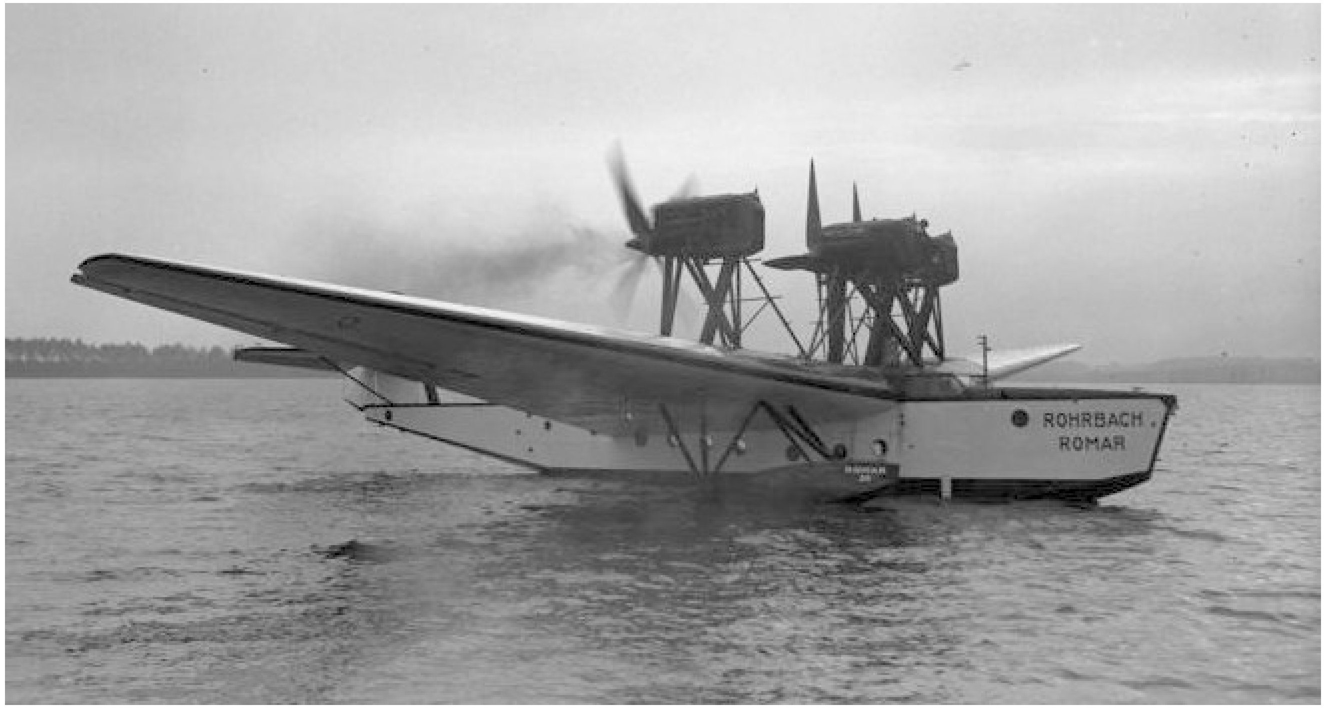


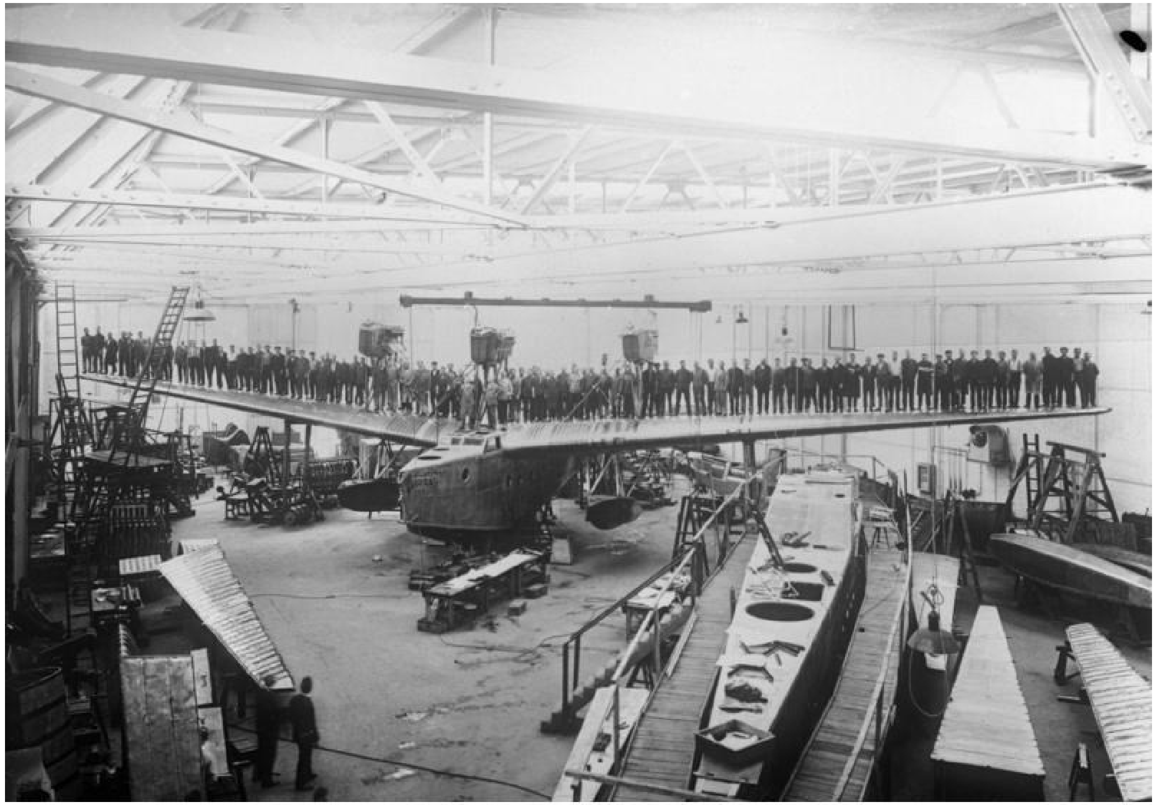




# German structures (Luftwaffe)

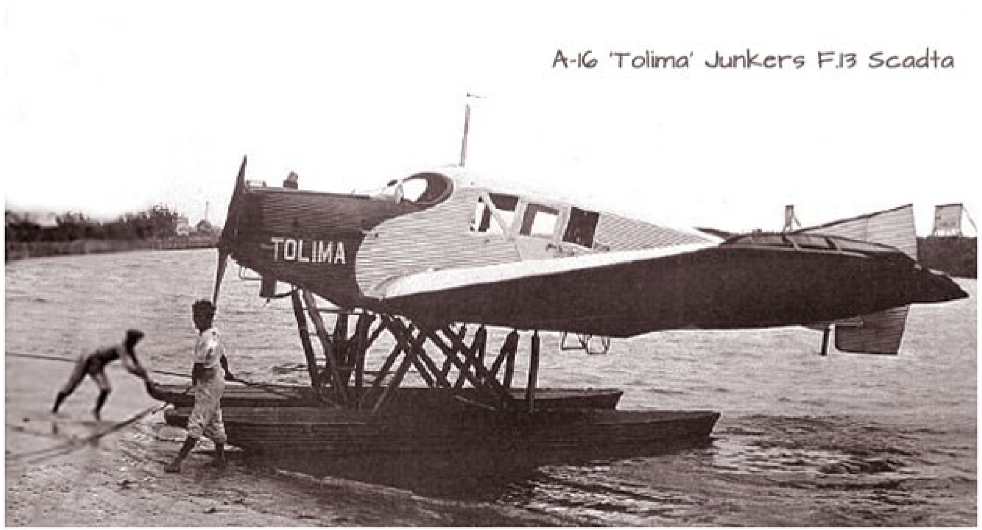
Adolf Rohrbach



Bundesarchiv, Bild 102-14295
Foto: o.Ang. | 1933

# German structures (Junkers F13)



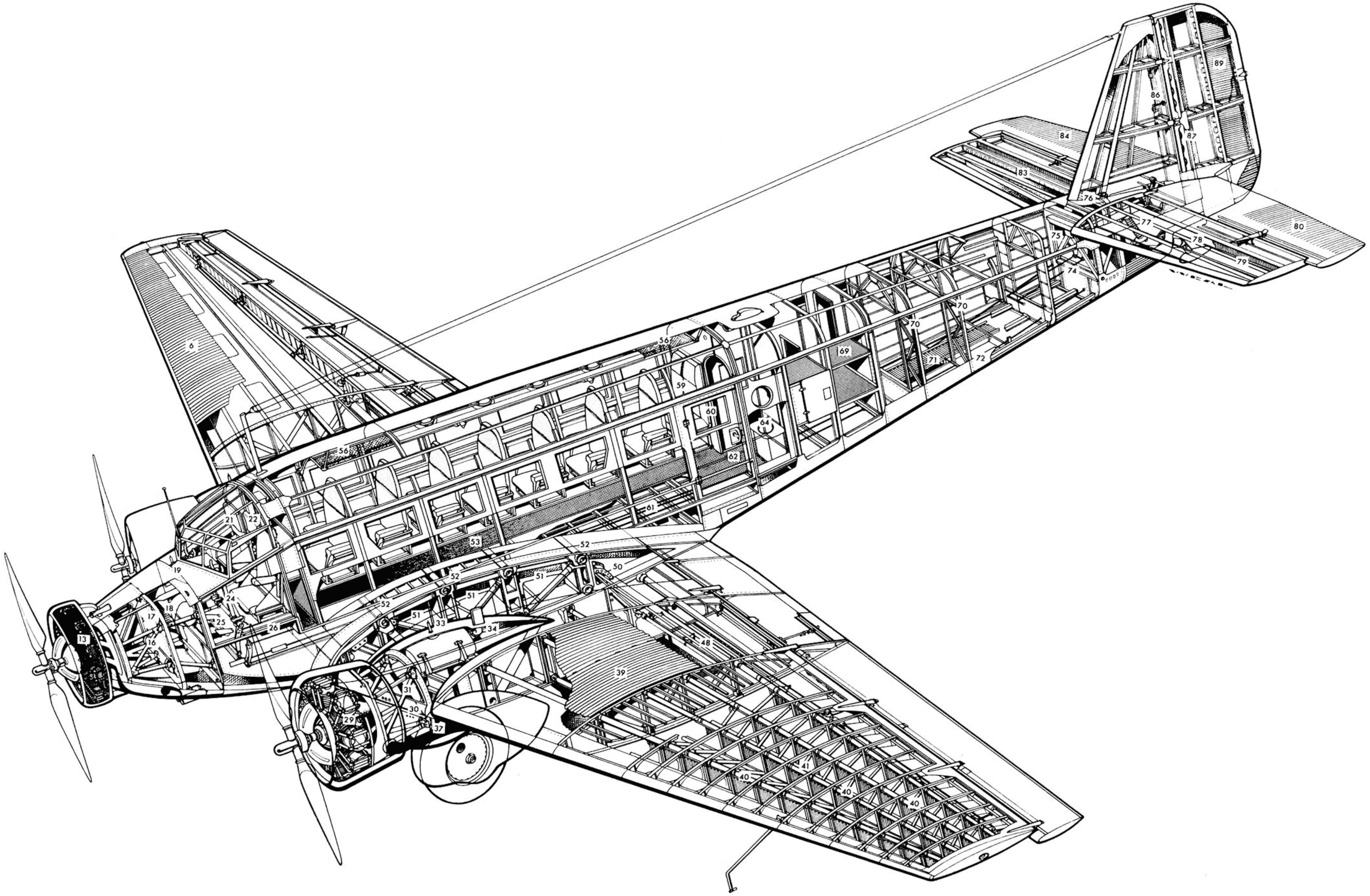



# German structures (Junkers JU52)

Streamlined skin to increase speed with limited engine power

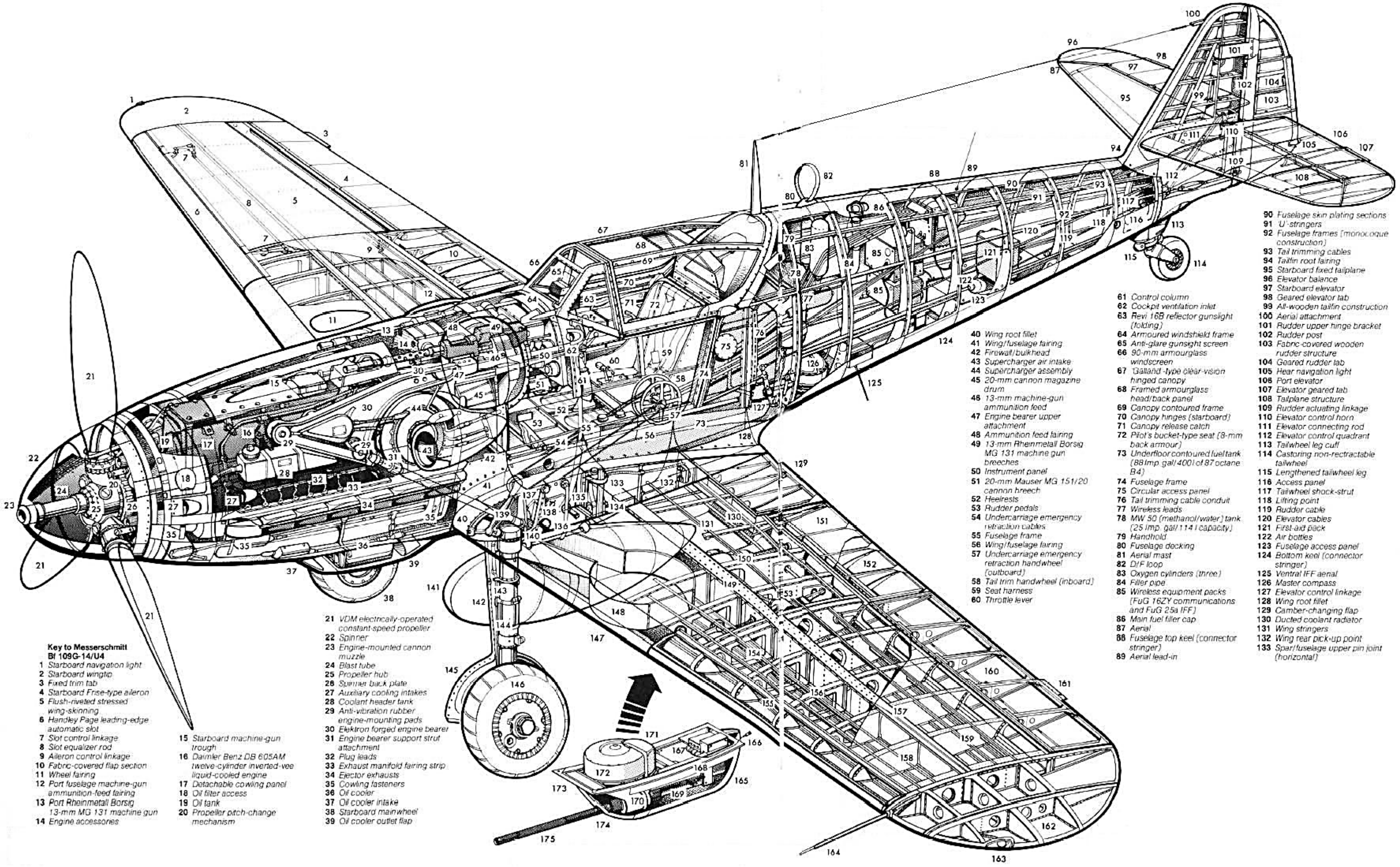
Corrugated aluminum skin (“duralumin”)


# German structures (Junkers JU52)



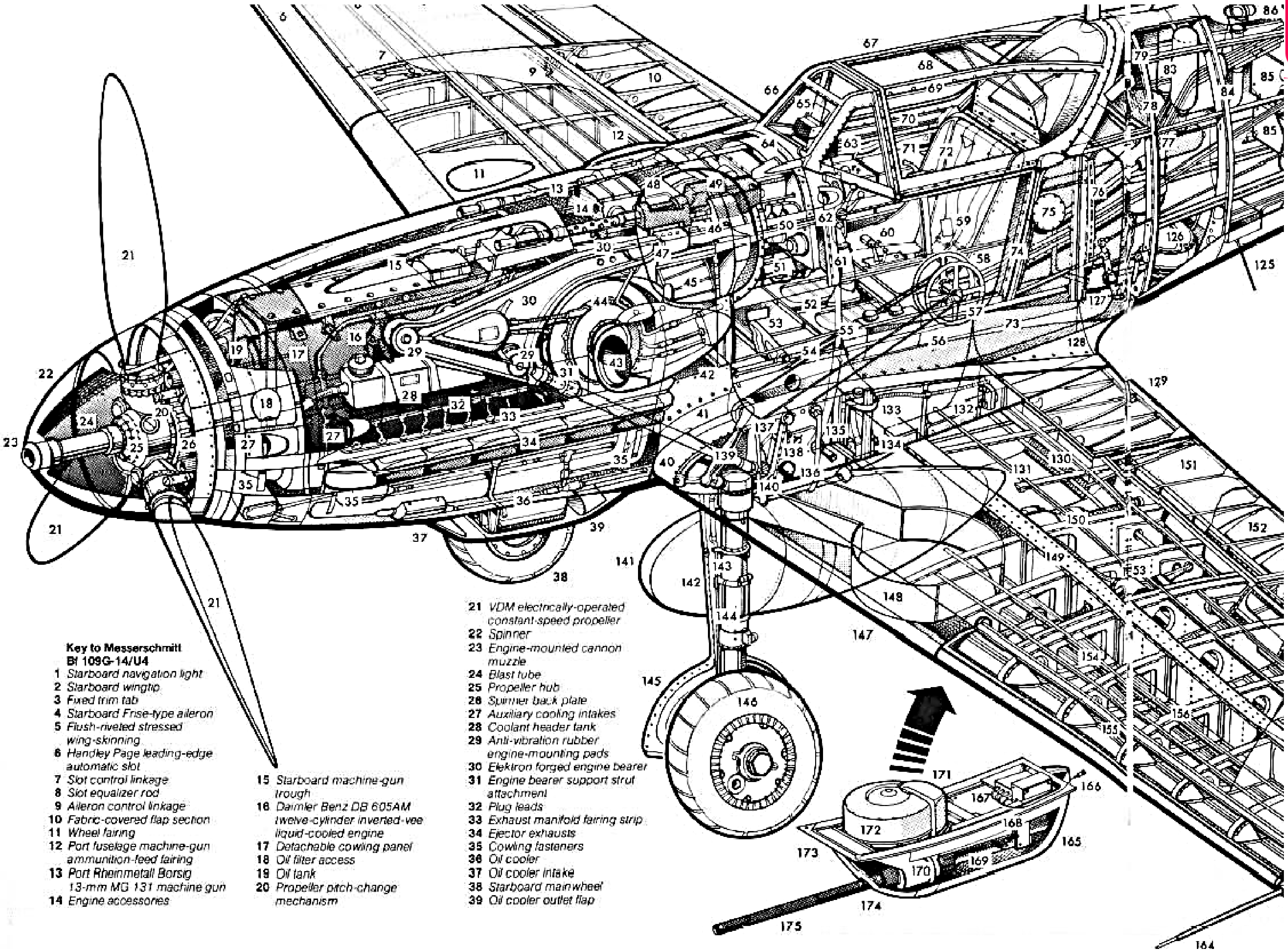
# German structures (Messerschmitt Bf 109)

# Messerschmitt Bf-109G-14



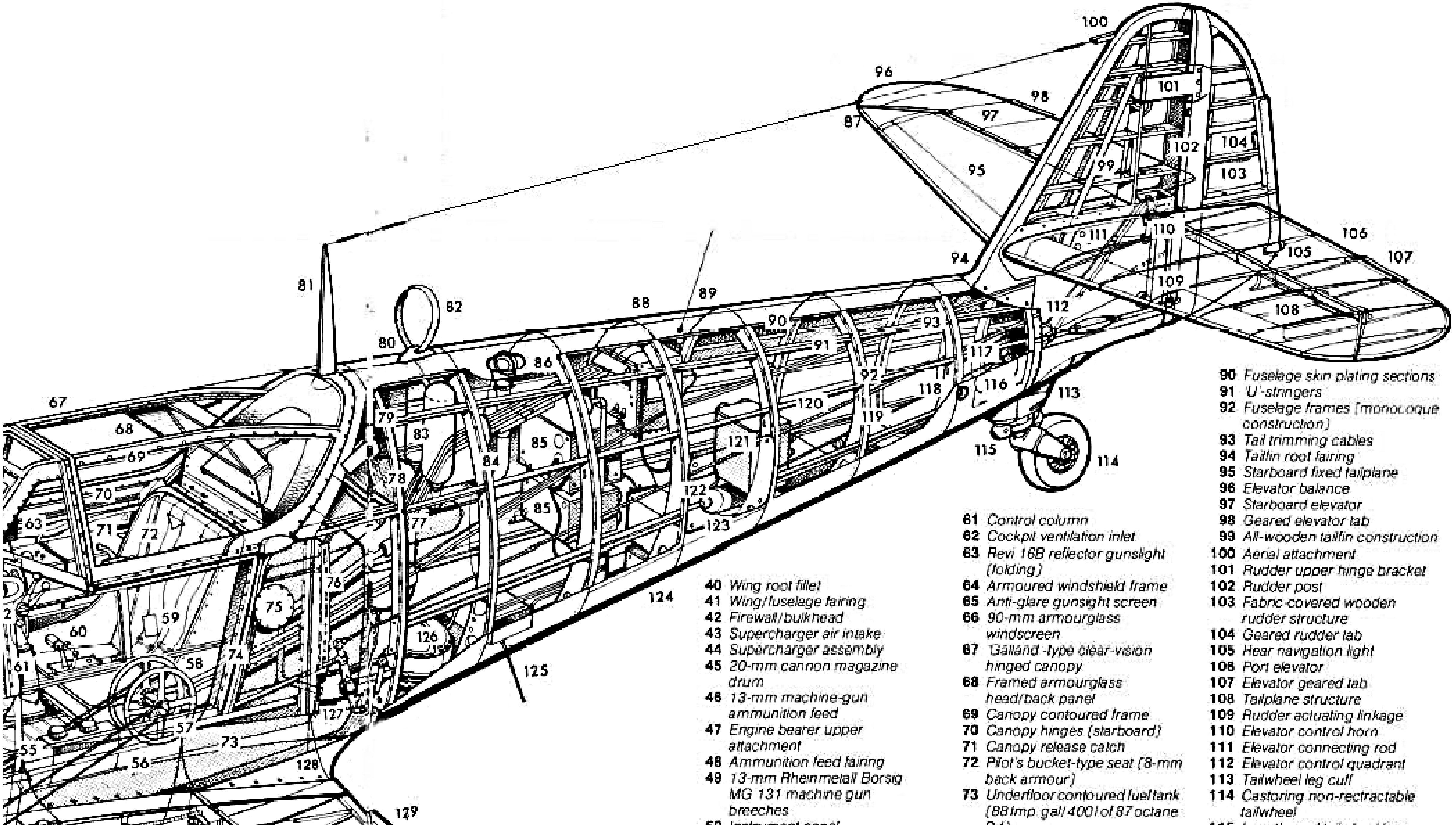
**Key to Messerschmitt Bf 109G-14/U4**

1 *Starboard navigation light*
2 *Starboard wingtip*
3 *Fixed trim tab*
4 *Starboard Frise-type aileron*
5 *Flush-riveted stressed wing-skinning*
6 *Handley Page leading-edge automatic slot*
7 *Slot control linkage*
8 *Slot equalizer rod*
9 *Aileron control linkage*
10 *Fabric-covered flap section*
11 *Wheel fairing*
12 *Port fuselage machine-gun ammunition-feed fairing*
13 *Port Rheinmetall Borsig 13-mm MG 131 machine gun*
14 *Engine accessories*
15 *Starboard machine-gun trough*
16 *Daimler Benz DB 605AM twelve-cylinder inverted-vee liquid-cooled engine*
17 *Detachable cowling panel*
18 *Oil filter access*
19 *Oil tank*
20 *Propeller pitch-change mechanism*
21 *VDM electrically-operated constant-speed propeller*
22 *Spinner*
23 *Engine-mounted cannon muzzle*
24 *Blast tube*
25 *Propeller hub*
26 *Spinner back plate*
27 *Auxiliary cooling intakes*
28 *Coolant header tank*
29 *Anti-vibration rubber engine-mounting pads*
30 *Elektron forged engine bearer*
31 *Engine bearer support strut attachment*
32 *Plug leads*
33 *Exhaust manifold fairing strip*
34 *Ejector exhausts*
35 *Cowling fasteners*
36 *Oil cooler*
37 *Oil cooler intake*
38 *Starboard mainwheel*
39 *Oil cooler outlet flap*
40 *Wing root fillet*
41 *Wing/fuselage fairing*
42 *Firewall/bulkhead*
43 *Supercharger air intake*
44 *Supercharger assembly*
45 *20-mm cannon magazine drum*
46 *13-mm machine-gun ammunition feed*
47 *Engine bearer upper attachment*
48 *Ammunition feed fairing*
49 *13-mm Rheinmetall Borsig MG 131 machine gun breeches*
50 *Instrument panel*
51 *20-mm Mauser MG 151/20 cannon breech*
52 *Heelrests*
53 *Rudder pedals*
54 *Undercarriage emergency retraction cables*
55 *Fuselage frame*
56 *Wing/fuselage fairing*
57 *Undercarriage emergency retraction handwheel (outboard)*
58 *Tail trim handwheel (inboard)*
59 *Seat harness*
60 *Throttle lever*
61 *Control column*
62 *Cockpit ventilation inlet*
63 *Revi 16B reflector gunsight (folding)*
64 *Armoured windshield frame*
65 *Anti-glare gunsight screen*
66 *90-mm armourglass windscreen*
67 *'Galland'-type clear-vision hinged canopy*
68 *Framed armourglass head/back panel*
69 *Canopy contoured frame*
70 *Canopy hinges (starboard)*
71 *Canopy release catch*
72 *Pilot's bucket-type seat (8-mm back armour)*
73 *Underfloor contoured fuel tank (88 Imp. gal/400 l of 87 octane B4)*
74 *Fuselage frame*
75 *Circular access panel*
76 *Tail trimming cable conduit*
77 *Wireless leads*
78 *MW 50 (methanol/water) tank (25 Imp. gal/114 l capacity)*
79 *Handhold*
80 *Fuselage decking*
81 *Aerial mast*
82 *D/F loop*
83 *Oxygen cylinders (three)*
84 *Filler pipe*
85 *Wireless equipment packs (FuG 16ZY communications and FuG 25a IFF)*
86 *Main fuel filler cap*
87 *Aerial*
88 *Fuselage top keel (connector stringer)*
89 *Aerial lead-in*
90 *Fuselage skin plating sections*
91 *'U'-stringers*
92 *Fuselage frames (monocoque construction)*
93 *Tail trimming cables*
94 *Tailfin root fairing*
95 *Starboard fixed tailplane*
96 *Elevator balance*
97 *Starboard elevator*
98 *Geared elevator tab*
99 *All-wooden tailfin construction*
100 *Aerial attachment*
101 *Rudder upper hinge bracket*
102 *Rudder post*
103 *Fabric-covered wooden rudder structure*
104 *Geared rudder tab*
105 *Rear navigation light*
106 *Port elevator*
107 *Elevator geared tab*
108 *Tailplane structure*
109 *Rudder actuating linkage*
110 *Elevator control horn*
111 *Elevator connecting rod*
112 *Elevator control quadrant*
113 *Tailwheel leg cuff*
114 *Castoring non-rectractable tailwheel*
115 *Lengthened tailwheel leg*
116 *Access panel*
117 *Tailwheel shock-strut*
118 *Lifting point*
119 *Rudder cable*
120 *Elevator cables*
121 *First-aid pack*
122 *Air bottles*
123 *Fuselage access panel*
124 *Bottom keel (connector stringer)*
125 *Ventral IFF aerial*
126 *Master compass*
127 *Elevator control linkage*
128 *Wing root fillet*
129 *Camber-changing flap*
130 *Ducted coolant radiator*
131 *Wing stringers*
132 *Wing rear pick-up point*
133 *Spar/fuselage upper pin joint (horizontal)*
134 *Spar/fuselage lower pin joint (vertical)*
135 *Flaps equalizer rod*
136 *Rustsatz R3 auxiliary fuel tank ventral rack*
137 *Undercarriage electrical interlock*
138 *Wing horizontal pin forward pick-up*
139 *Undercarriage retraction jack mechanism*
140 *Undercarriage pivot-bevel*
141 *Auxiliary fuel tank (Rustsatz R3) of 66 Imp gal (300 l) capacity*
142 *Mainwheel leg fairing*
143 *Mainwheel oleo leg*
144 *Brake lines*
145 *Mainwheel fairing*
146 *Port mainwheel*
147 *Leading-edge skin*
148 *Port mainwheel well*
149 *Wing spar*
150 *Flap actuating linkage*
151 *Fabric-covered control surfaces*
152 *Slotted flap structure*
153 *Leading-edge slot actuating mechanism*
154 *Slot equalizer rod*
155 *Handley Page automatic leading-edge slot*
156 *Wing stringers*
157 *Spar flange decrease*
158 *Wing ribs*
159 *Flush-riveted stressed wing-skinning*
160 *Metal-framed Frise-type aileron*
161 *Fixed trim tab*
162 *Wingtip construction*
163 *Port navigation light*
164 *Angled pitot head*
165 *Rustsatz R6 optional underwing cannon gondola*
166 *14-point plug connection*
167 *Electrical junction box*
168 *Cannon rear mounting bracket*
169 *20-mm Mauser MG 151/20 cannon*
170 *Cannon front mounting bracket*
171 *Ammunition feed chute*
172 *Ammunition magazine drum*
173 *Underwing panel*
174 *Gondola fairing*
175 *Cannon barrel*



**Key to Messerschmitt Bf 109G-14/U4**

1 Starboard navigation light
2 Starboard wingtip
3 Fixed trim tab
4 Starboard Frise-type aileron
5 Flush-riveted stressed wing-skinning
6 Handley Page leading-edge automatic slot
7 Slot control linkage
8 Slot equalizer rod
9 Aileron control linkage
10 Fabric-covered flap section
11 Wheel fairing
12 Port fuselage machine-gun ammunition-feed fairing
13 Port Rheinmetall Borsig 13-mm MG 131 machine gun
14 Engine accessories
15 Starboard machine-gun trough
16 Daimler Benz DB 605AM twelve-cylinder inverted-vee liquid-cooled engine
17 Detachable cowling panel
18 Oil filter access
19 Oil tank
20 Propeller pitch-change mechanism
21 VDM electrically-operated constant-speed propeller
22 Spinner
23 Engine-mounted cannon muzzle
24 Blast tube
25 Propeller hub
26 Spinner back plate
27 Auxiliary cooling intakes
28 Coolant header tank
29 Anti-vibration rubber engine-mounting pads
30 Elektron forged engine bearer
31 Engine bearer support strut attachment
32 Plug leads
33 Exhaust manifold fairing strip
34 Ejector exhausts
35 Cowling fasteners
36 Oil cooler
37 Oil cooler intake
38 Starboard mainwheel
39 Oil cooler outlet flap




**40** *Wing root fillet*
**41** *Wing/fuselage fairing*
**42** *Firewall/bulkhead*
**43** *Supercharger air intake*
**44** *Supercharger assembly*
**45** *20-mm cannon magazine drum*
**46** *13-mm machine-gun ammunition feed*
**47** *Engine bearer upper attachment*
**48** *Ammunition feed fairing*
**49** *13-mm Rheinmetall Borsig MG 131 machine gun breeches*

**61** *Control column*
**62** *Cockpit ventilation inlet*
**63** *Revi 16B reflector gunsight (folding)*
**64** *Armoured windshield frame*
**65** *Anti-glare gunsight screen*
**66** *90-mm armourglass windscreen*
**67** *'Galland'-type clear-vision hinged canopy*
**68** *Framed armourglass head/back panel*
**69** *Canopy contoured frame*
**70** *Canopy hinges (starboard)*
**71** *Canopy release catch*
**72** *Pilot's bucket-type seat (8-mm back armour)*
**73** *Underfloor contoured fuel tank (88 Imp gal/400 l of 87 octane*

**90** *Fuselage skin plating sections*
**91** *'U'-stringers*
**92** *Fuselage frames (monocoque construction)*
**93** *Tail trimming cables*
**94** *Tailfin root fairing*
**95** *Starboard fixed tailplane*
**96** *Elevator balance*
**97** *Starboard elevator*
**98** *Geared elevator tab*
**99** *All-wooden tailfin construction*
**100** *Aerial attachment*
**101** *Rudder upper hinge bracket*
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**112** *Elevator control quadrant*
**113** *Tailwheel leg cuff*
**114** *Castoring non-rectractable tailwheel*

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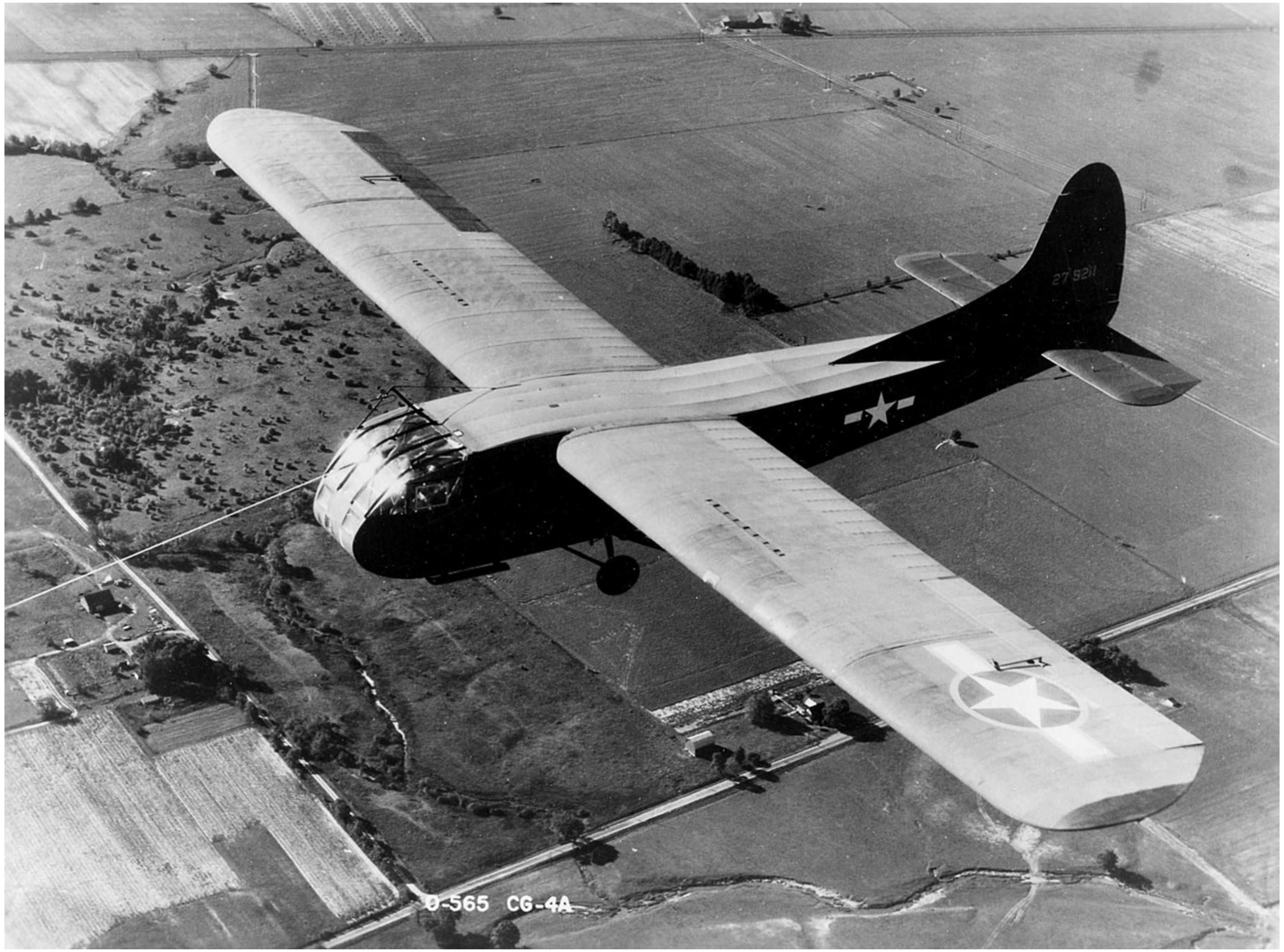
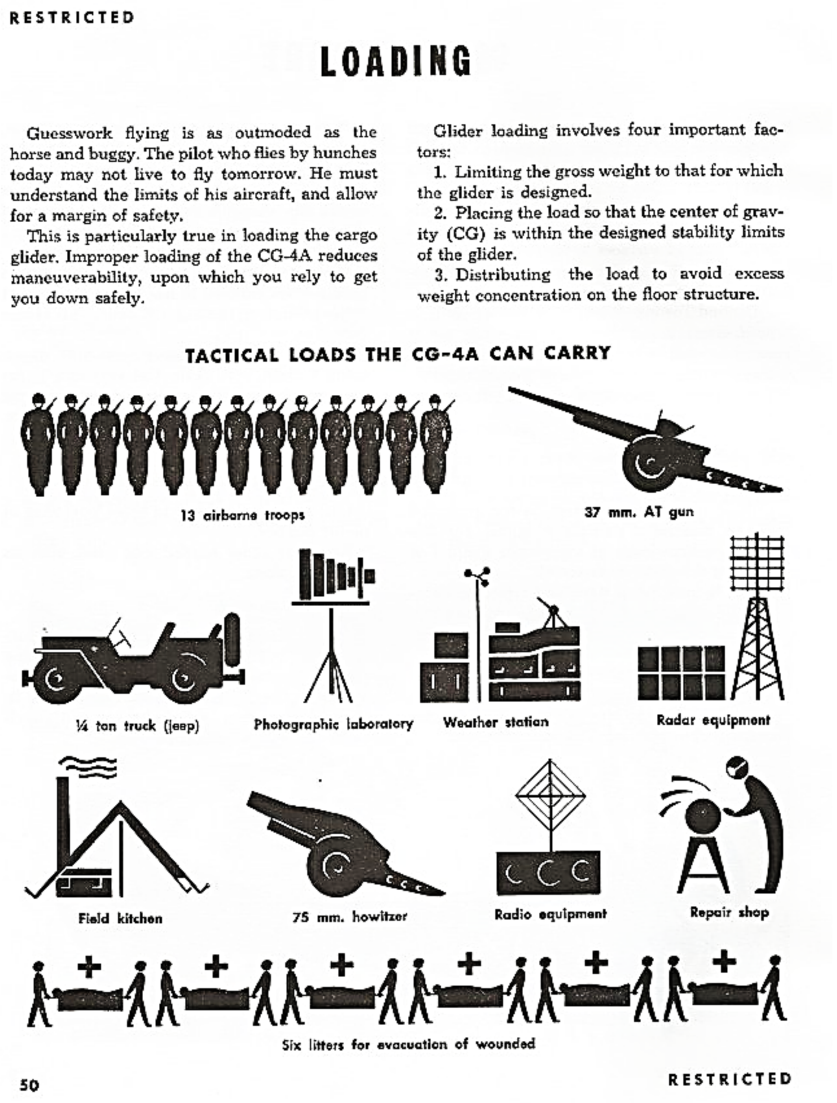
**135** *Fla*
**136** *Ru ve*
**137** *Ur int*
**138** *We pic*
**139** *Ur me*
**140** *Un*
**141** *Au R3 ca*
**142** *Ma*
**143** *Ma*
**144** *Br*
**145** *Ma*
**146** *Po*
**147** *Le*
**148** *Po*
**149** *Wi*
**150** *Fla*
**151** *Fa su*
**152** *Sk*
**153** *Le me*
**154** *Sk*
**155** *Ha lea*
**156** *Wi*
**157** *Sp*
**158** *Wi*

# USAF Structures (Waco CG-4)




# USAF Structures (Waco CG-4)



RESTRICTED

## LOADING

Guesswork flying is as outmoded as the horse and buggy. The pilot who flies by hunches today may not live to fly tomorrow. He must understand the limits of his aircraft, and allow for a margin of safety.

This is particularly true in loading the cargo glider. Improper loading of the CG-4A reduces maneuverability, upon which you rely to get you down safely.

Glider loading involves four important factors:

1. Limiting the gross weight to that for which the glider is designed.
2. Placing the load so that the center of gravity (CG) is within the designed stability limits of the glider.
3. Distributing the load to avoid excess weight concentration on the floor structure.

### TACTICAL LOADS THE CG-4A CAN CARRY

13 airborne troops

37 mm. AT gun

¼ ton truck (jeep)

Photographic laboratory

Weather station

Radar equipment

Field kitchen

75 mm. howitzer

Radio equipment

Repair shop

Six litters for evacuation of wounded

50

RESTRICTED

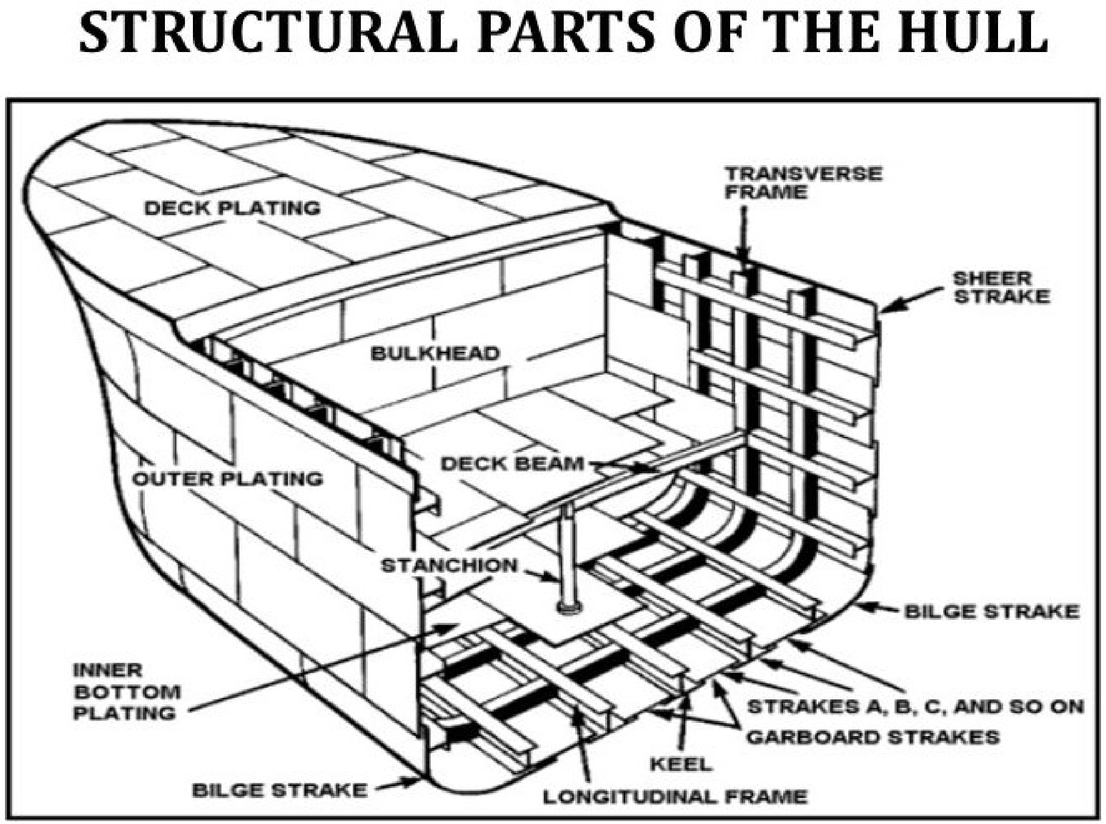
# History (Monocoque – Semimonocoque)

- Aircraft transportation begins. The challenge implies wider, and more resistant fuselages

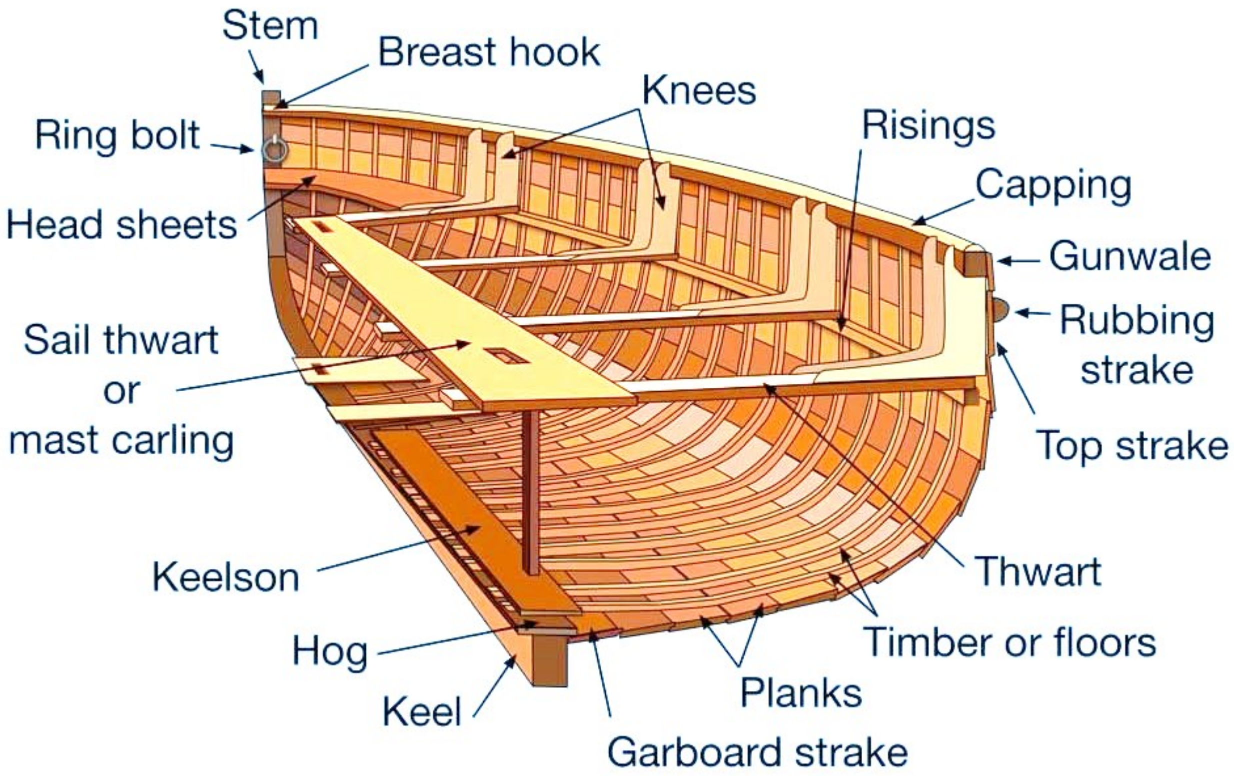
- The main inspiration was the hull shape of ships

- The flying boat is created as a solution for requirements

# History (Monocoque – Semimonocoque)




The hull is the main body of the ship below the main outside deck. The hull consists of an outside covering (or skin) and an inside framework to which the skin is secured.



# History (Monocoque – Semimonocoque)

# History (Monocoque – Semimonocoque)

**Curtiss HS-1** (Early flying boat)

# Monocoque structure

- The biggest advantage of a monocoque (single shell) structure is that the skin is now an active part of it

- In contrast with trusses, which, the members are the only capable to withstand loads

# Monocoque structure (Nimbus-2)

# Monocoque structure

**Mono**: integral, everything in one piece

**Coque**: from the French word “eggshell”

This structures are made by stressed skin, bulkheads and formers

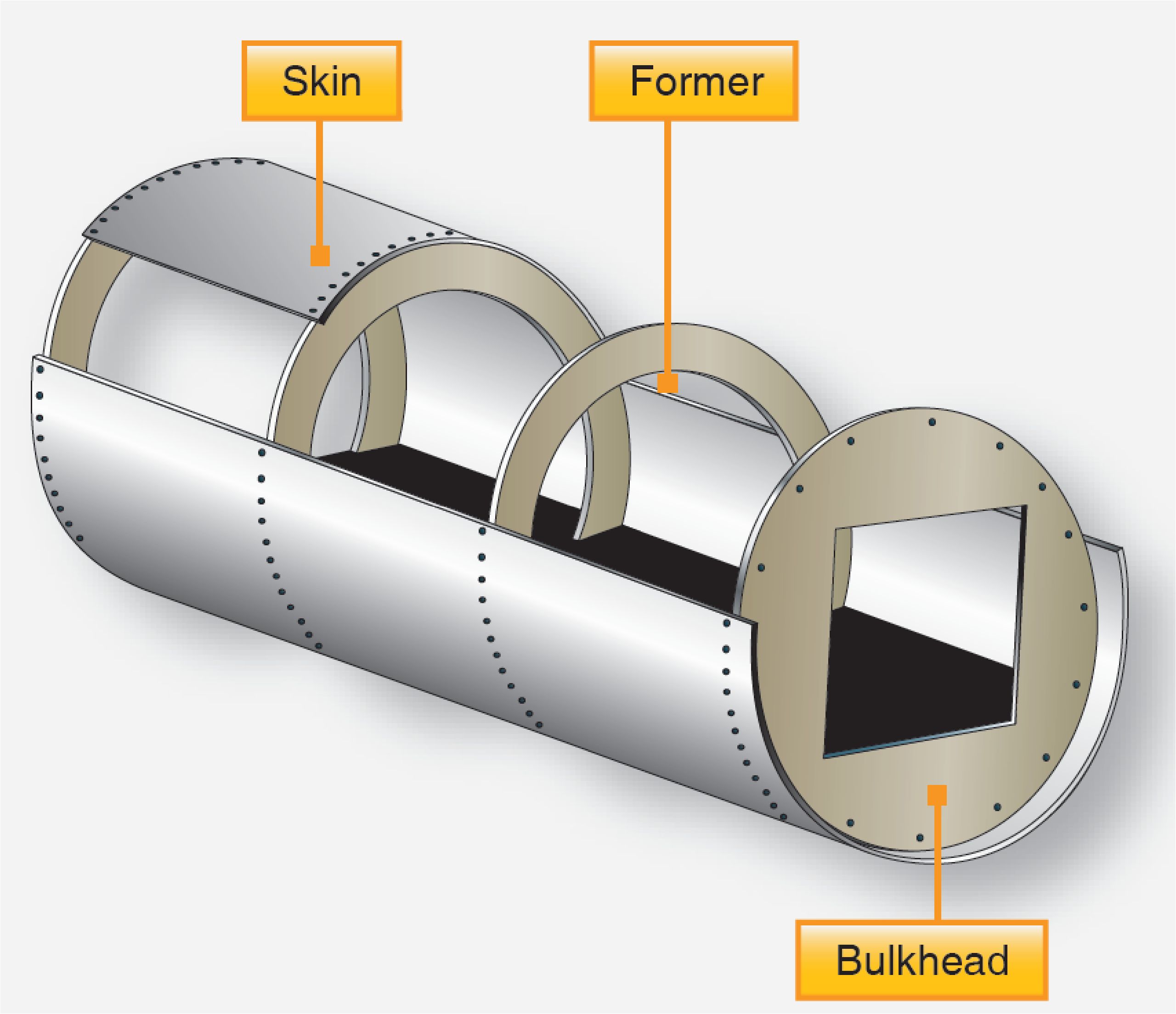
# Monocoque structure

- Loads are expected to be distributed by **union points** thus, these points are the heaviest (hard points)

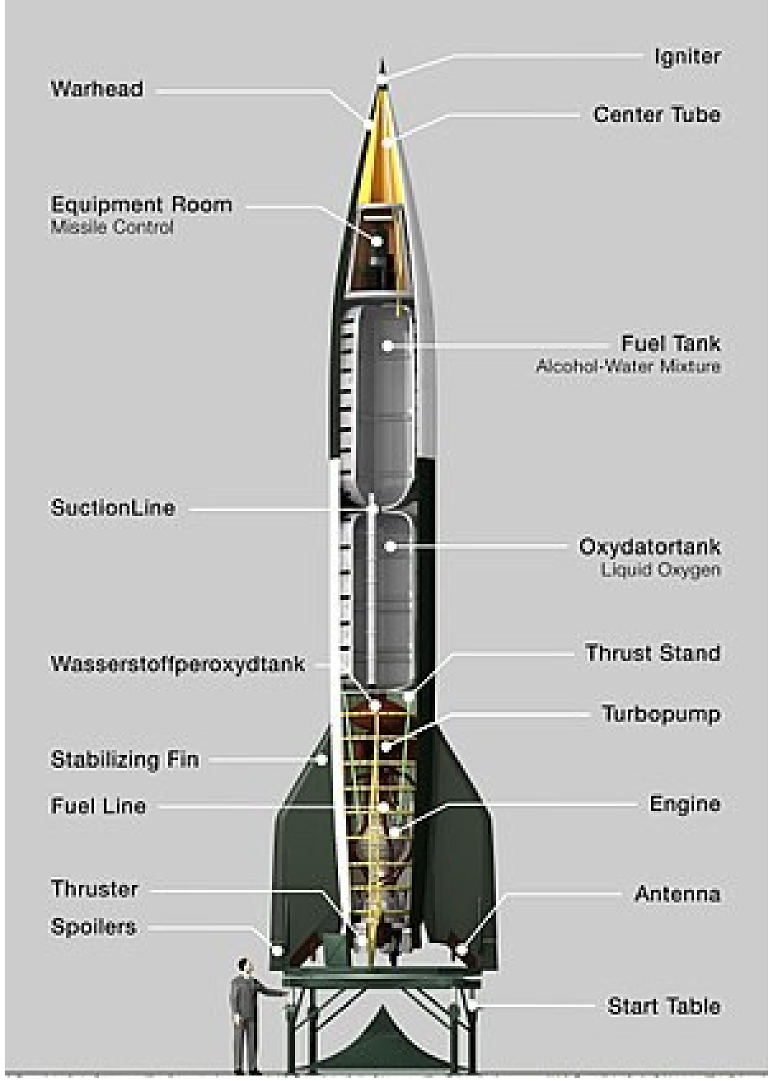
- The skin is now the principal mechanism of load distribution **“Stressed skin”**

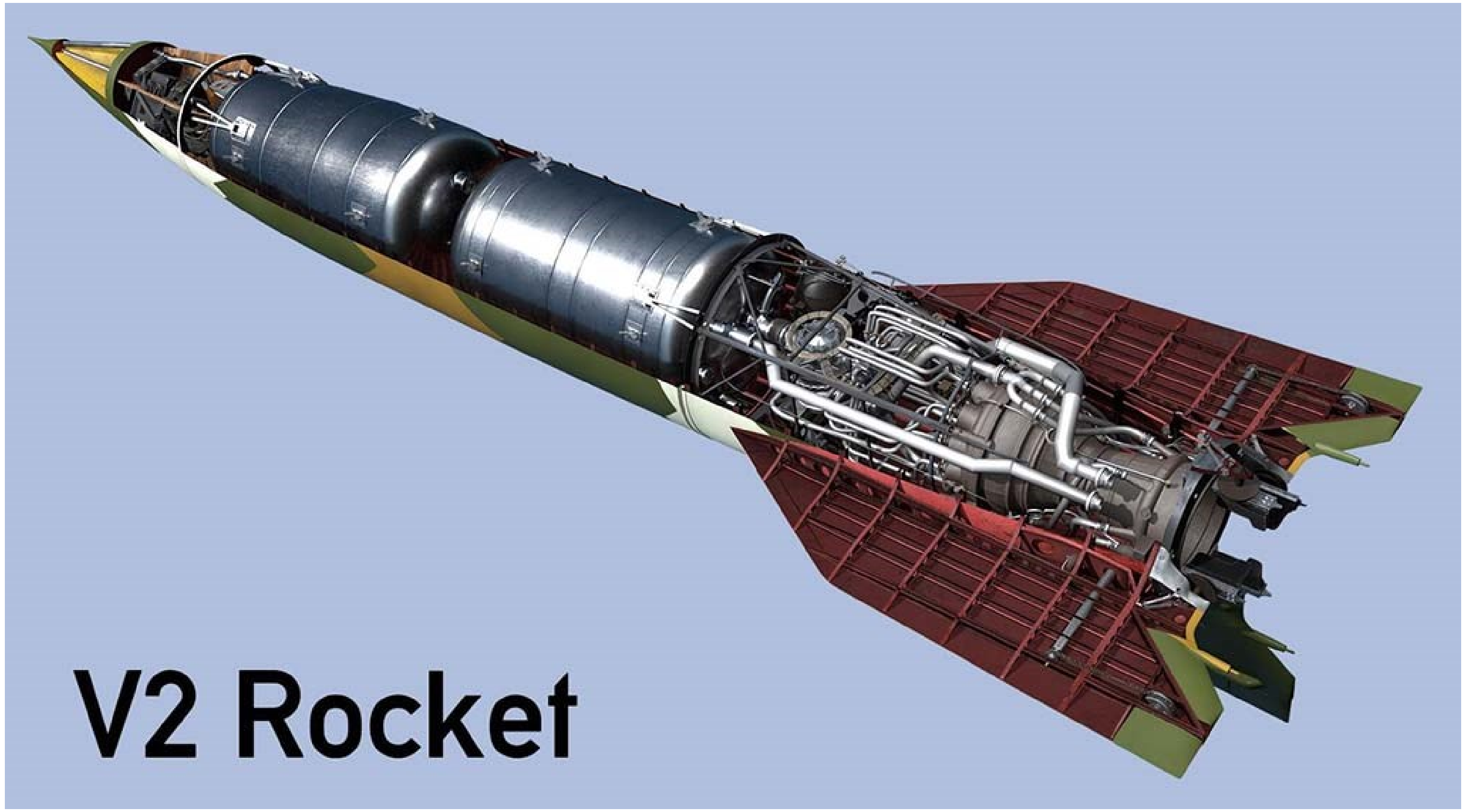
- The challenge of a monocoque structure is to preserve a suitable **strength under permissible weight limits**

# Monocoque structure

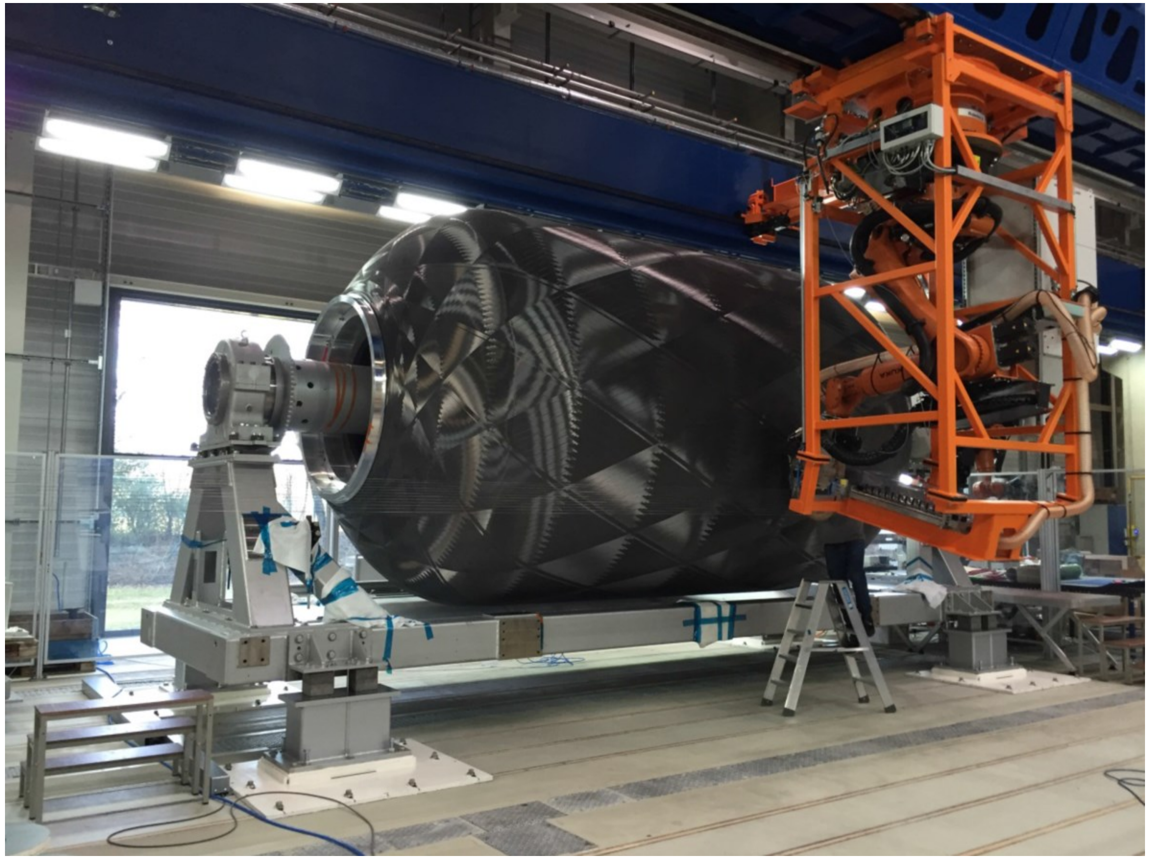


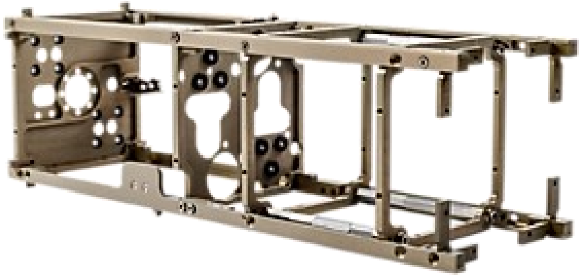
# Monocoque structure



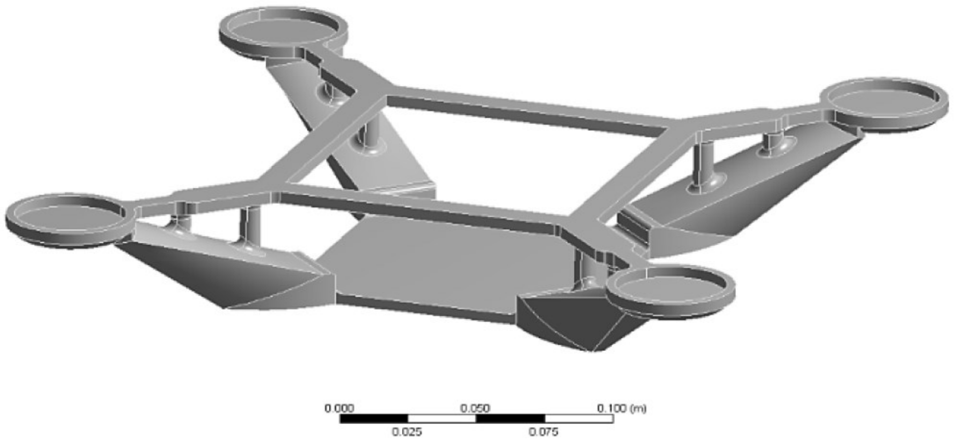



# Monocoque structure

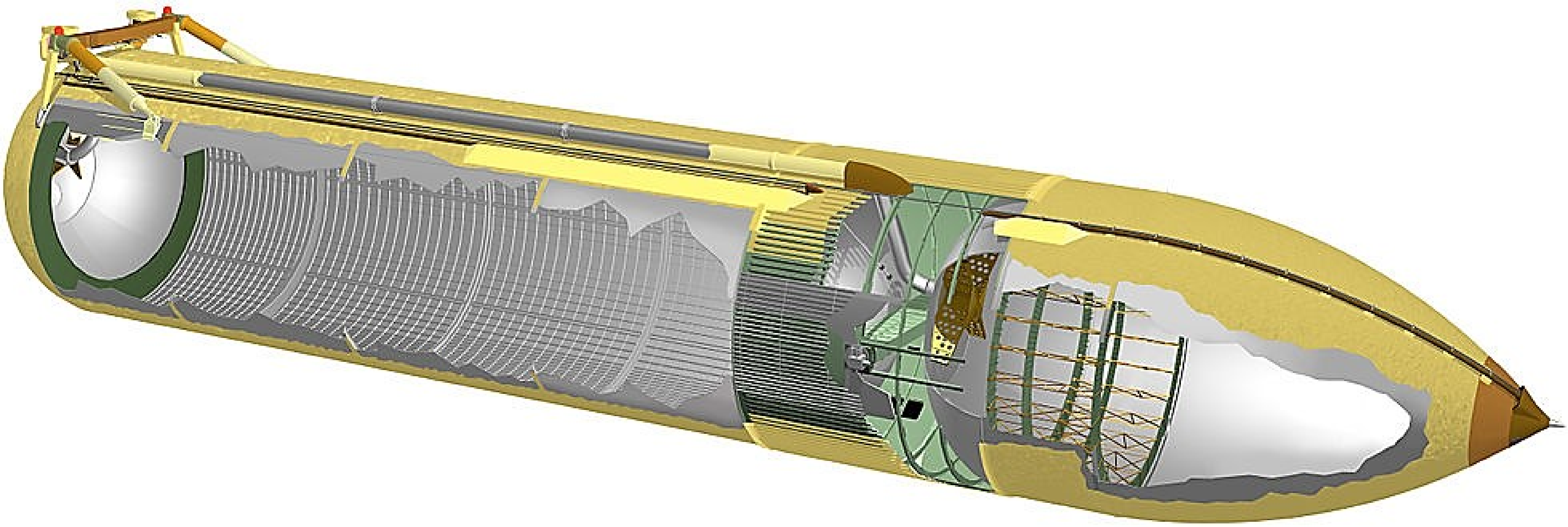




# Monocoque structure

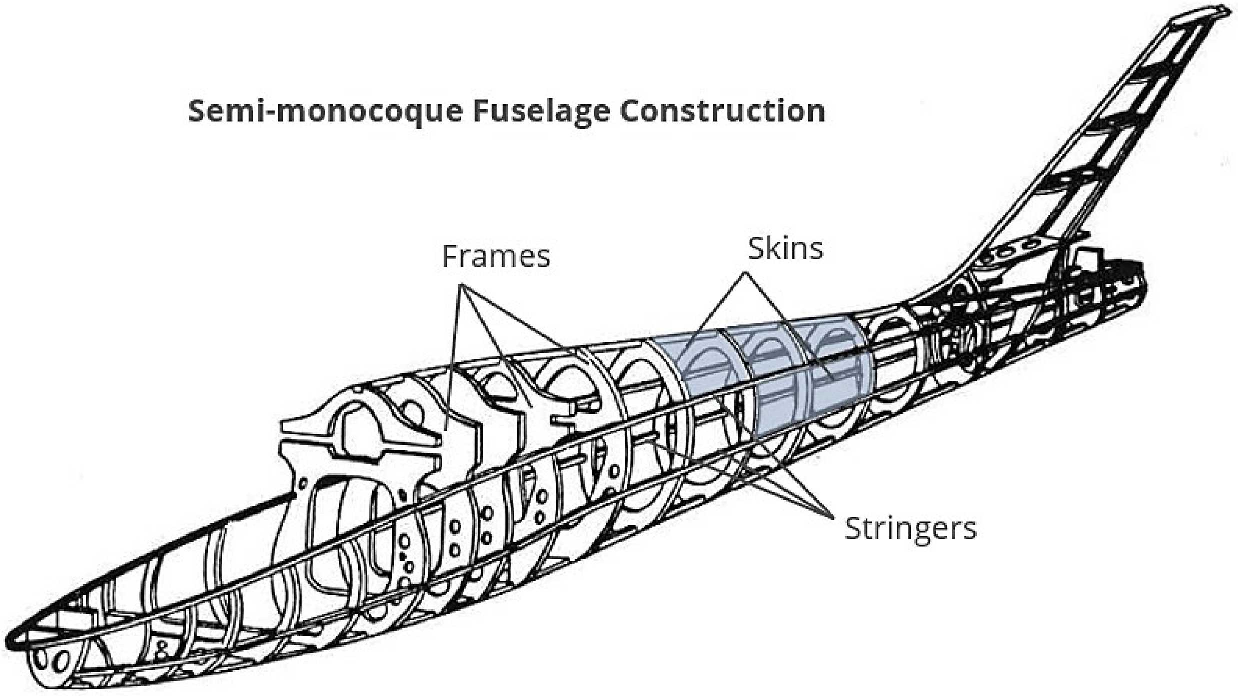



# Monocoque structure

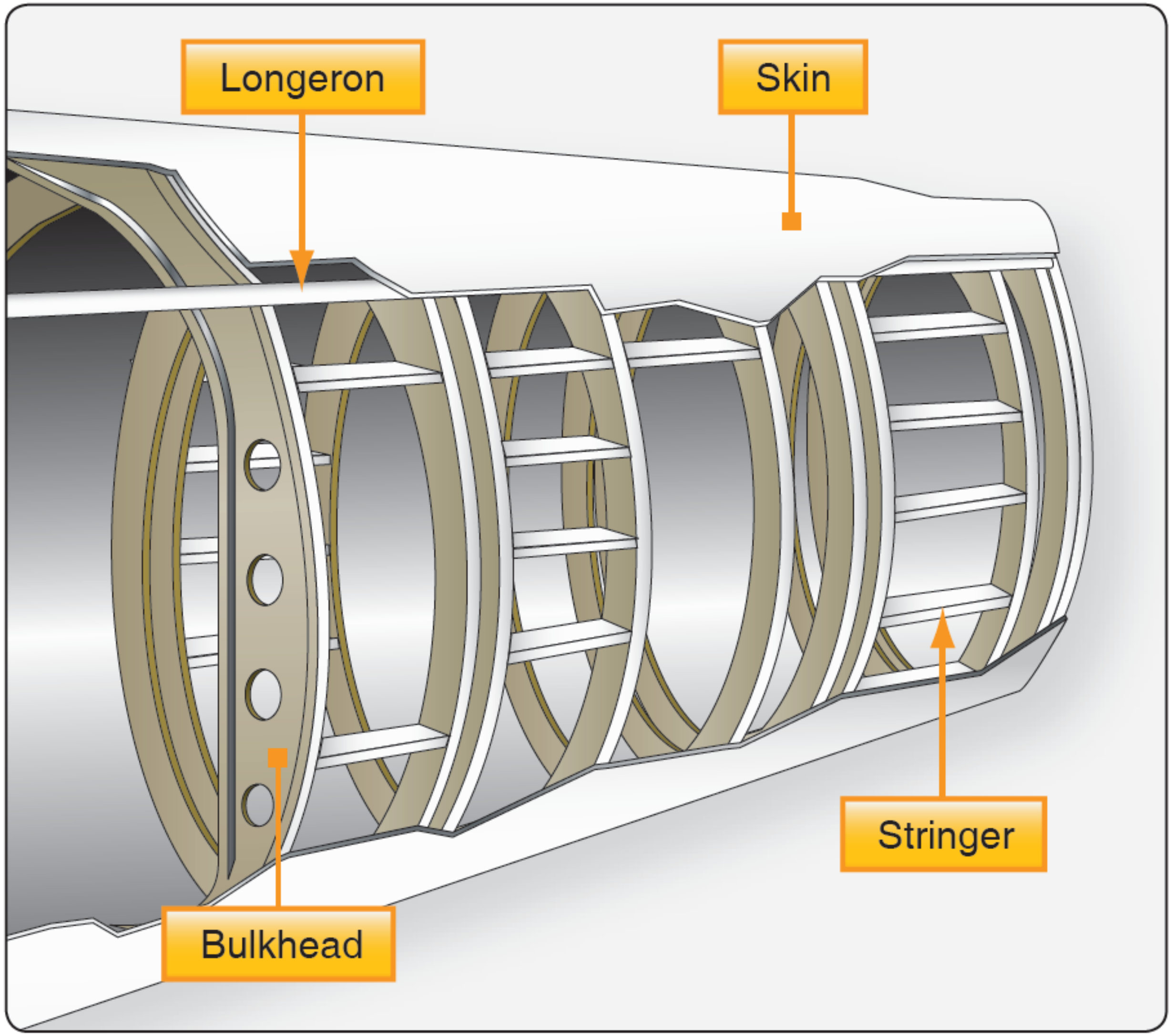


# Semi-monocoque structures

- Most of Aft-WW2 aircrafts, were built using semi-monocoque structures
- It is a solution for the **strength/weight ratio** inconvenience of the monocoque structures
- A semi monocoque structure is formed by frames, bulkheads, and a stressed skin however, this is reinforced by longerons and stringers



# Semi-monocoque structures




*Manufactures may change the name of a part of the semi-monocoque structure.

# Semi-monocoque structures (USAF)

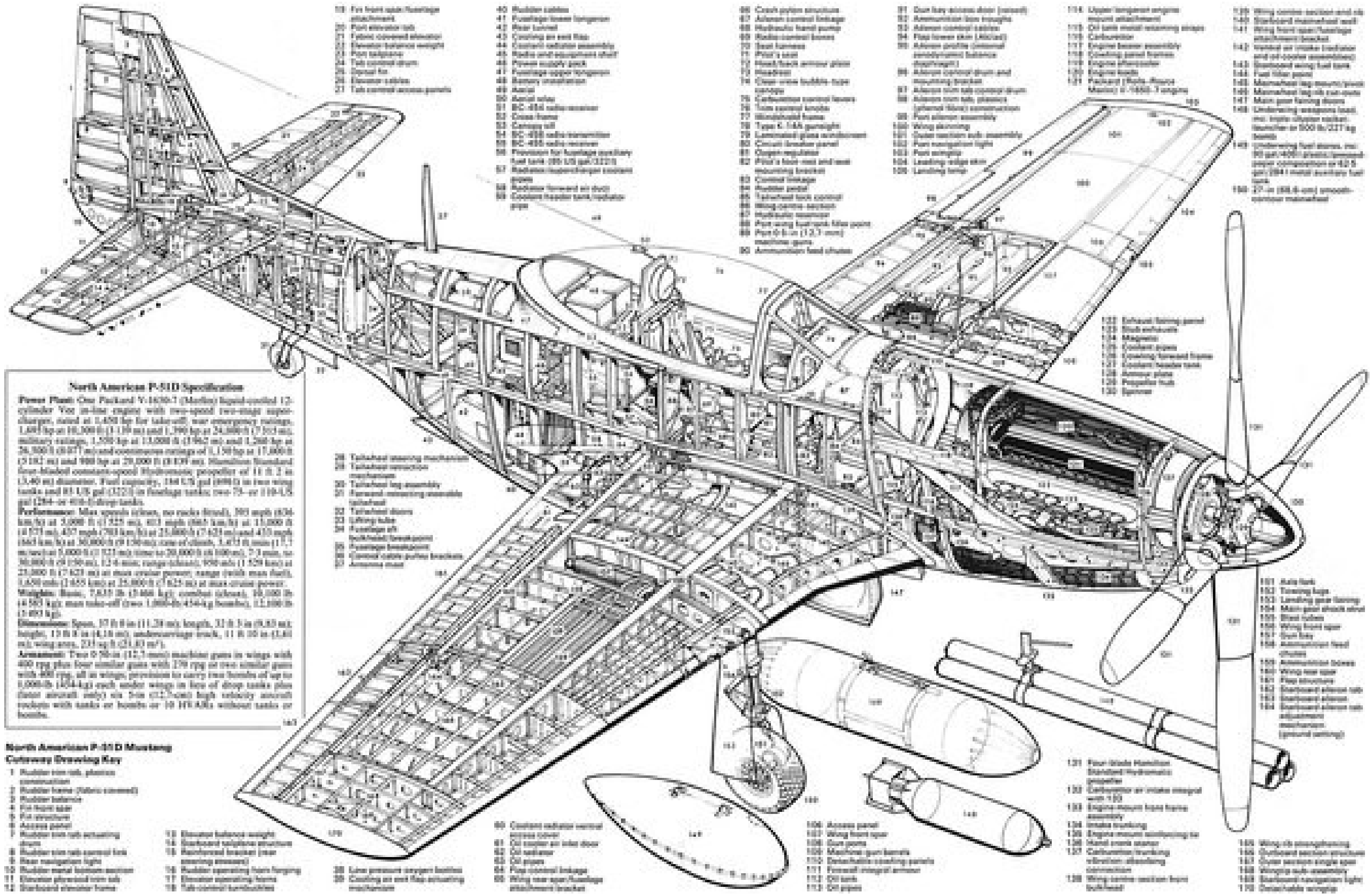
This airplane used semi-monocoque metal construction, together with features such as retractable landing gear.

As we have seen **these concepts were not invented in the United States** but were substantially advanced by American designers

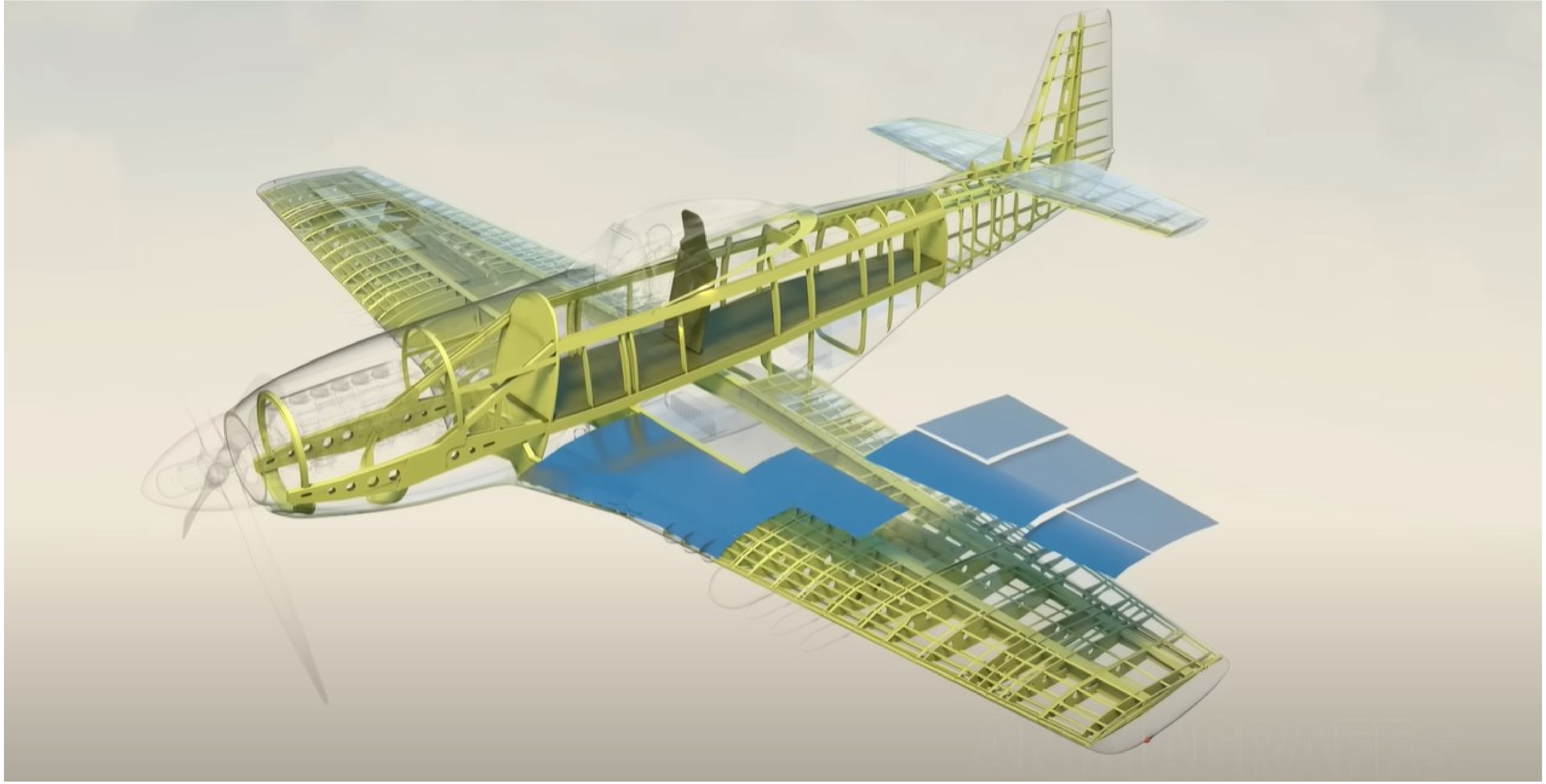
# Semi-monocoque structures (USAF)


P-51 Mustang

# Semi-monocoque structures (USAF)



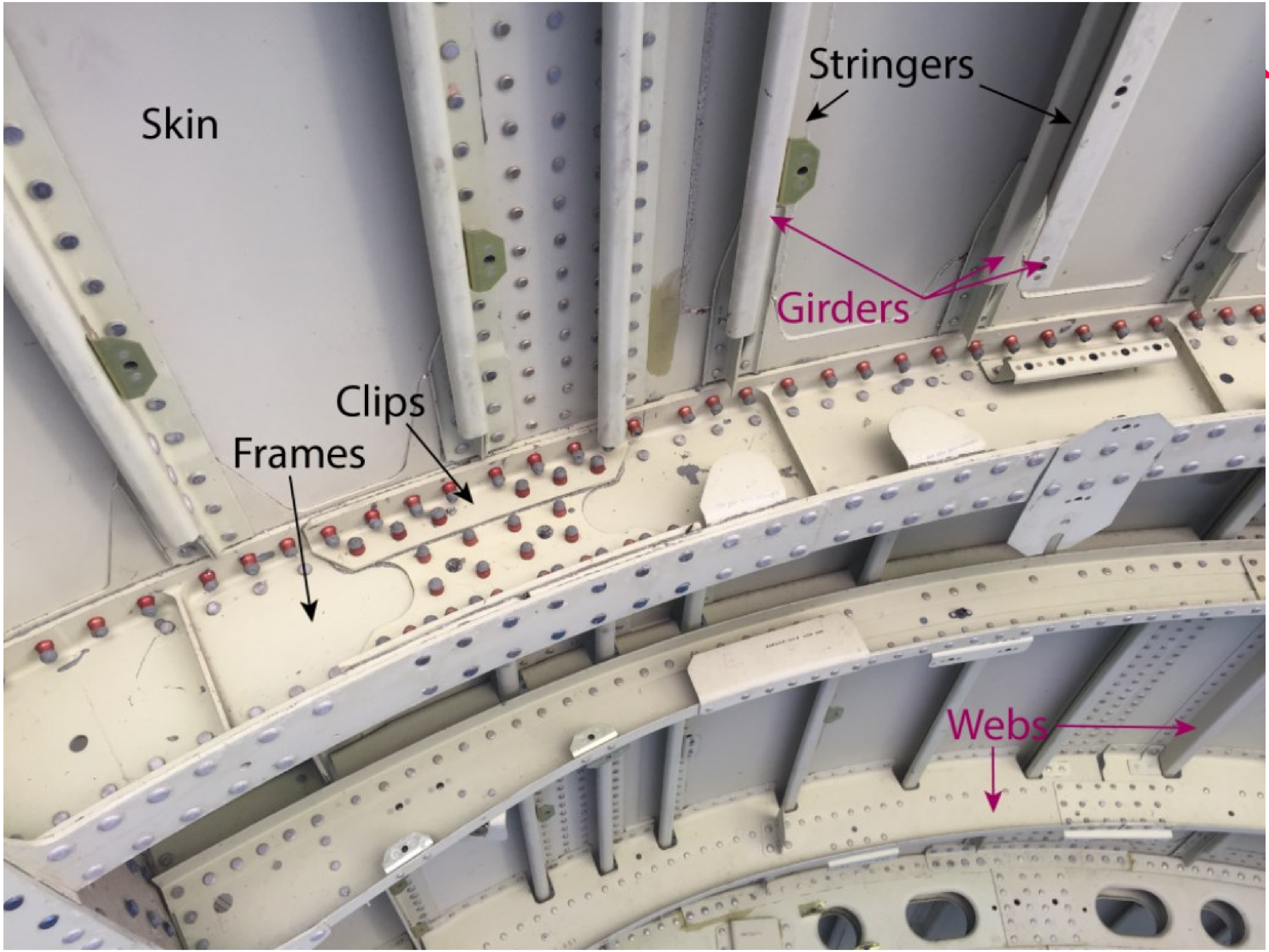
# Semi-monocoque structures (USAF)



https://www.youtube.com/watch?v=hjsrqMe0B3s&ab_channel=Animagraffs

# Semi-monocoque structures

The NACA played a significant role in airplane structures development in 1930 ’s. They developed new structural analysis methods and provided valuable test results to American industry.


Skin
Stringers
Girders
Clips
Frames
Webs


INTERDICTION DE FUMER OU DE VAPOTER
NO SMOKING OR VAPING
DEFENSE DE FUMER

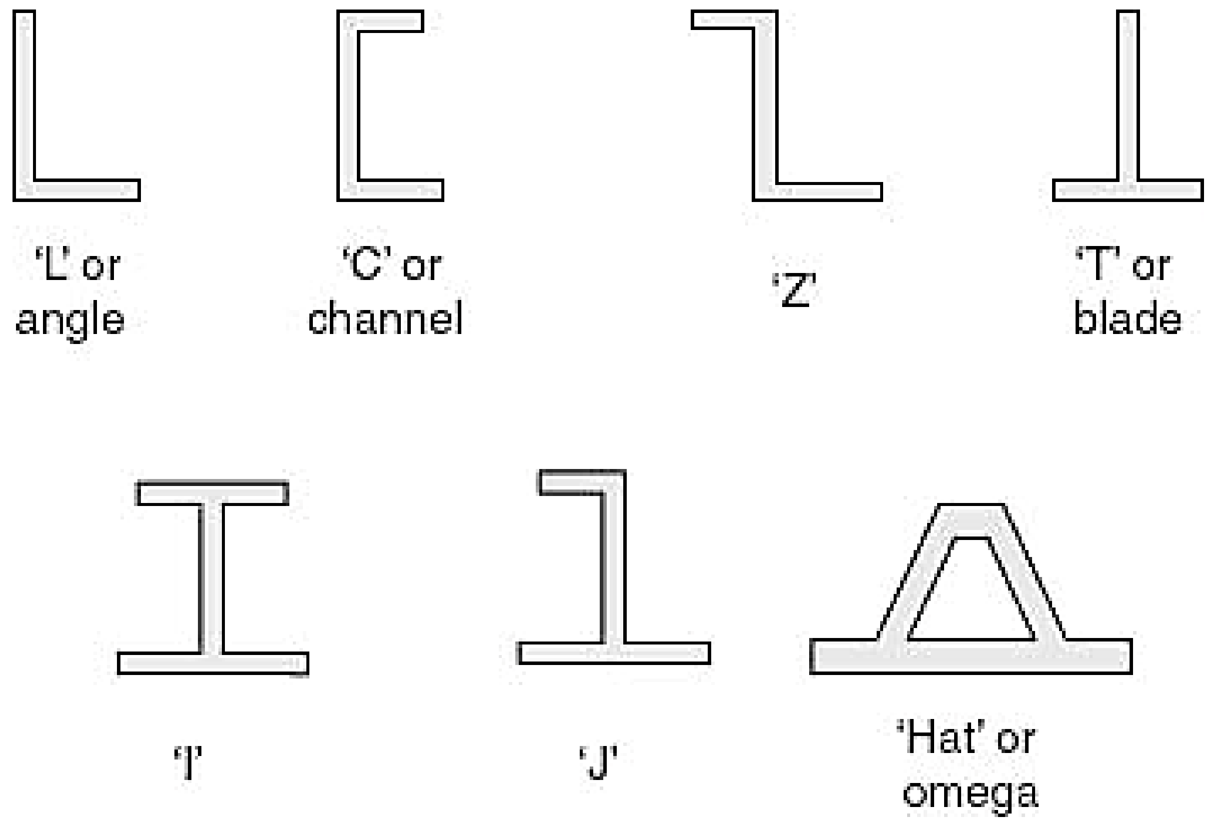

OLYMPUS

# Skin stiffeners, longerons and stringers

Gives support to the skin, helps to preserve a desirable shape of the structure

The come in a variety of cross section shapes. Usually, longerons are bigger tan stringers

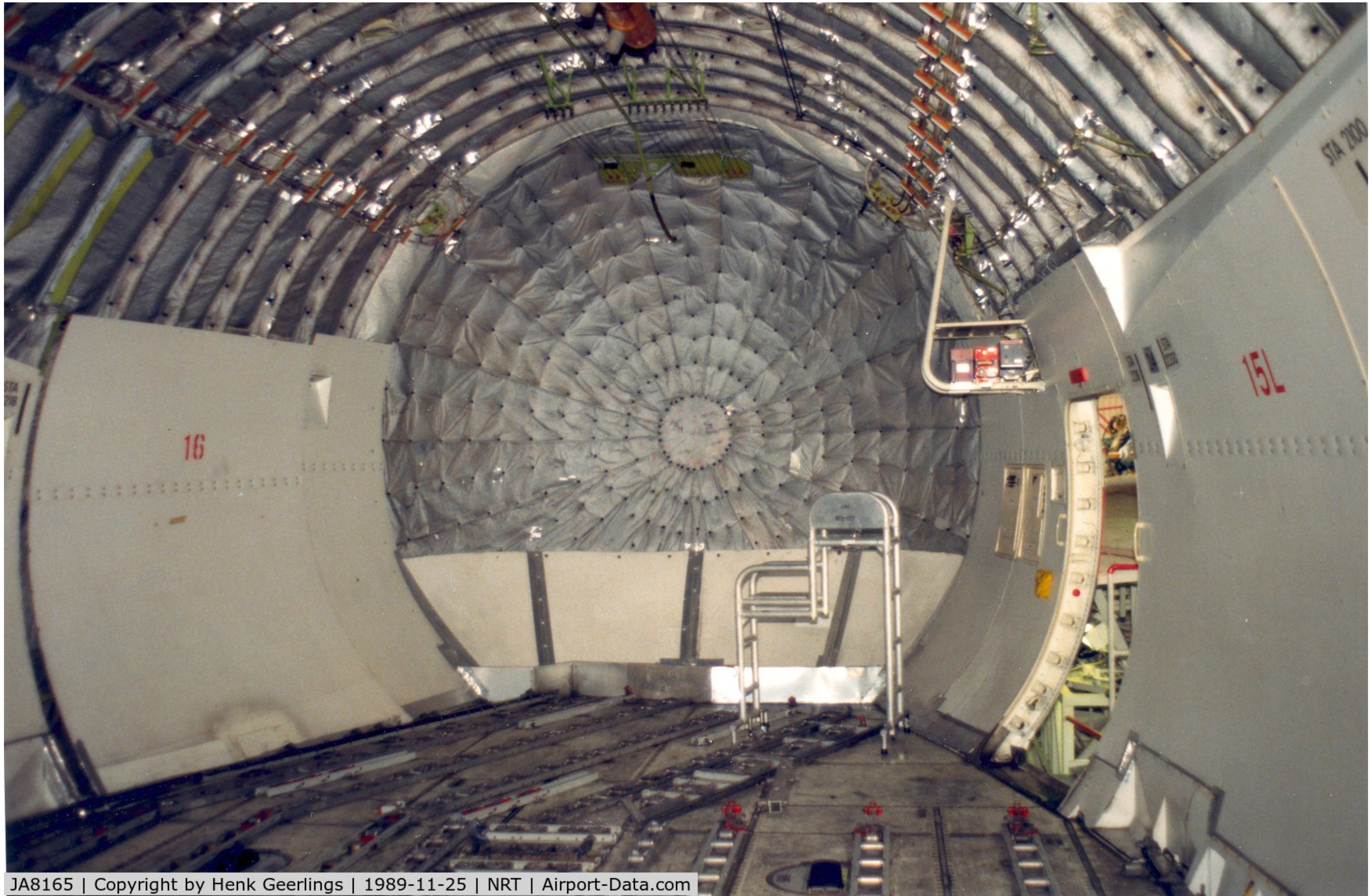
They can be made of composite or metallic materials



# Skin stiffeners, longerons and stringers

# Skin stiffeners, longerons and stringers

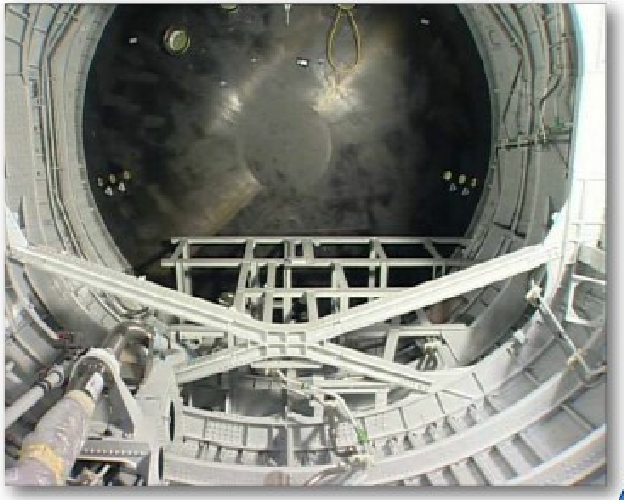
# Skin stiffeners, longerons and stringers



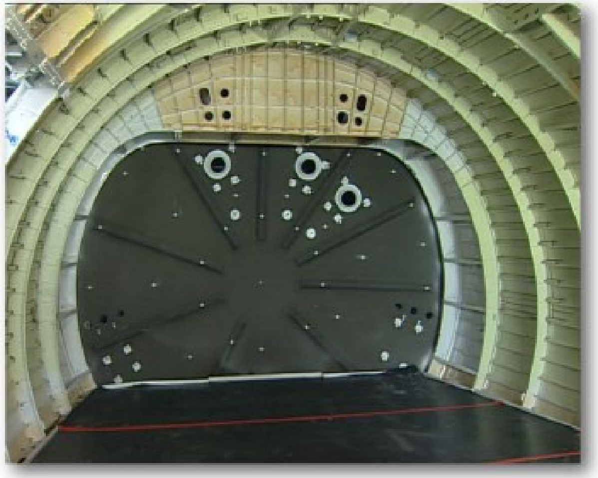
# Skin stiffeners, longerons and stringers

# Skin stiffeners, longerons and stringers

REAR PRESSURE BULKHEAD
(VIEW FROM UNPRESSURIZED AREA)



REAR PRESSURE BULKHEAD
(VIEW FROM PRESSURIZED AREA)



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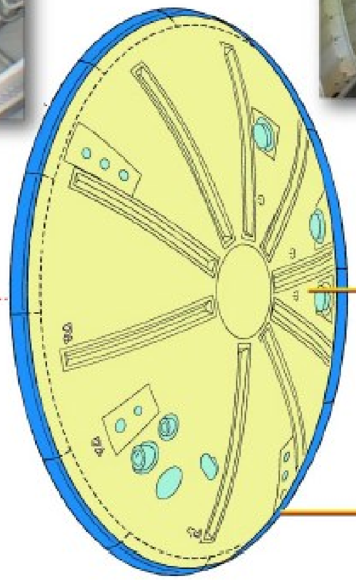


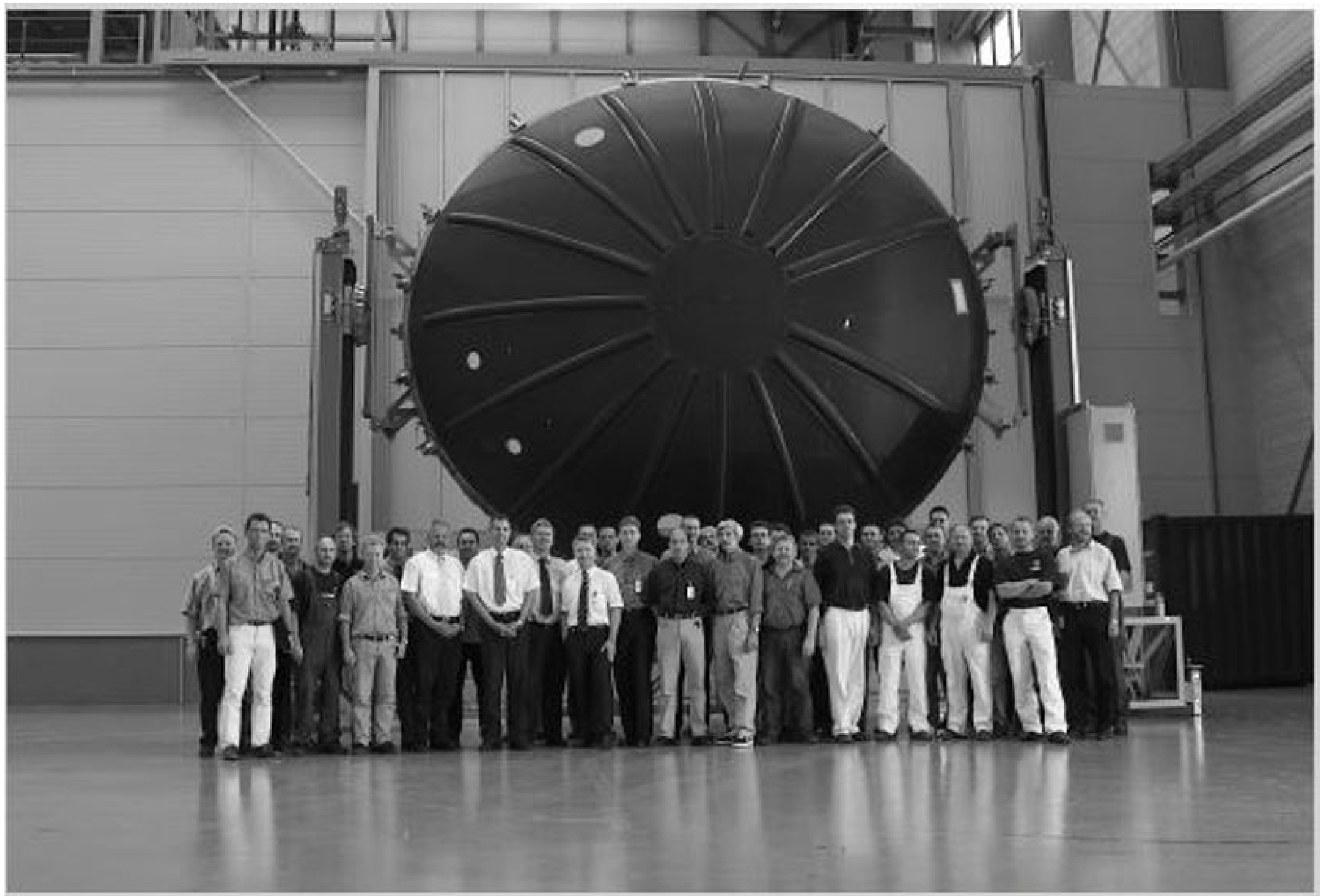
REAR PRESSURE BULKHEAD (SKIN & INTEGRATED STIFFENERS)
CFRP, MONOLITHIC STRUCTURE

RIM ANGLES
TI. ALLOY

CFRP : Carbon Fiber Reinforced Plastic

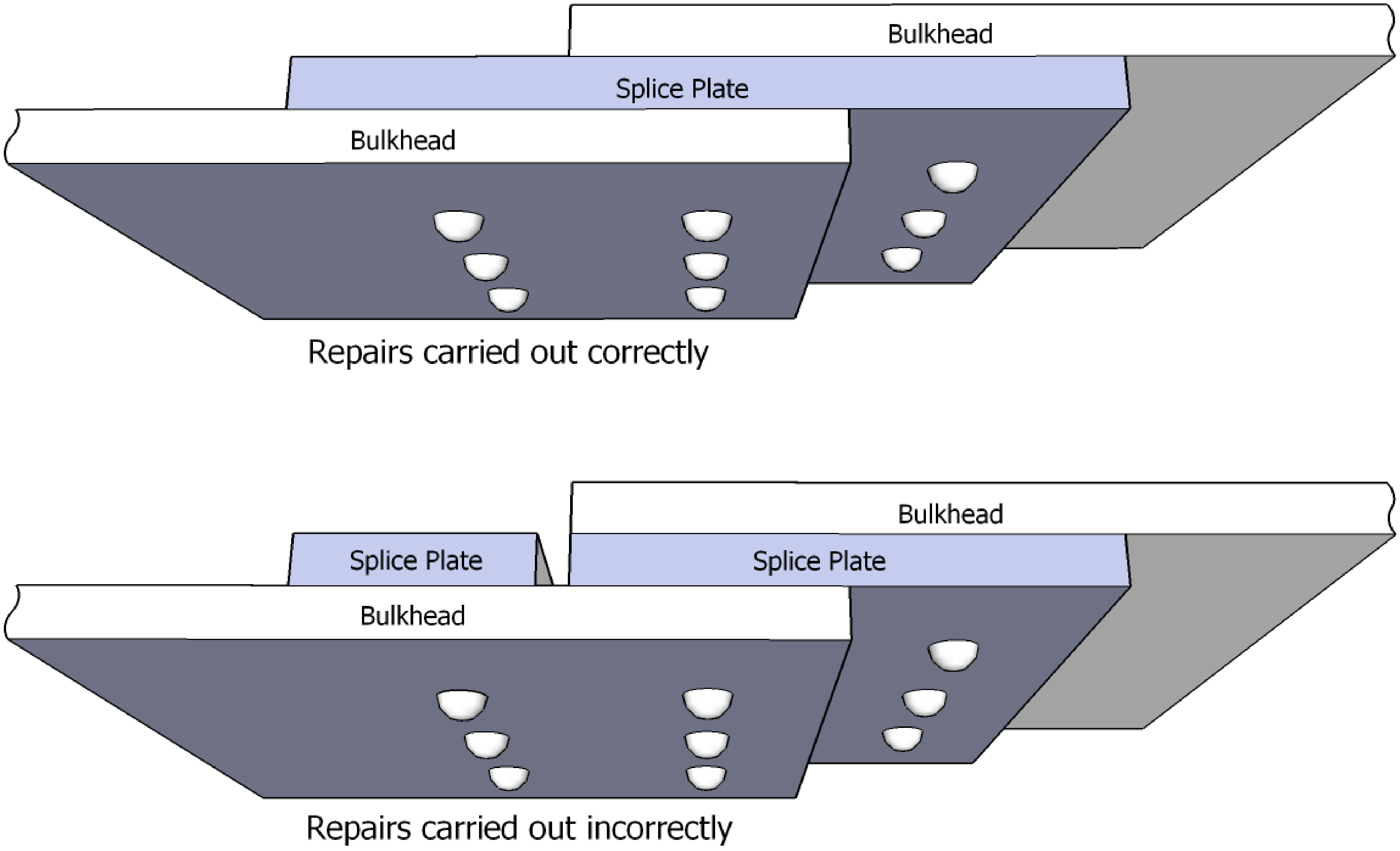
CONE/REAR FUSELAGE - REAR PRESSURE BULKHEAD

# Skin stiffeners, longerons and stringers



Completed A380 Pressure Bulkhead

# Japan Air Lines Flight 123 (1985)




1. Tailstrike 7 years before crash
2. Boeing technicians repair that damage. The repair didn’t meet Boeing’s approved methods
3. Cutting the splice plate caused a 70% reduction of fatigue cracking resistance
4. The incorrect repair would fail after 11000 pressurization cycles. The aircraft accomplished 12318 successful flights until crash

FAA report: https://www.faa.gov/sites/faa.gov/files/JAL123_Acc_Report.pdf

# Semi-monocoque structures

Semi monocoque structures are made with **composite and/or metallic materials** such as aluminum, magnesium, titanium (high temperature)

**Any component** of the semi monocoque structure **by its own can not support high loads**

When each component is reunited in the system, they form a **stiff and strong structure**

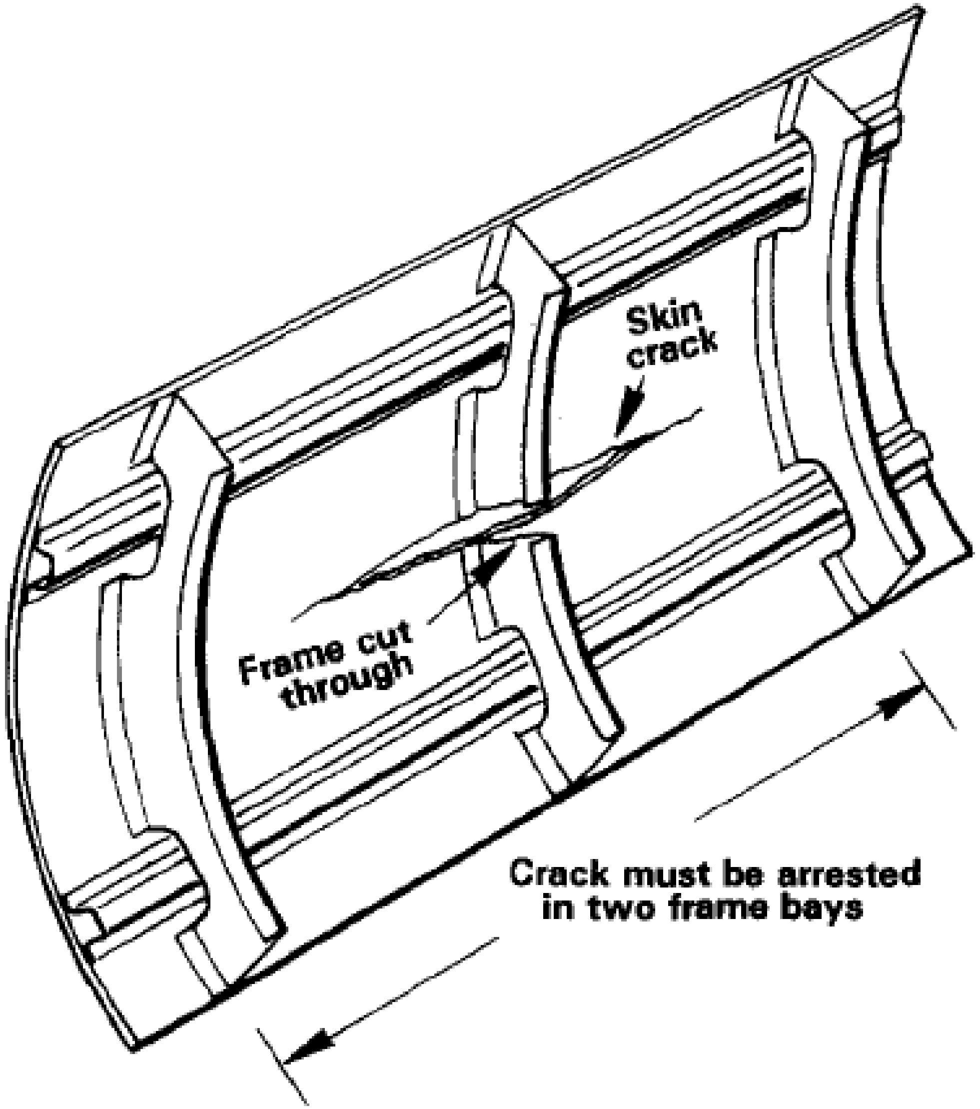
# Semi-monocoque structures

Advantages:

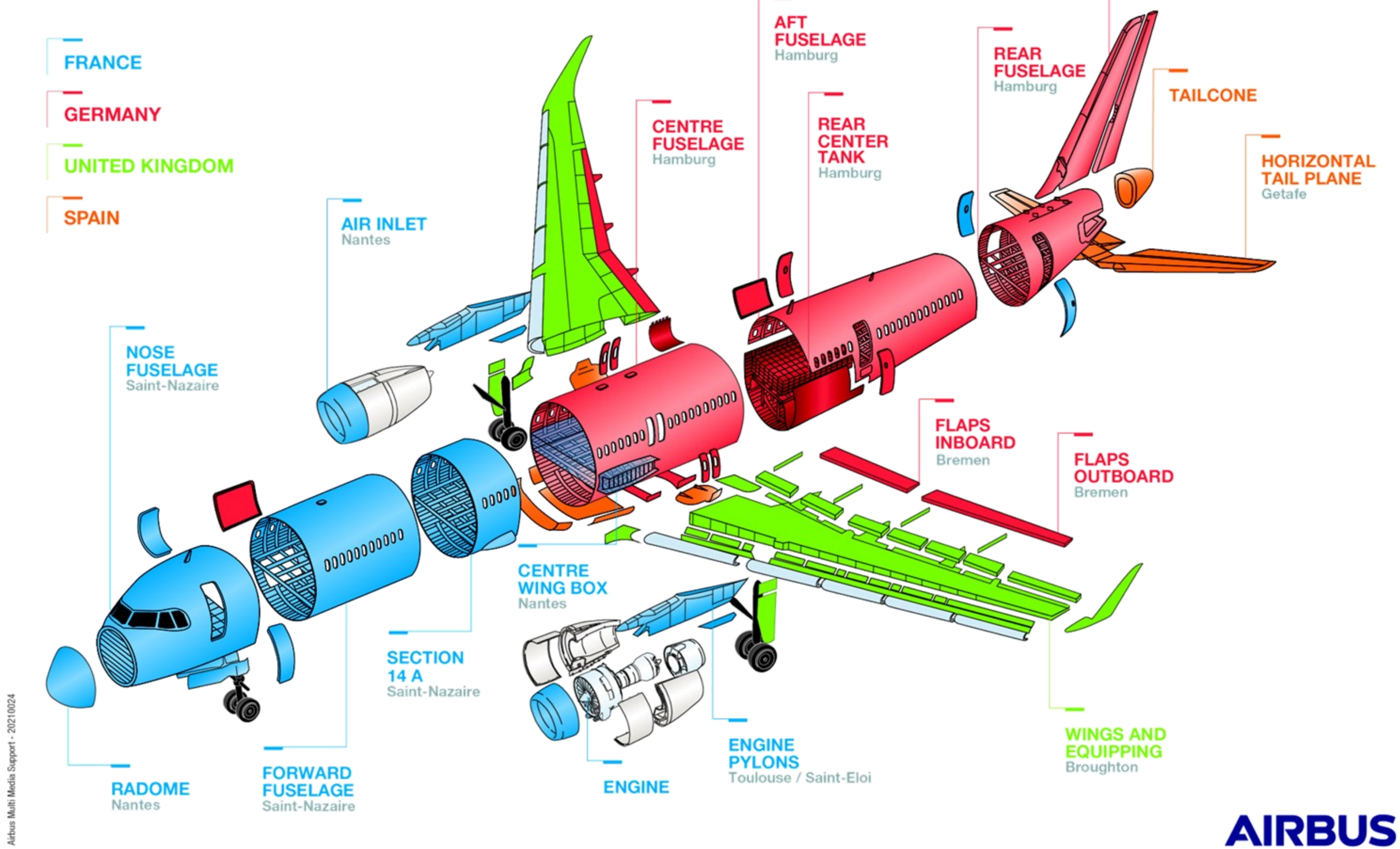
**Manufacturing process** of an aerodynamic shape structure is less complicated in terms of stiffness and strength

Loads are **uniformly distributed**

Due to redundant elements, **the structure can withstand loads even if a component fails**



# A321XLR



FRANCE
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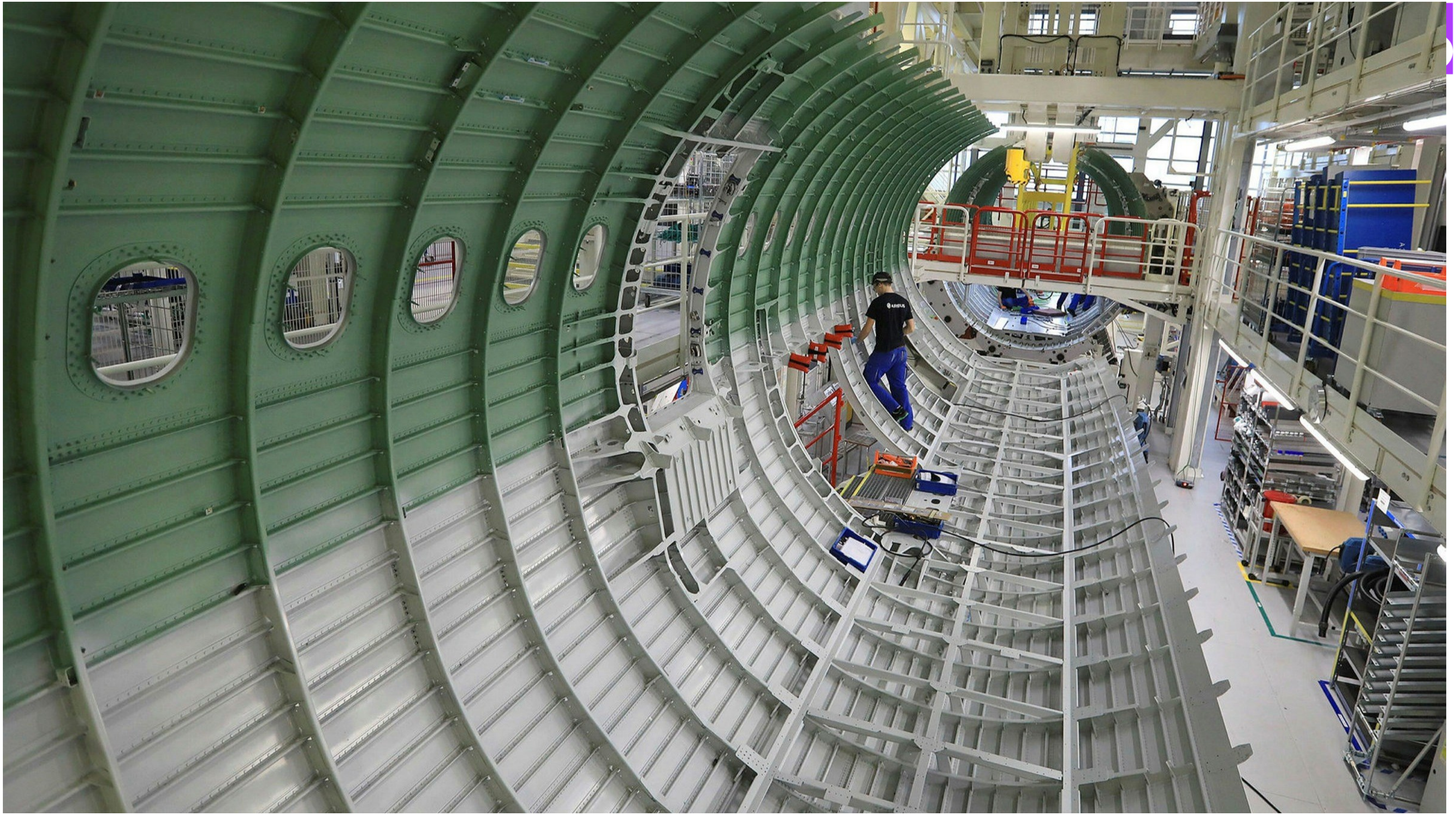
UNITED KINGDOM
SPAIN
VERTICAL TAIL PLANE
Stade
AFT FUSELAGE
Hamburg
REAR FUSELAGE
Hamburg
TAILCONE
CENTRE FUSELAGE
Hamburg
REAR CENTER TANK
Hamburg
HORIZONTAL TAIL PLANE
Getafe
AIR INLET
Nantes
NOSE FUSELAGE
Saint-Nazaire
FLAPS INBOARD
Bremen
FLAPS OUTBOARD
Bremen
CENTRE WING BOX
Nantes
SECTION 14 A
Saint-Nazaire
ENGINE PYLONS
Toulouse / Saint-Eloi
WINGS AND EQUIPPING
Broughton
RADOME
Nantes
FORWARD FUSELAGE
Saint-Nazaire
ENGINE
Airbus Multi Media Support - 20210024


DREAMLINER

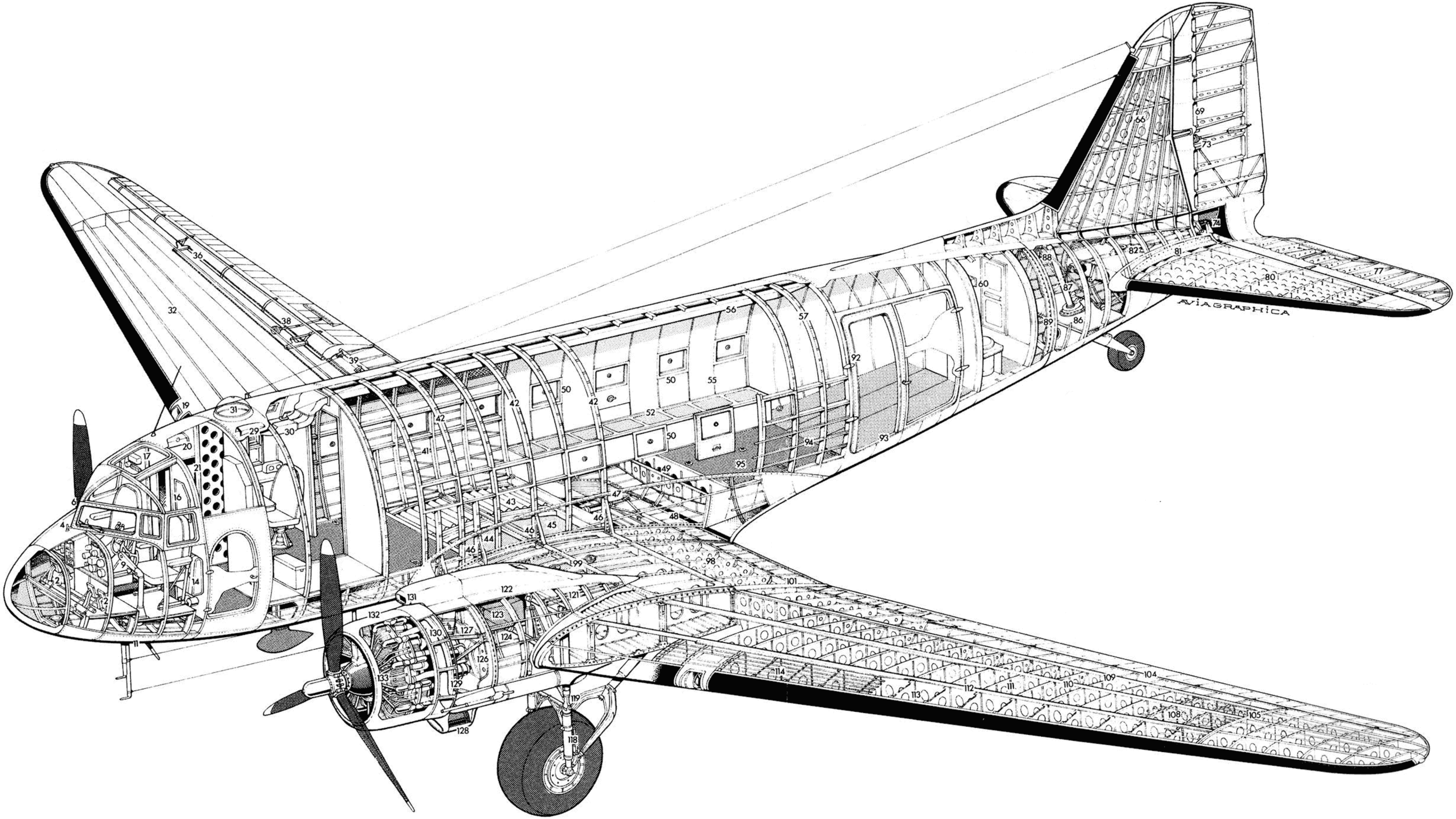


# Semi-monocoque structures

**Wider and longer fuselages** were achieved with semi-monocoque structures (Higher capacities for PAX and loads)

Flying boats were transformed into **aerodynamic shape fuselages**

A great example is the **Douglas DC 3** which imposed a paradigm of a “**modern**” aircraft

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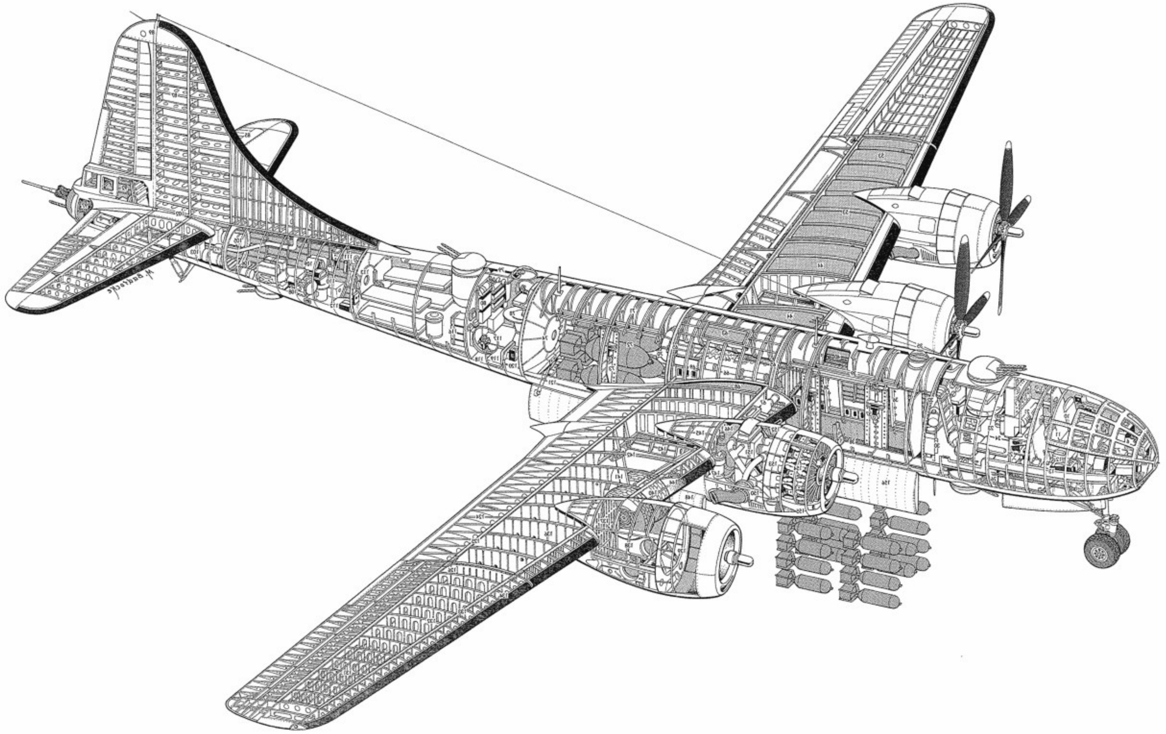
https://youtu.be/hiVdF2UBY4Y

https://www.youtube.com/watch?v=NZLbTuBDhJg&ab_channel=Animagraffs

# History



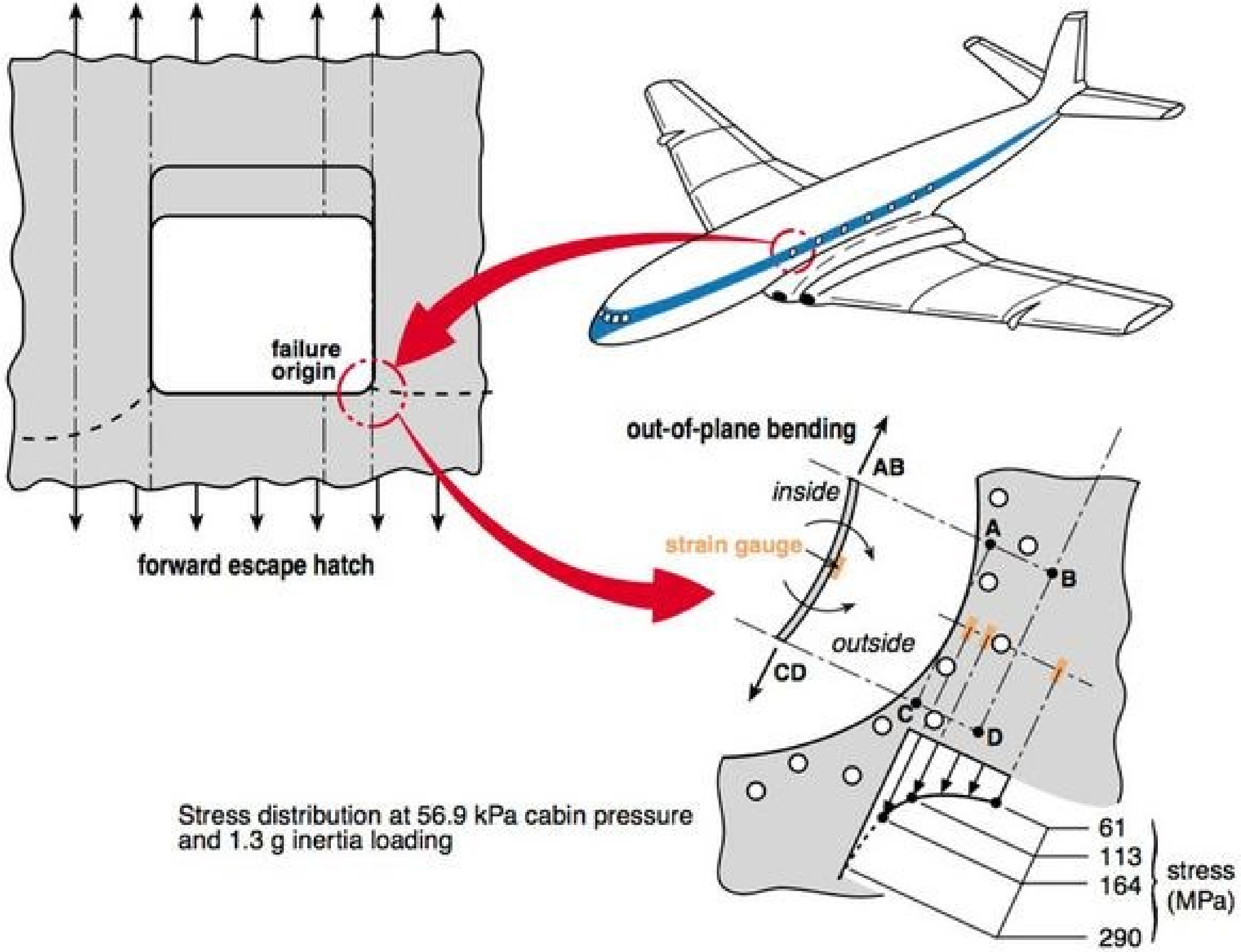
# History

After WWII, **new propulsion systems arrived**

These aircrafts, “jets”, **flight higher and faster** than any aircraft made before (pressurization is needed)

**Upgrades in aerodynamics were needed** thus, new structural approaches (new materials and alloys)

# History (De Havilland Comet)



# History (jetliners)


Sud Aviation Caravelle
France (First flight 1955)


Tupolev TU-104
USSR (First flight 1955)

# History (jetliners)


Boeing 707
USA (First flight 1957)


Douglas DC-8
USA (First flight 1958)

# History (jetliners)

**Deliveries**

Comet 4: 76

Douglas DC-8: 556

Boeing 707: 1011

# History (jetliners)

New manufacturing processes were developed in order to **reduce skin thicknesses and enhance its strength** (etching, machining)

**Aerodynamic loads increases** due to higher dynamic pressure (thin wings were needed)

**Box beams** were developed (stiffer beams)

Wingbox
Center wingbox

# History (jetliners)

Since 50’s civil aviation started to growth. **Aluminum became essential**

**Weight became the fundamental factor.** New materials were considered (composites)

Thickness reduction presented problems related to weight/strength ratio (Sandwich structures are considered)

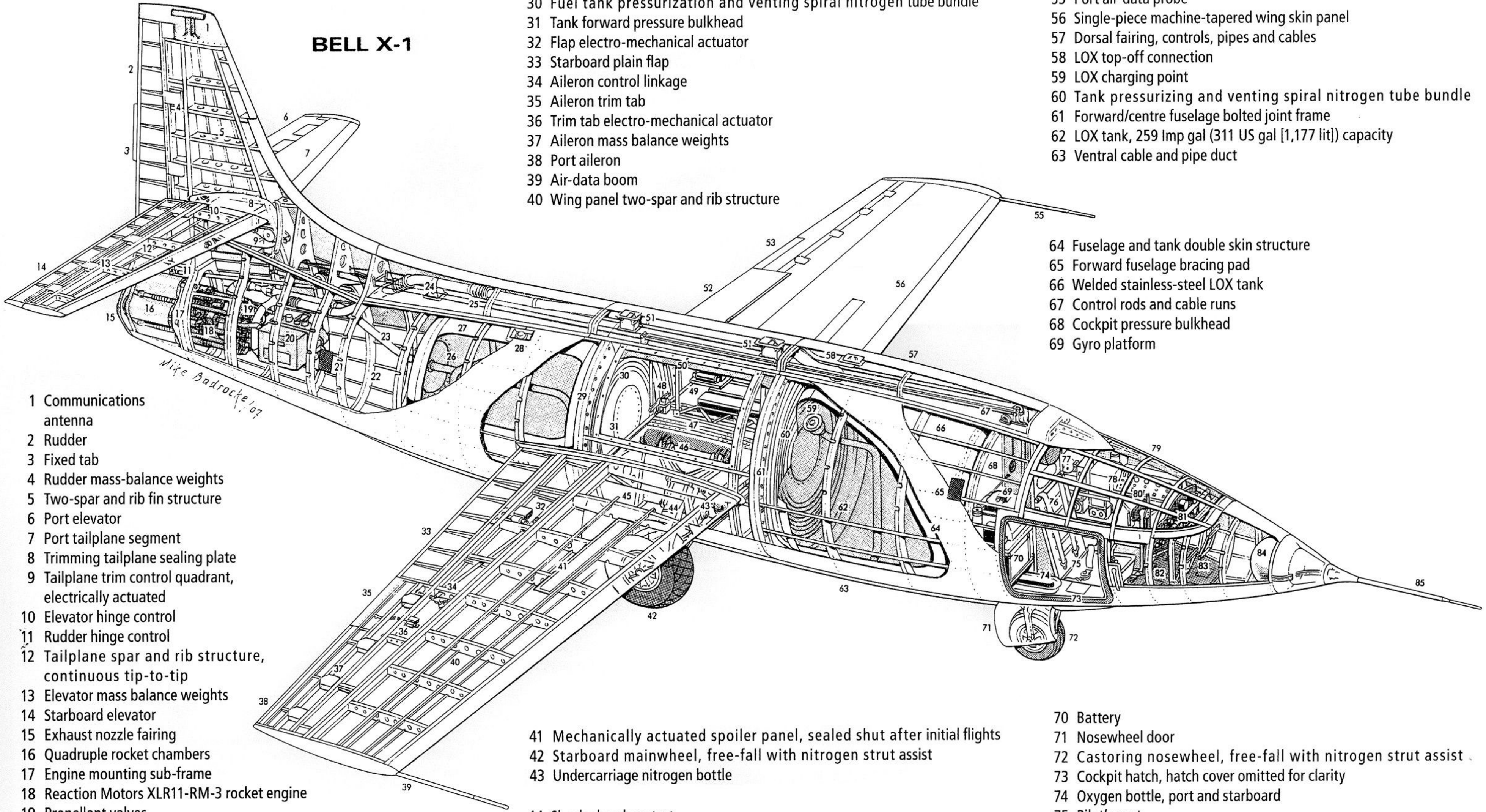
# History (jetliners)

The primary structural challenge for supersonic aircraft was the need to use **wings with smaller thickness to chord ratios**

This meant that the load bearing elements were closer to each other and **did not resemble deep beams**

Rather they were more like **thick plate structures**. **Multiple spars** with thicker skins were used. Sometimes a **full depth honeycomb** structure was employed

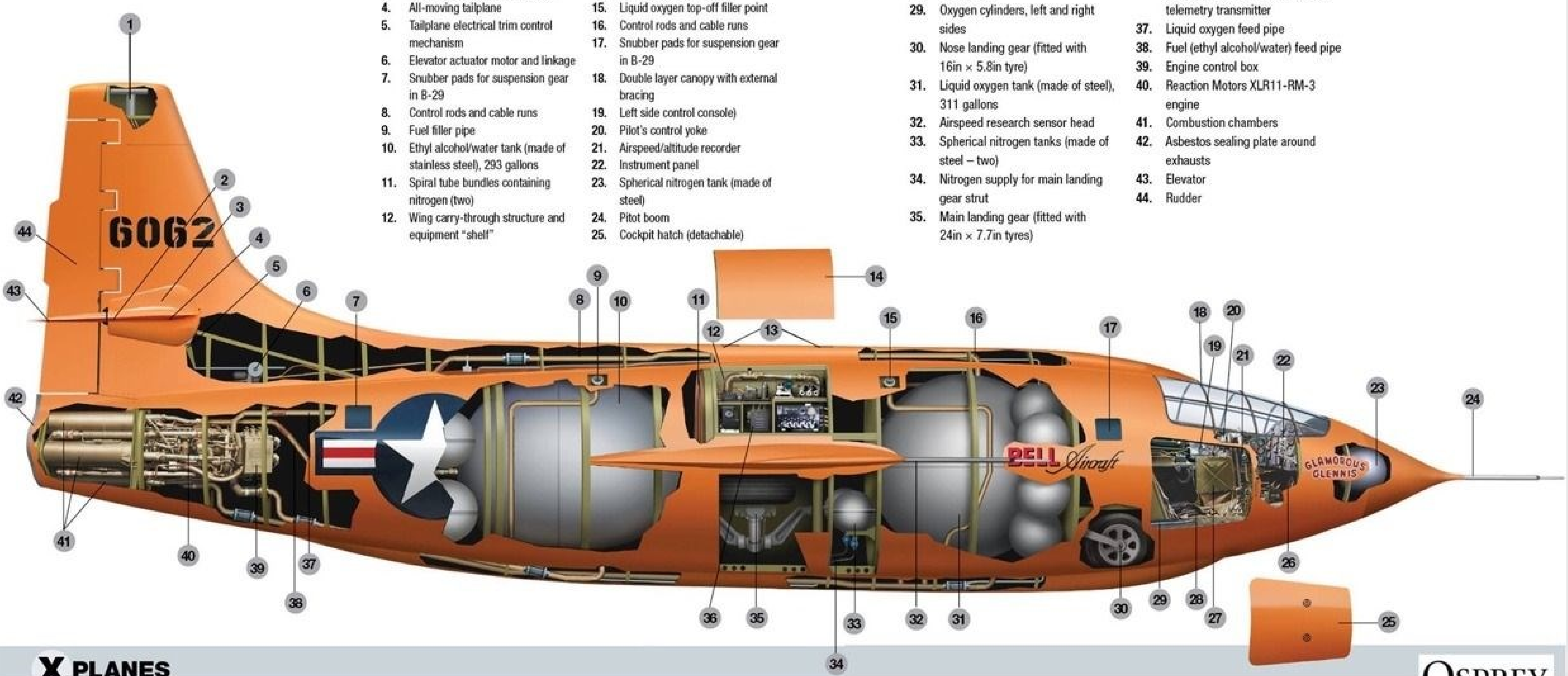
# BELL X-1



1 Communications antenna
2 Rudder
3 Fixed tab
4 Rudder mass-balance weights
5 Two-spar and rib fin structure
6 Port elevator
7 Port tailplane segment
8 Trimming tailplane sealing plate
9 Tailplane trim control quadrant, electrically actuated
10 Elevator hinge control
11 Rudder hinge control
12 Tailplane spar and rib structure, continuous tip-to-tip
13 Elevator mass balance weights
14 Starboard elevator
15 Exhaust nozzle fairing
16 Quadruple rocket chambers
17 Engine mounting sub-frame
18 Reaction Motors XLR11-RM-3 rocket engine
19 Propellant valves
20 Control box
21 Rear fuselage bracing pad for carrier aircraft
22 Rear fuselage frame and stringer structure
23 Fuel feed pipe
24 Liquid oxygen (LOX) insulated feed pipe
25 Pipe expansion joints
26 Ethyl-alcohol fuel tank, 244 Imp gal (293 US gal [1,109 lit]) capacity
27 Welded stainless-steel tank structure
28 Fuel filler point
29 Centre/aft fuselage bolted joint frame
30 Fuel tank pressurization and venting spiral nitrogen tube bundle
31 Tank forward pressure bulkhead
32 Flap electro-mechanical actuator
33 Starboard plain flap
34 Aileron control linkage
35 Aileron trim tab
36 Trim tab electro-mechanical actuator
37 Aileron mass balance weights
38 Port aileron
39 Air-data boom
40 Wing panel two-spar and rib structure
41 Mechanically actuated spoiler panel, sealed shut after initial flights
42 Starboard mainwheel, free-fall with nitrogen strut assist
43 Undercarriage nitrogen bottle
44 Shock absorber strut
45 Mainwheel door
46 Mainwheel leg and breaker strut hinge mounting
47 Wing panel centreline joint
48 Aileron control linkage
49 Test and recording equipment, interchangeable
50 Centre fuselage access hatch
51 Aircraft suspension links and spring-loaded doors
52 Port plain flap
53 Aileron tab
54 Port aileron
55 Port air-data probe
56 Single-piece machine-tapered wing skin panel
57 Dorsal fairing, controls, pipes and cables
58 LOX top-off connection
59 LOX charging point
60 Tank pressurizing and venting spiral nitrogen tube bundle
61 Forward/centre fuselage bolted joint frame
62 LOX tank, 259 Imp gal (311 US gal [1,177 lit]) capacity
63 Ventral cable and pipe duct
64 Fuselage and tank double skin structure
65 Forward fuselage bracing pad
66 Welded stainless-steel LOX tank
67 Control rods and cable runs
68 Cockpit pressure bulkhead
69 Gyro platform
70 Battery
71 Nosewheel door
72 Castoring nosewheel, free-fall with nitrogen strut assist
73 Cockpit hatch, hatch cover omitted for clarity
74 Oxygen bottle, port and starboard
75 Pilot's seat
76 Seat harness
77 Headrest
78 Port side console panel
79 Externally-braced windscreen panel
80 Control yoke
81 Instrument panel
82 Cockpit floor
83 Rudder pedals
84 Nitrogen bottle
85 Pitot head

## XS-1 CUTAWAY

1. Radio antenna
2. Elevator mass balance weights
3. Tailplane actuator sealing plate
4. All-moving tailplane
5. Tailplane electrical trim control mechanism
6. Elevator actuator motor and linkage
7. Snubber pads for suspension gear in B-29
8. Control rods and cable runs
9. Fuel filler pipe
10. Ethyl alcohol/water tank (made of stainless steel), 293 gallons
11. Spiral tube bundles containing nitrogen (two)
12. Wing carry-through structure and equipment "shelf"
13. Link points for suspension in B-29 launch bay
14. Fuselage access hatch
15. Liquid oxygen top-off filler point
16. Control rods and cable runs
17. Snubber pads for suspension gear in B-29
18. Double layer canopy with external bracing
19. Left side control console)
20. Pilot's control yoke
21. Airspeed/altitude recorder
22. Instrument panel
23. Spherical nitrogen tank (made of steel)
24. Pitot boom
25. Cockpit hatch (detachable)
26. Rudder pedals
27. Battery
28. Pilot's seat
29. Oxygen cylinders, left and right sides
30. Nose landing gear (fitted with 16in × 5.8in tyre)
31. Liquid oxygen tank (made of steel), 311 gallons
32. Airspeed research sensor head
33. Spherical nitrogen tanks (made of steel – two)
34. Nitrogen supply for main landing gear strut
35. Main landing gear (fitted with 24in × 7.7in tyres)
36. Test equipment bay containing (typically) oscillograph, manometer, accelerometer and performance telemetry transmitter
37. Liquid oxygen feed pipe
38. Fuel (ethyl alcohol/water) feed pipe
39. Engine control box
40. Reaction Motors XLR11-RM-3 engine
41. Combustion chambers
42. Asbestos sealing plate around exhausts
43. Elevator
44. Rudder




X PLANES
BELL X-1

OSPREY PUBLISHING

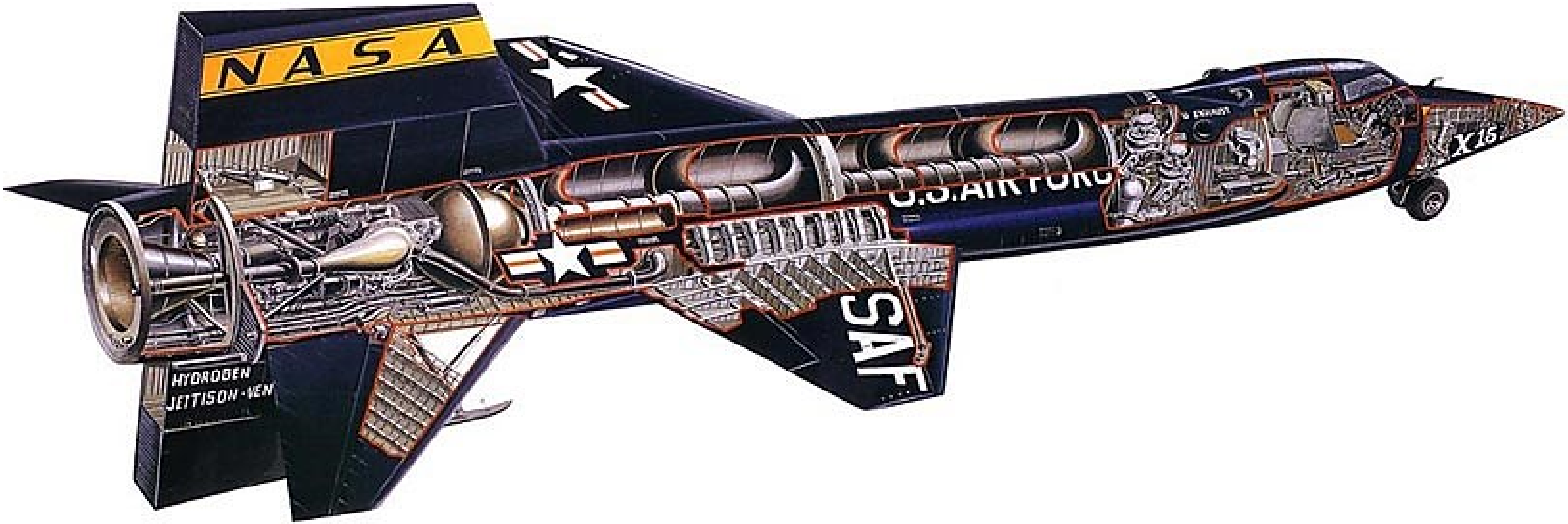
# History

Due to the skin friction, the upper fuselage reached temperatures over 240 °F. While other parts reached 665 °F

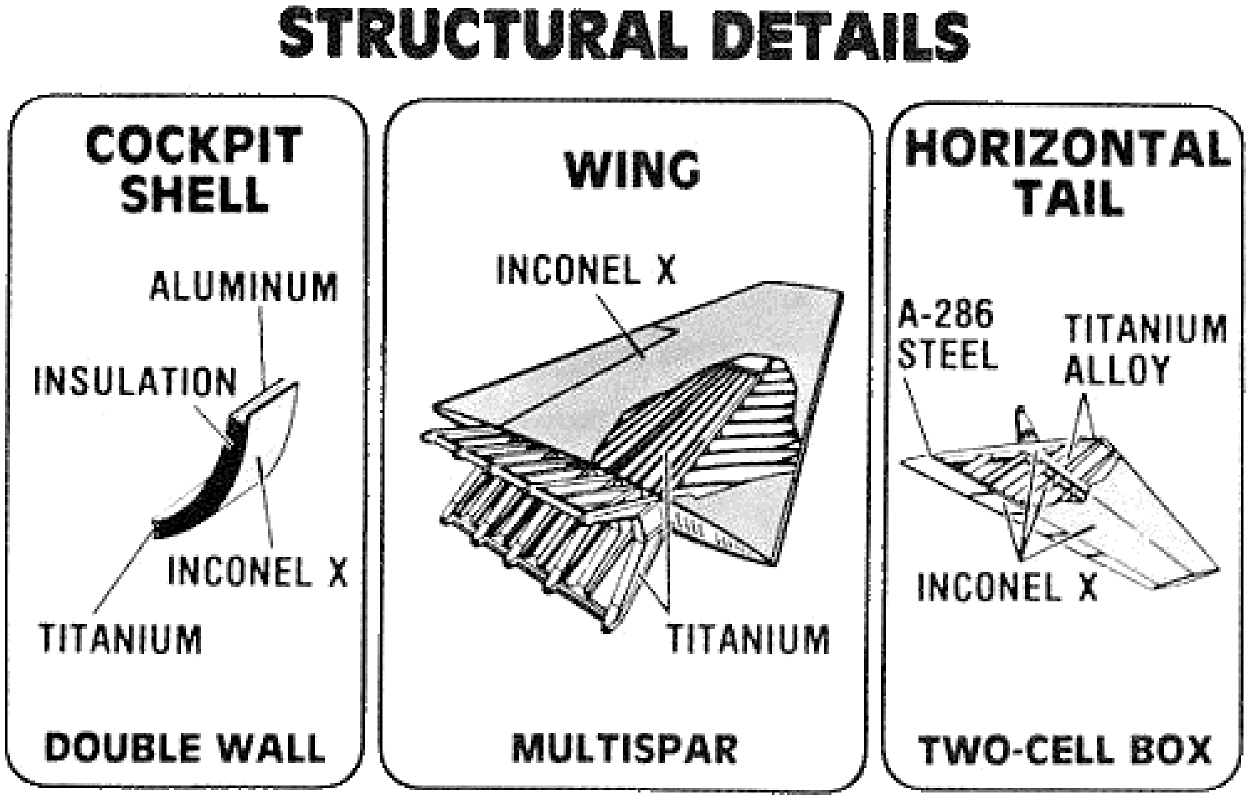
Inconel X was used for wing skins because it retained strength at these high temperatures even though it was a difficult material to work with

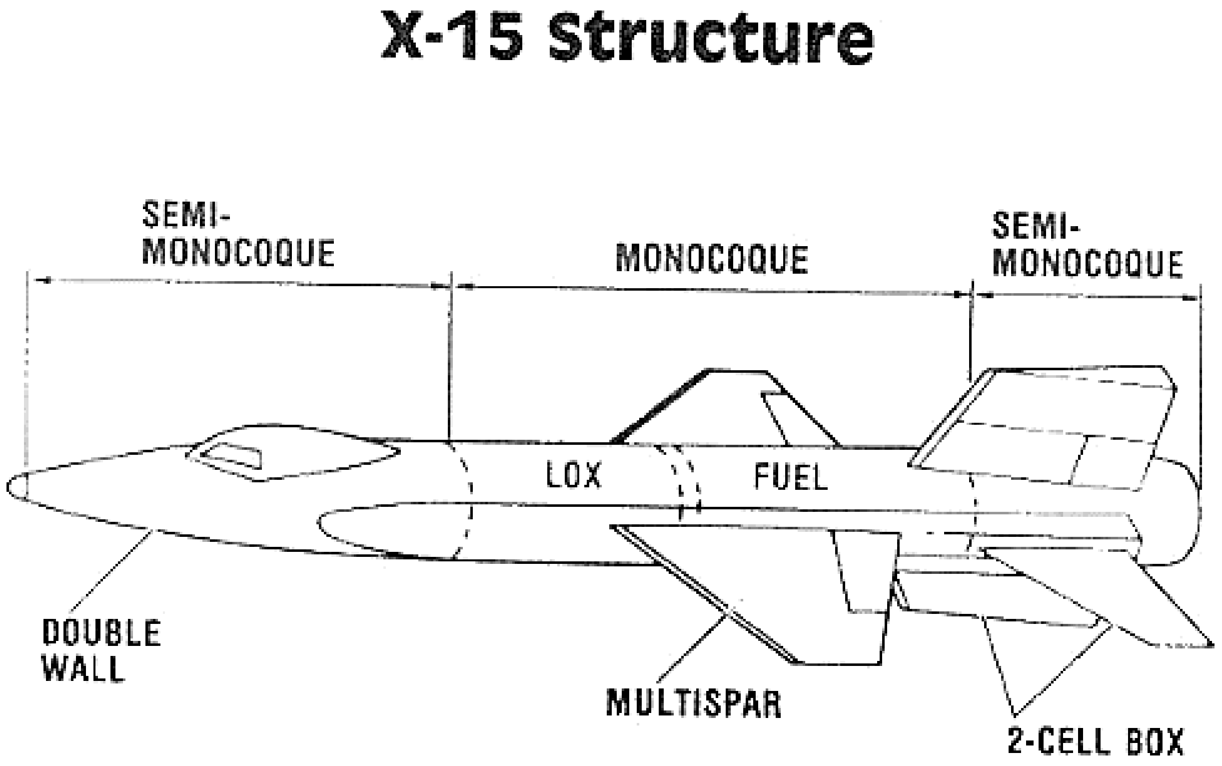
Titanium frame

# History



# History


STRUCTURAL DETAILS
COCKPIT SHELL
ALUMINUM
INSULATION
INCONEL X
TITANIUM
DOUBLE WALL
WING
INCONEL X
TITANIUM
MULTISPAR
HORIZONTAL TAIL
A-286 STEEL
TITANIUM ALLOY
INCONEL X
TWO-CELL BOX

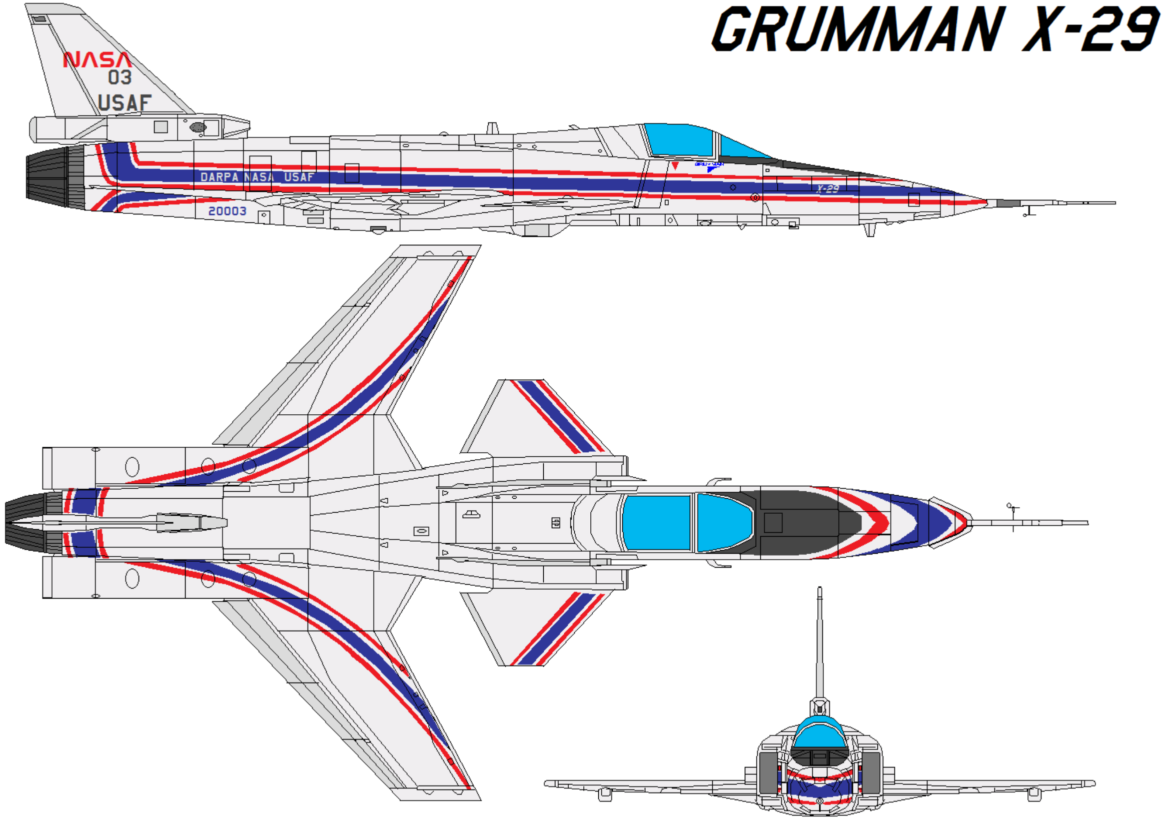

X-15 Structure
SEMI-MONOCOQUE
MONOCOQUE
SEMI-MONOCOQUE
LOX
FUEL
DOUBLE WALL
MULTISPAR
2-CELL BOX

# History (Sweep wings)

These aircraft were mechanized structures that included heavy wing pivots and motors or hydraulics to move the wing in flight

# History


NASA
049
USAF
GRUMMAN DARPA NASA USAF
X-29


GRUMMAN X-29
NASA
03
USAF
DARPA NASA USAF
20003

# History

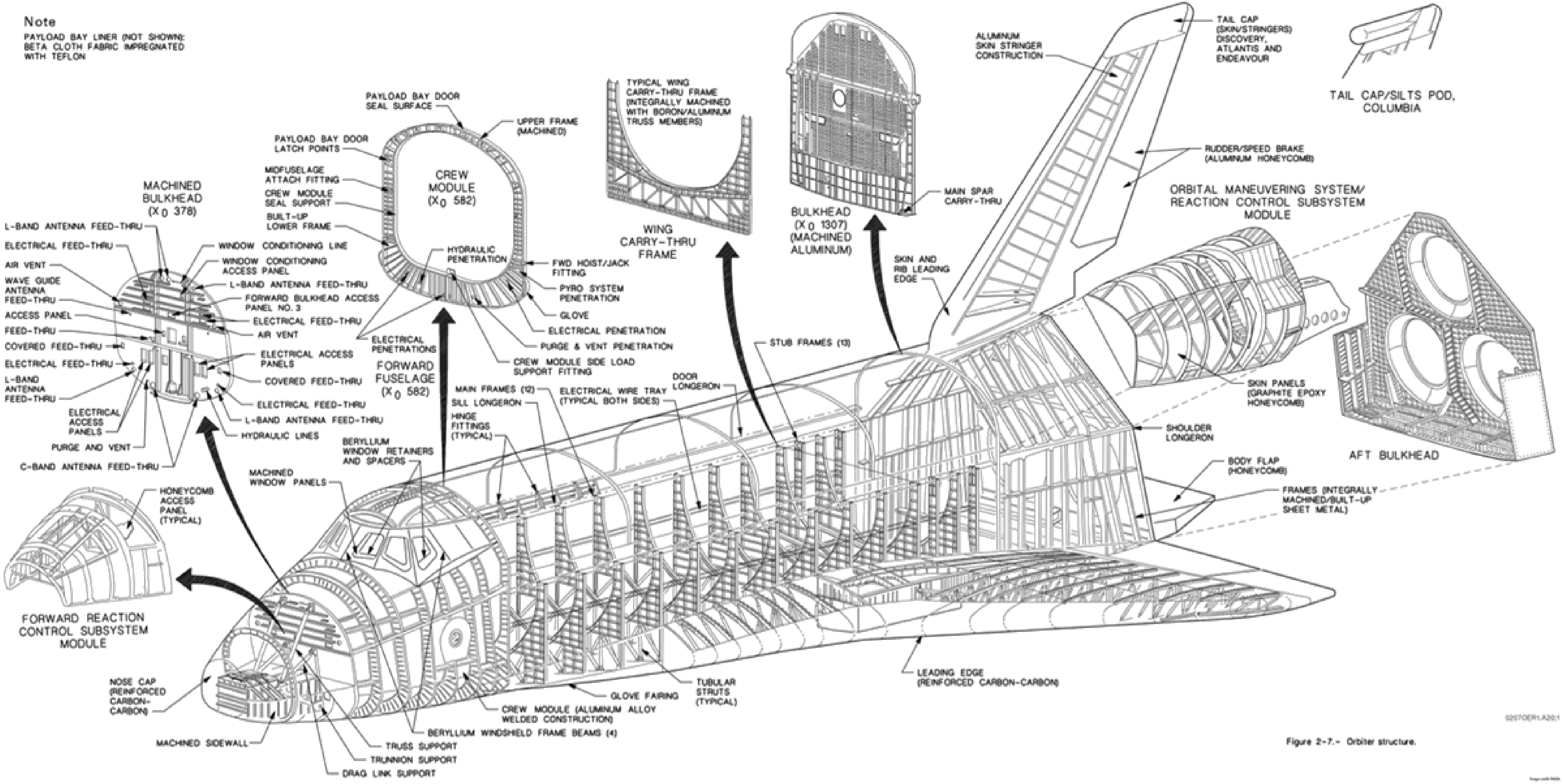
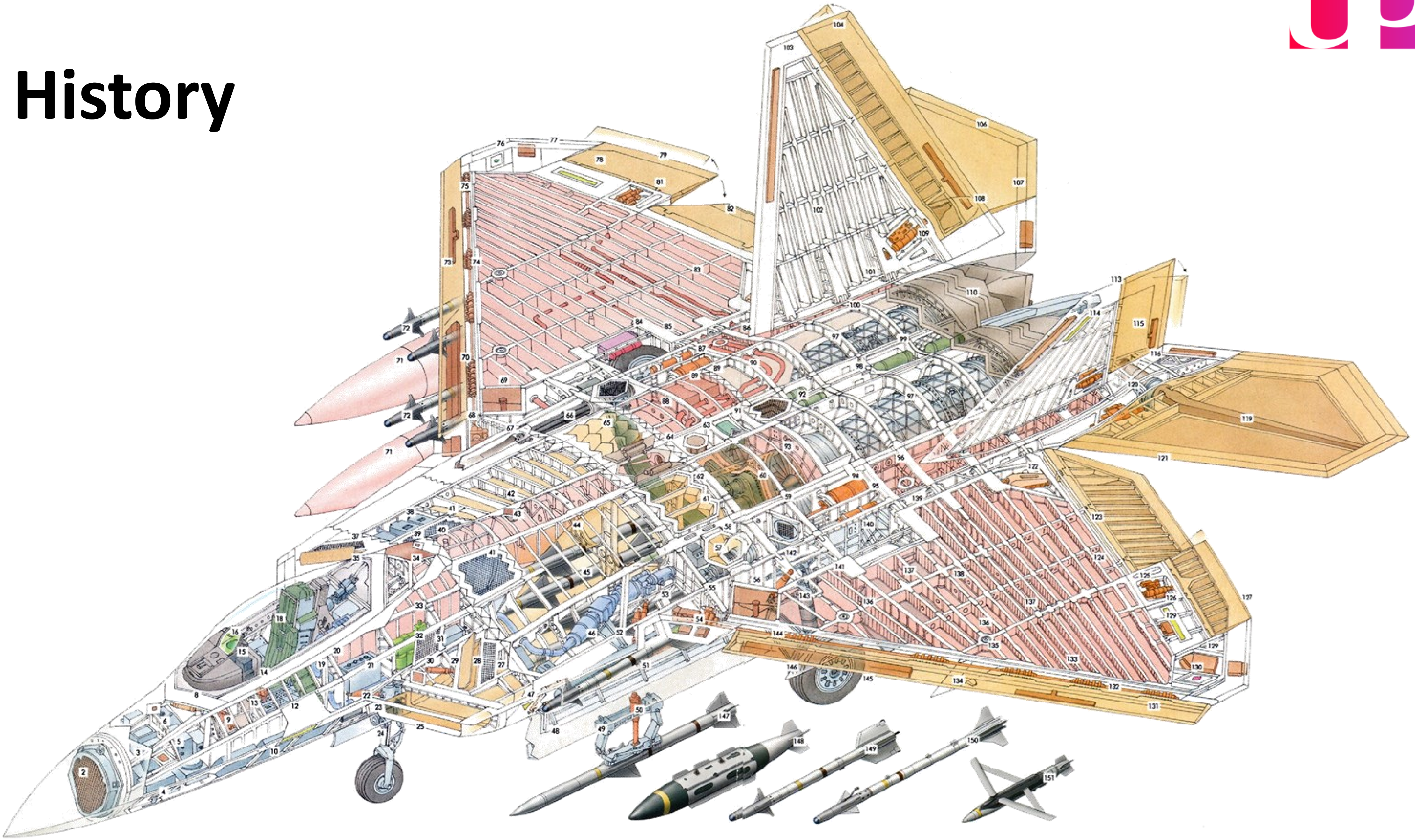
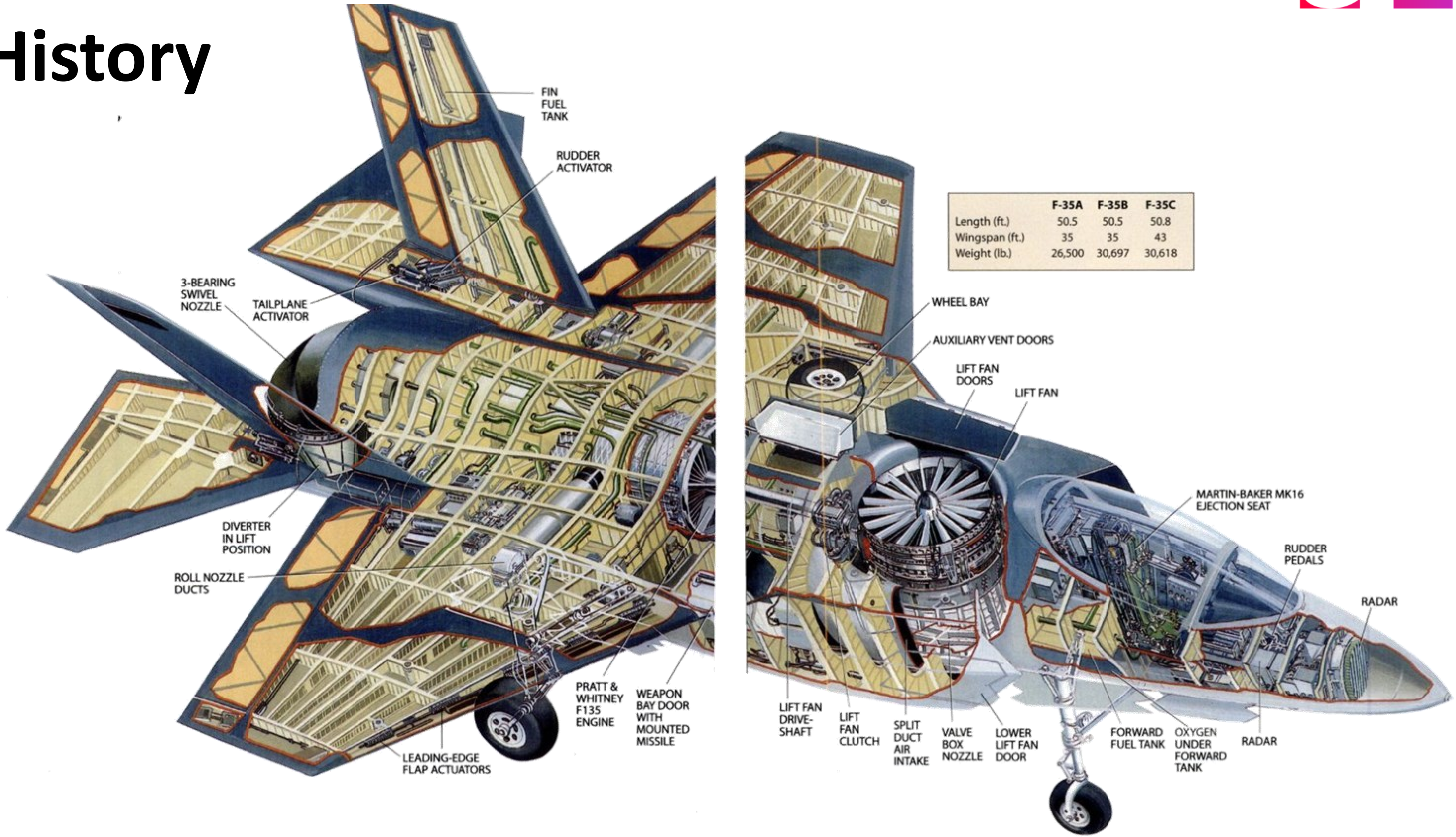



Figure 2-7.- Orbiter structure.

# History



# History



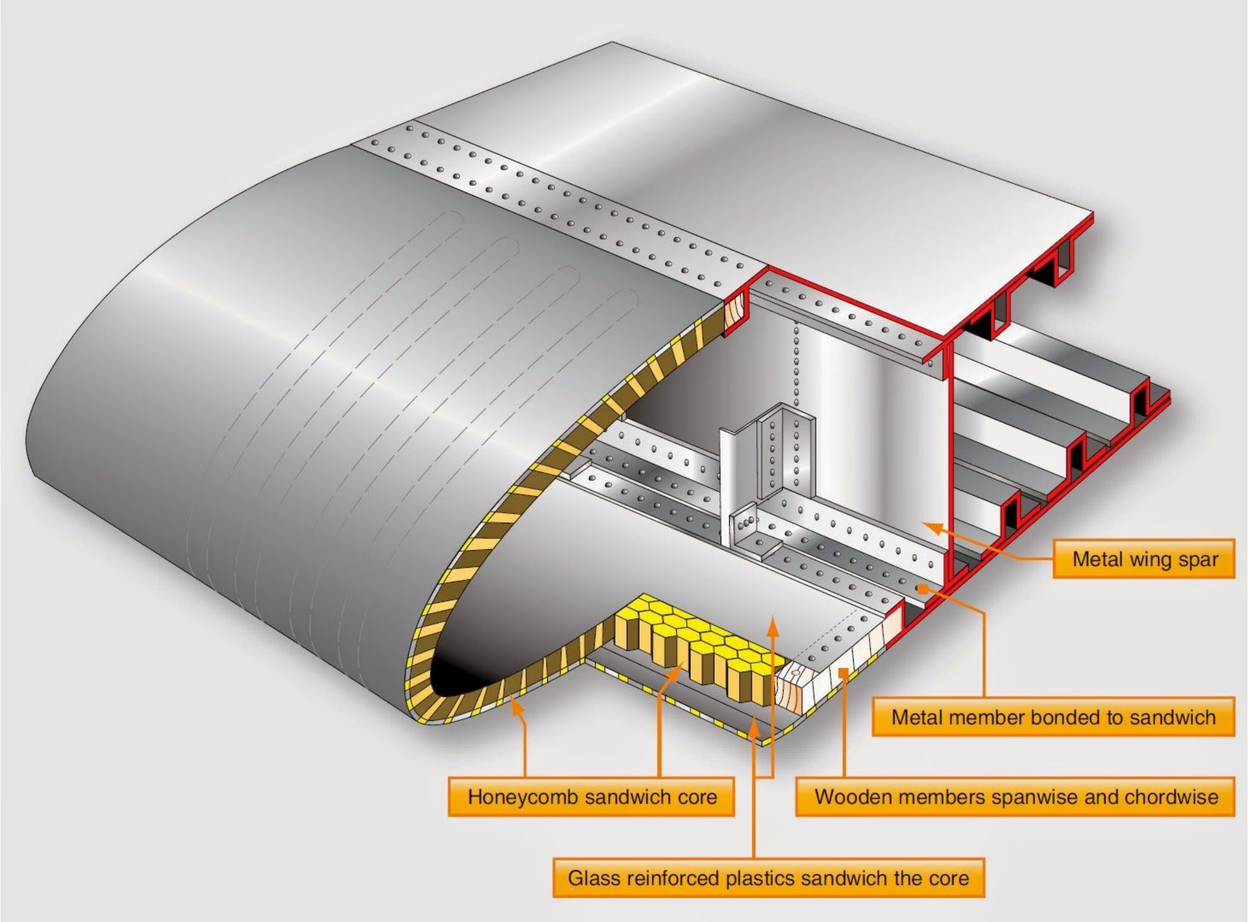

| | F-35A | F-35B | F-35C |
|---|---|---|---|
| Length (ft.) | 50.5 | 50.5 | 50.8 |
| Wingspan (ft.) | 35 | 35 | 43 |
| Weight (lb.) | 26,500 | 30,697 | 30,618 |

# History

**Sandwich structures provides stiffness to the skin**, by means of a **lightweight core** (noise reduction and isolation are reached)

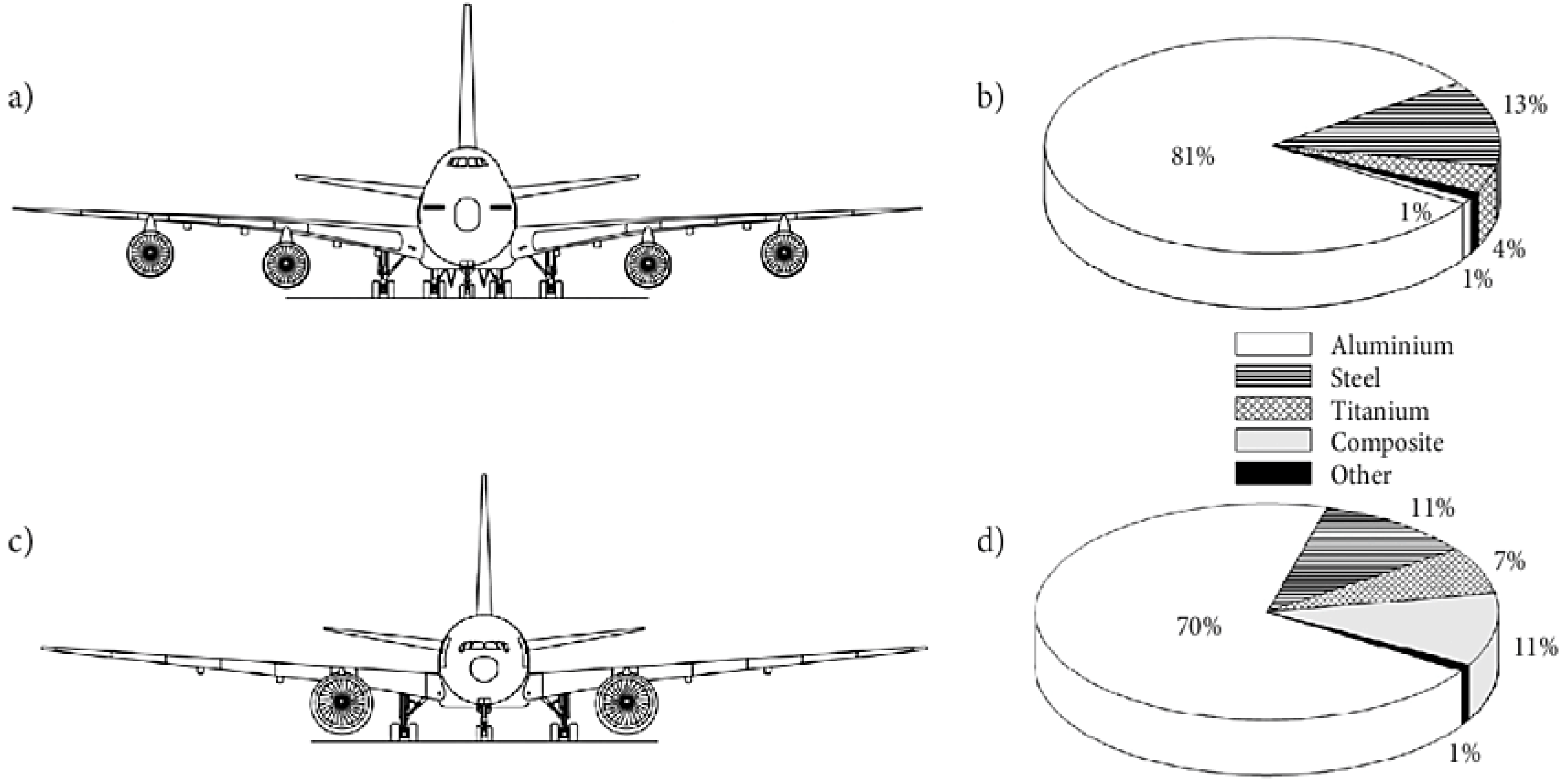
Honeycomb structures were designed in order to **develop complex forms**

On the other hand, due to its **low density**, **composite materials** started to **replace metallic parts**

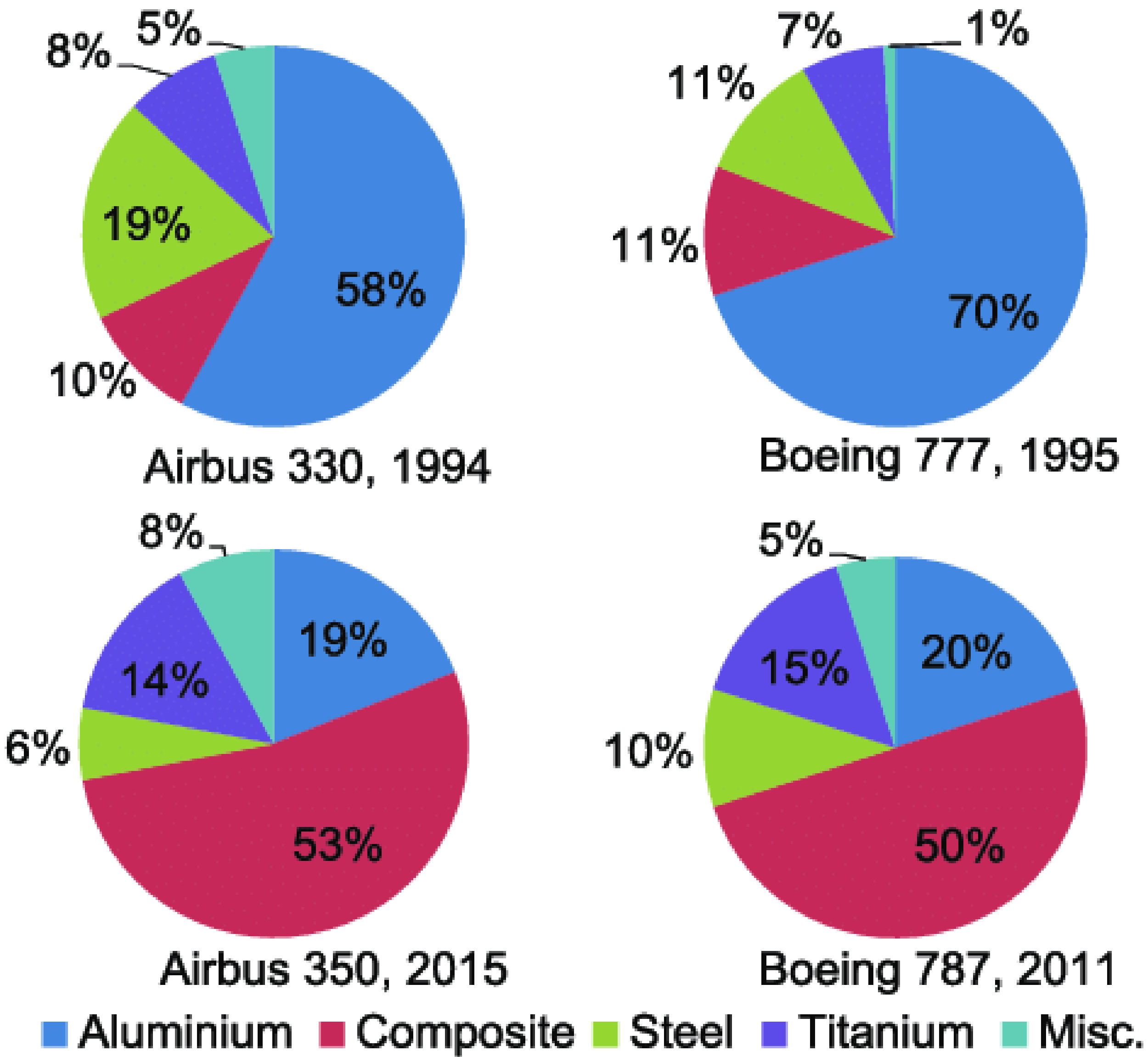


# History

Initially, sandwich materials were used in parts such as panels, control surfaces and floors.



# History (materials)

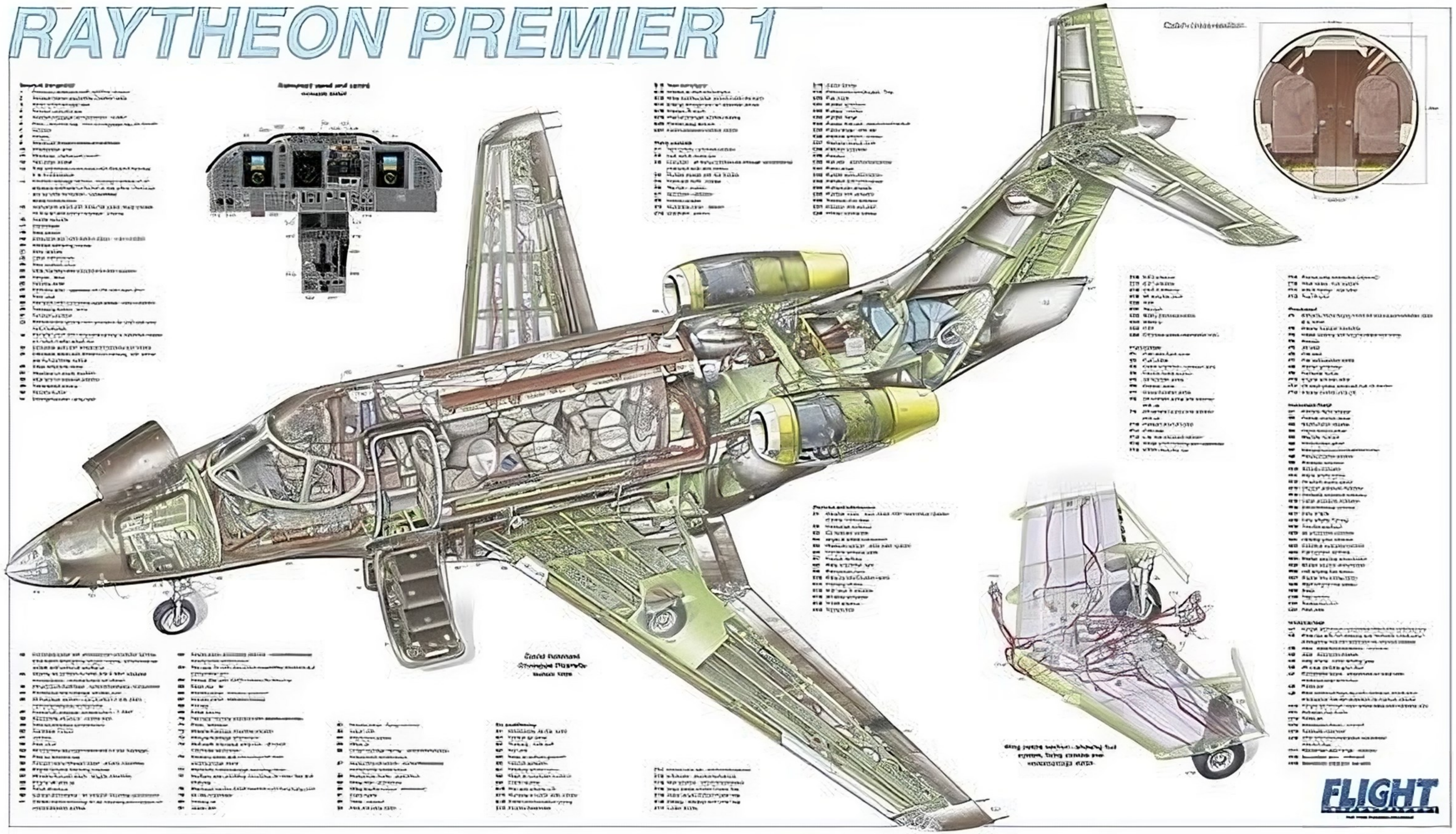


# History (materials)

Beechcraft Premier Business Jet

**The fuselage is a three piece, filament wound component**. An outer and inner layer of composite material forms a sandwich structure that resists internal pressure and other fuselage loads

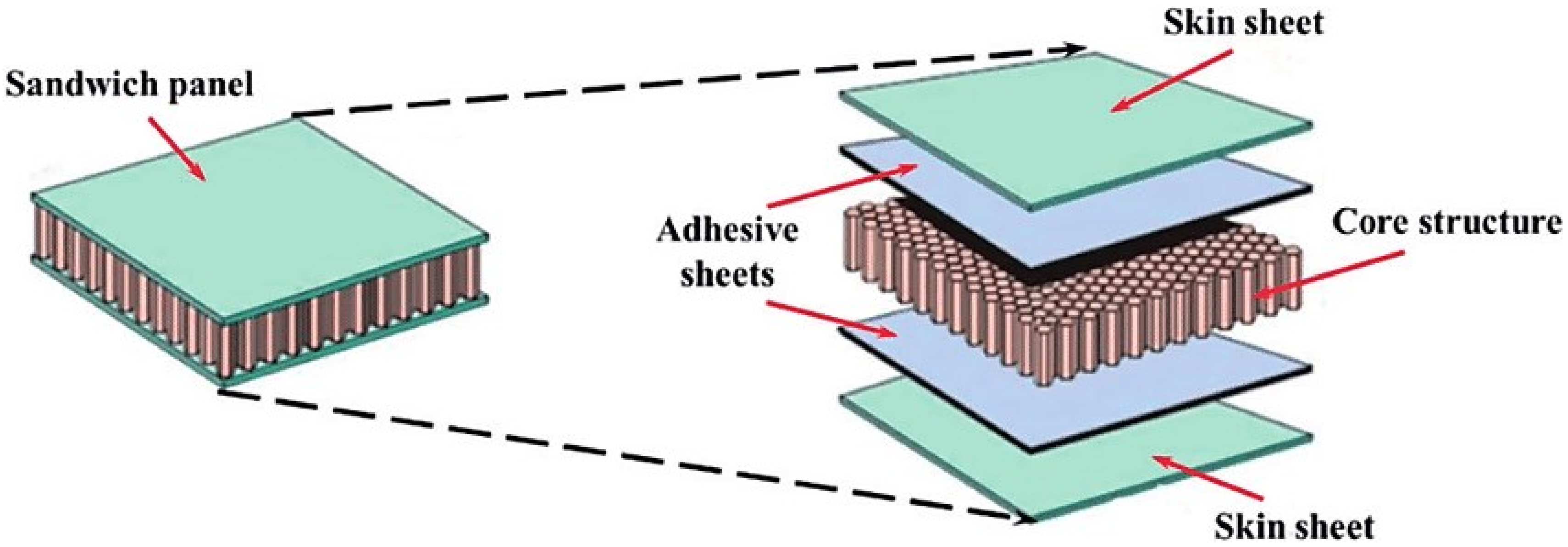
# History (materials)



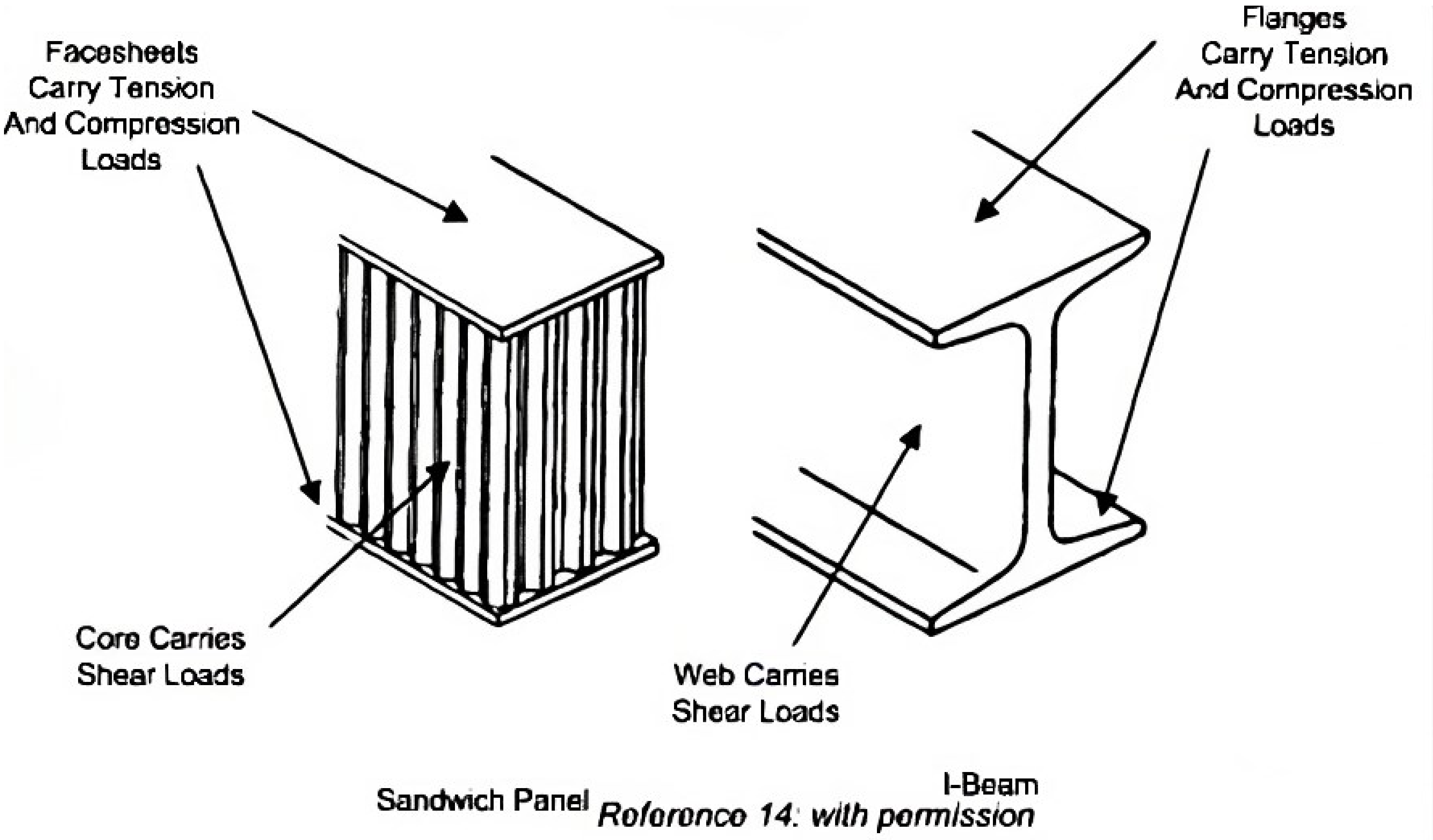
# Sandwich structure

Sandwich structures were fundamental in the space race developing

They are suitable for satellites, due to their low density and high strength

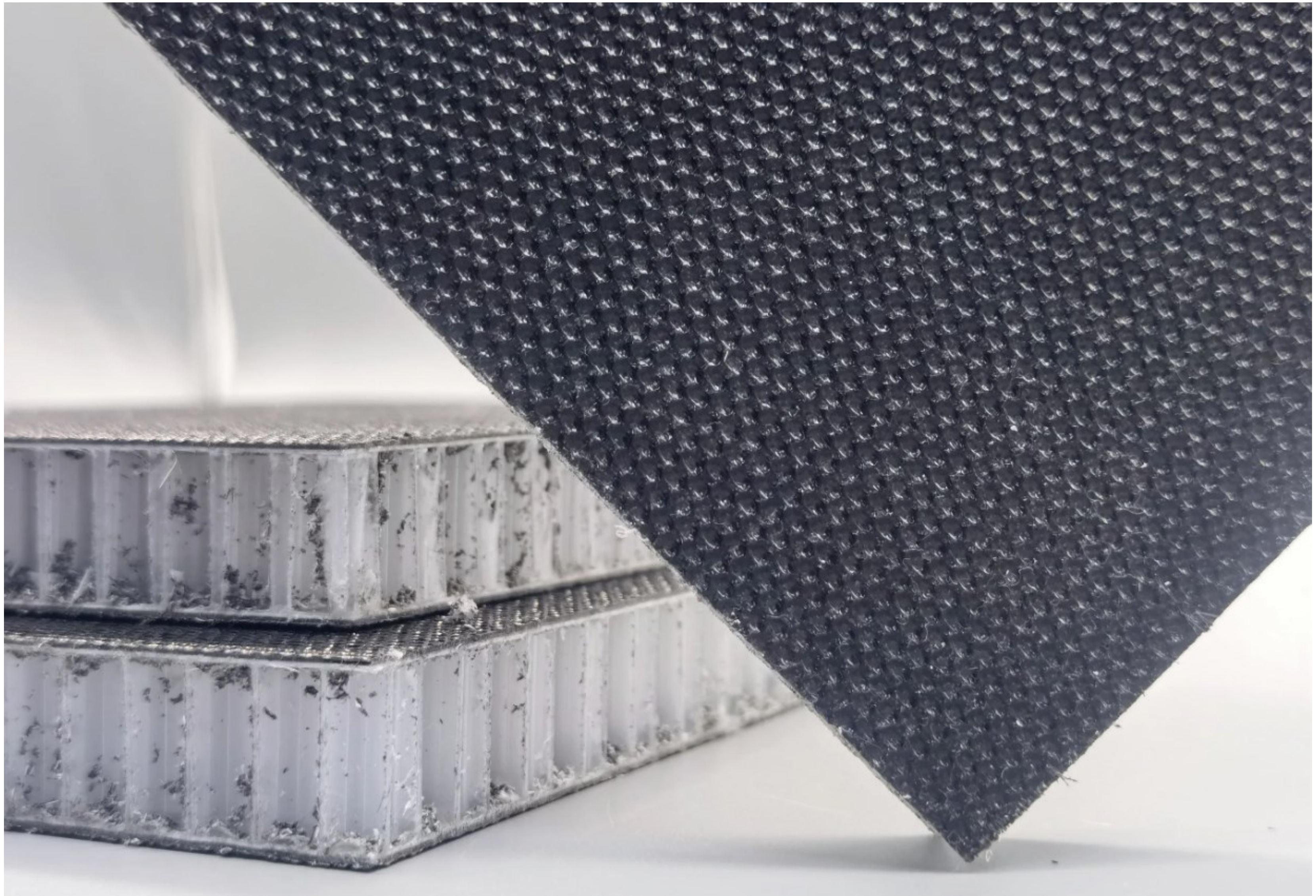


# Sandwich structure

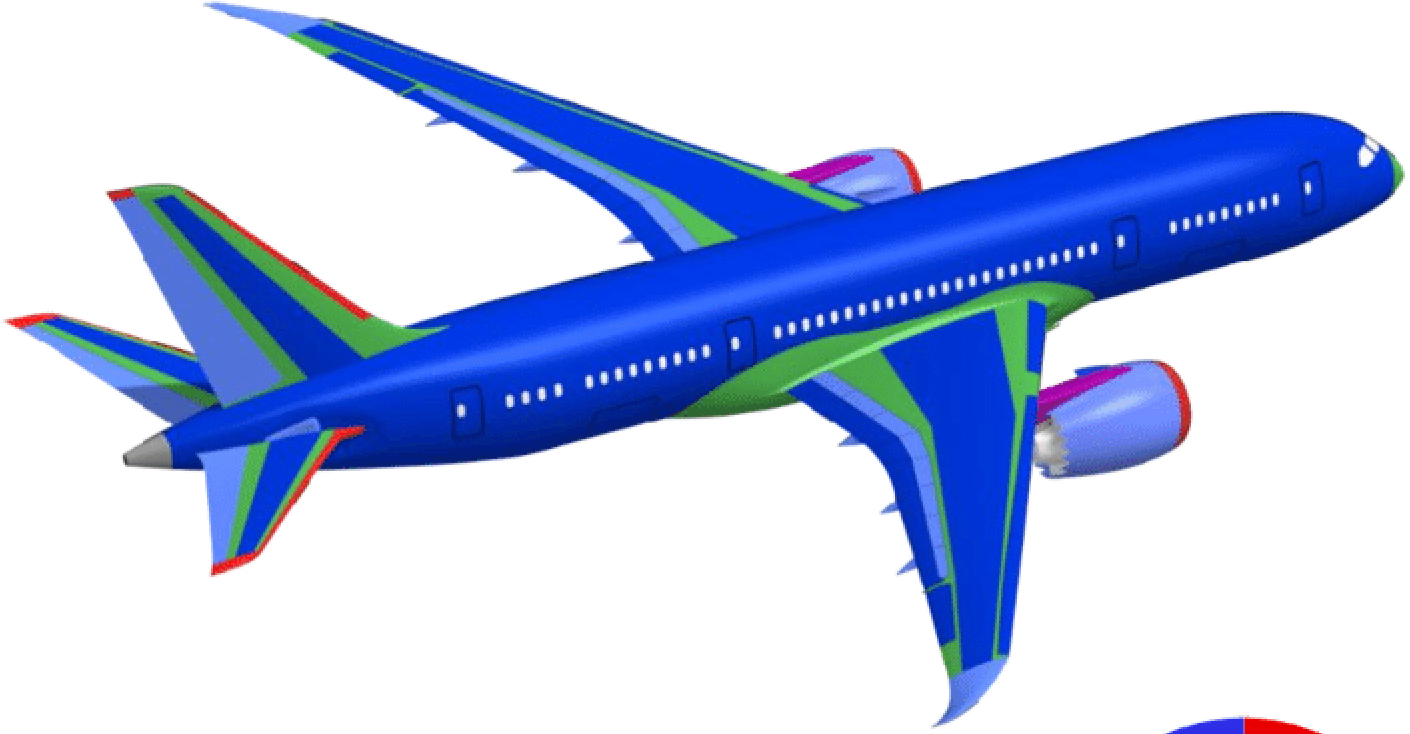


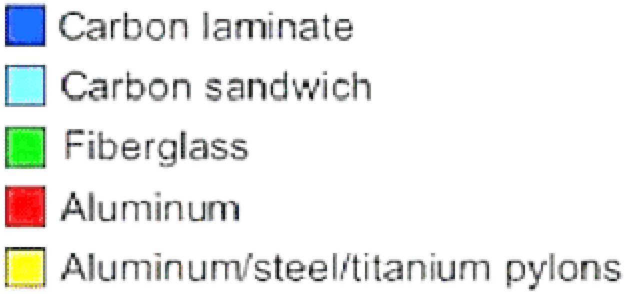

Reference 14: with permission

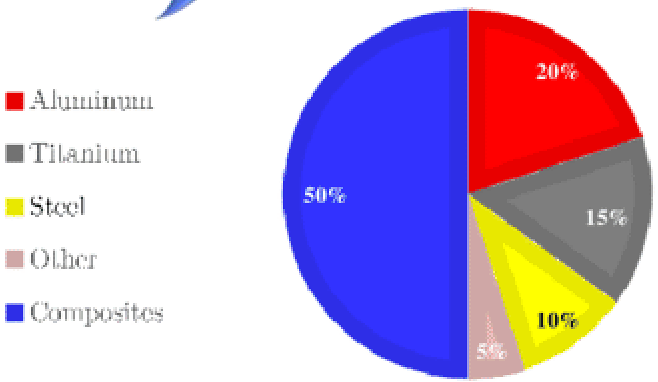
# Sandwich structure



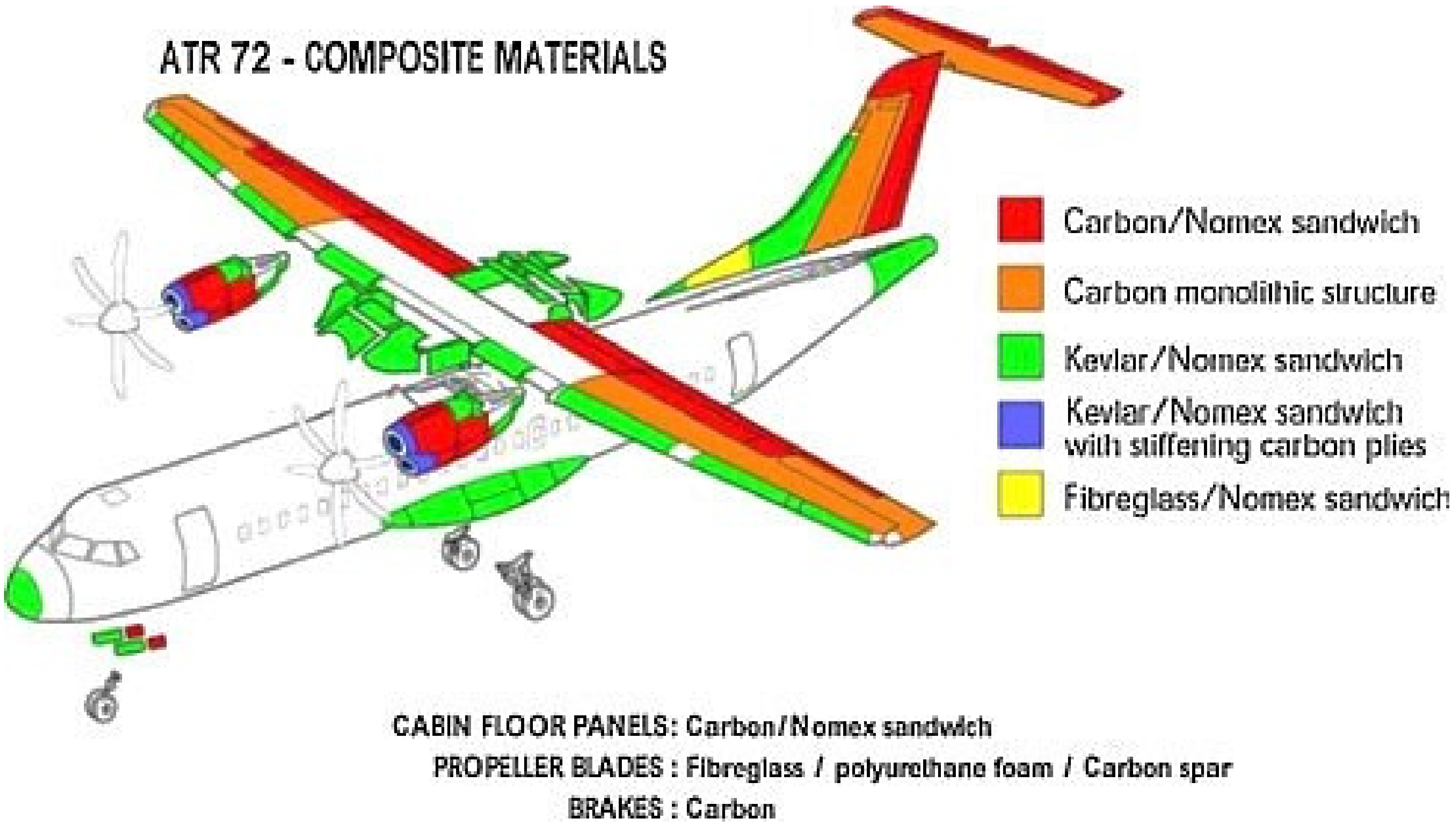
# Sandwich structure





# History

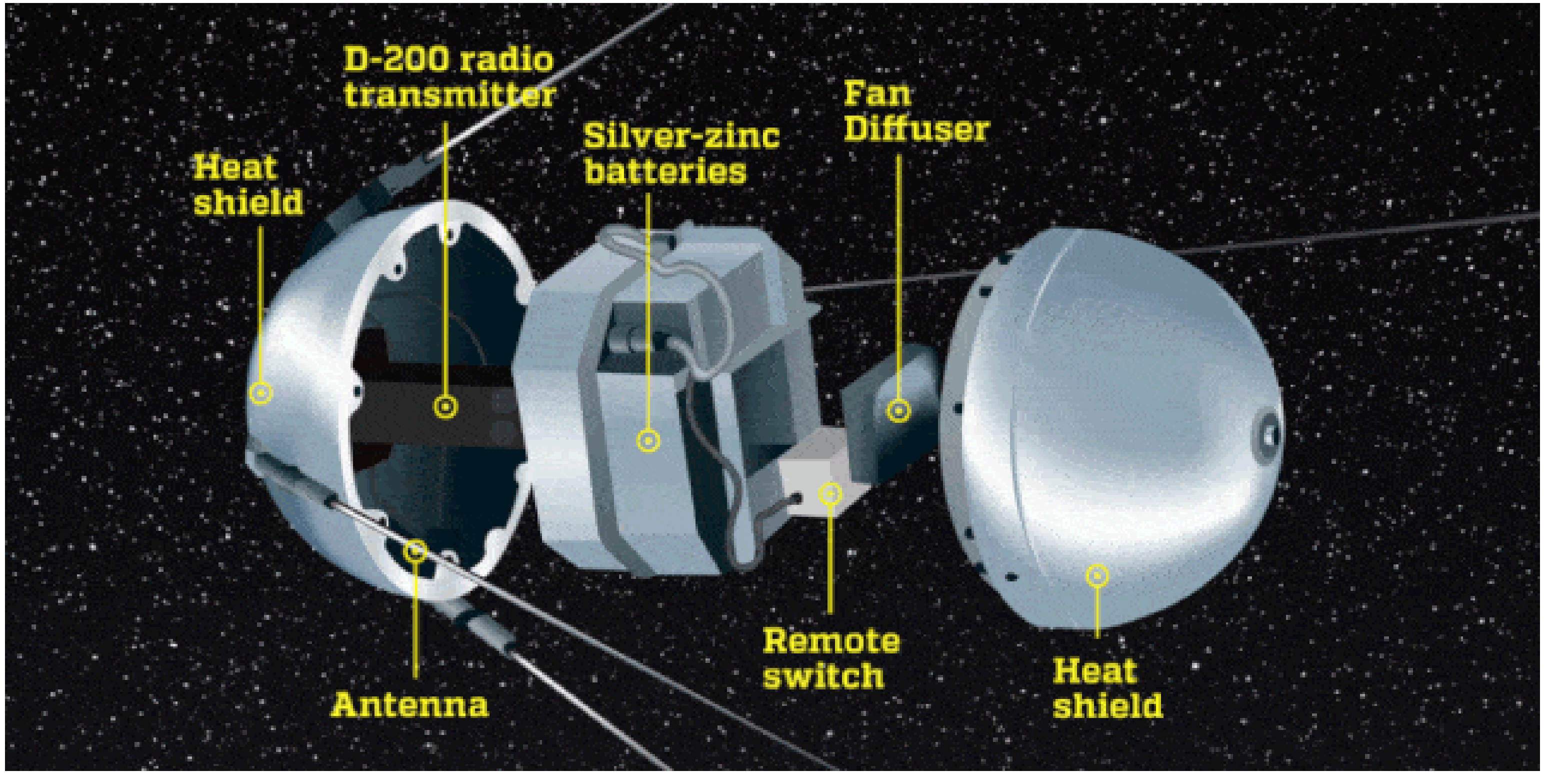


ATR 72 - COMPOSITE MATERIALS
Carbon/Nomex sandwich
Carbon monolithic structure
Kevlar/Nomex sandwich
Kevlar/Nomex sandwich with stiffening carbon plies
Fibreglass/Nomex sandwich
CABIN FLOOR PANELS: Carbon/Nomex sandwich
PROPELLER BLADES : Fibreglass / polyurethane foam / Carbon spar
BRAKES : Carbon

# Spacecrafts

The Space Age began October 4th, 1957, with the launch of Sputnik I

It consisted of an aluminum sphere with a diameter of 58 cm



# Spacecraft characteristics

Long autonomous life

Design life approaching 15 years or better (It depends…)

Minimal repair/maintenance opportunities

Requirement for degradation

# Spacecraft harsh conditions

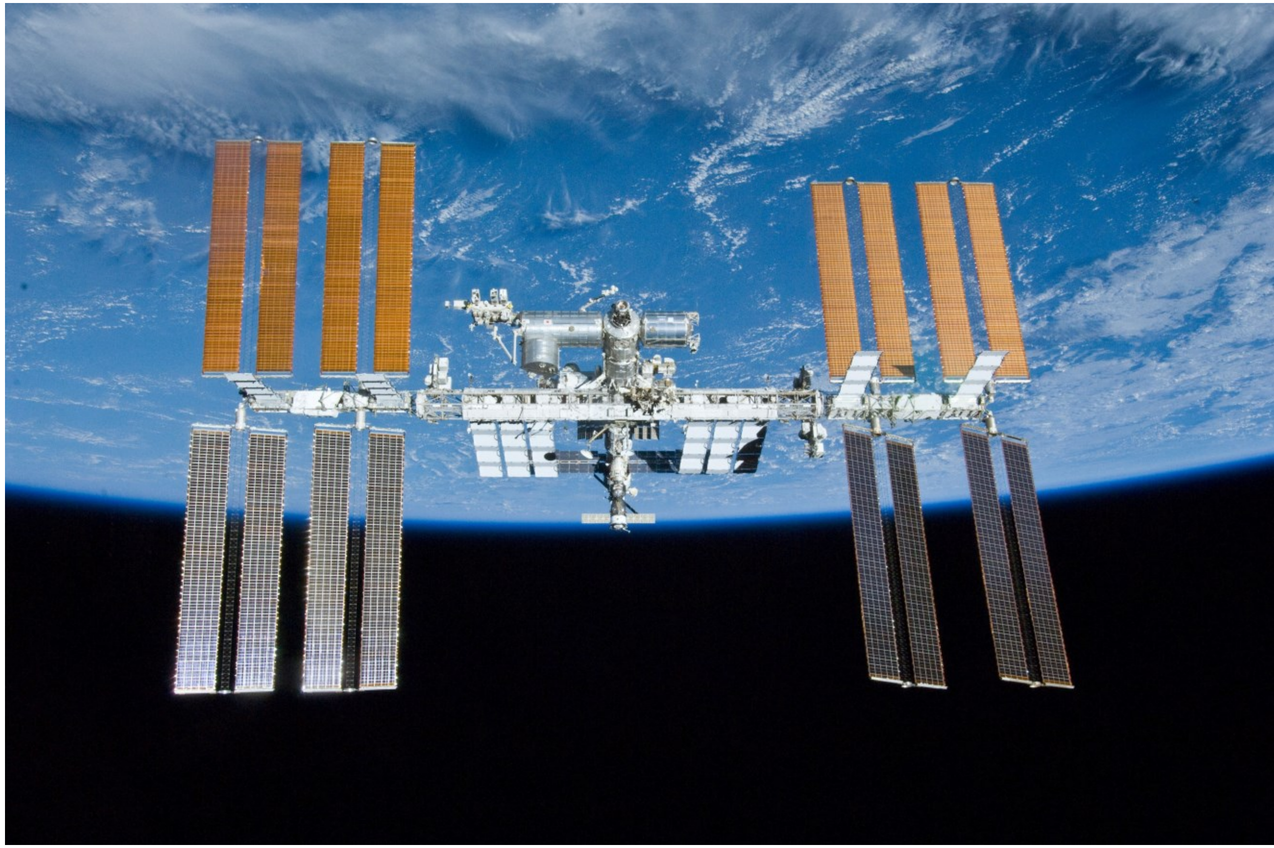
Vacuum pressure

Radiation, solar UV

Atomic oxygen (corrosion)

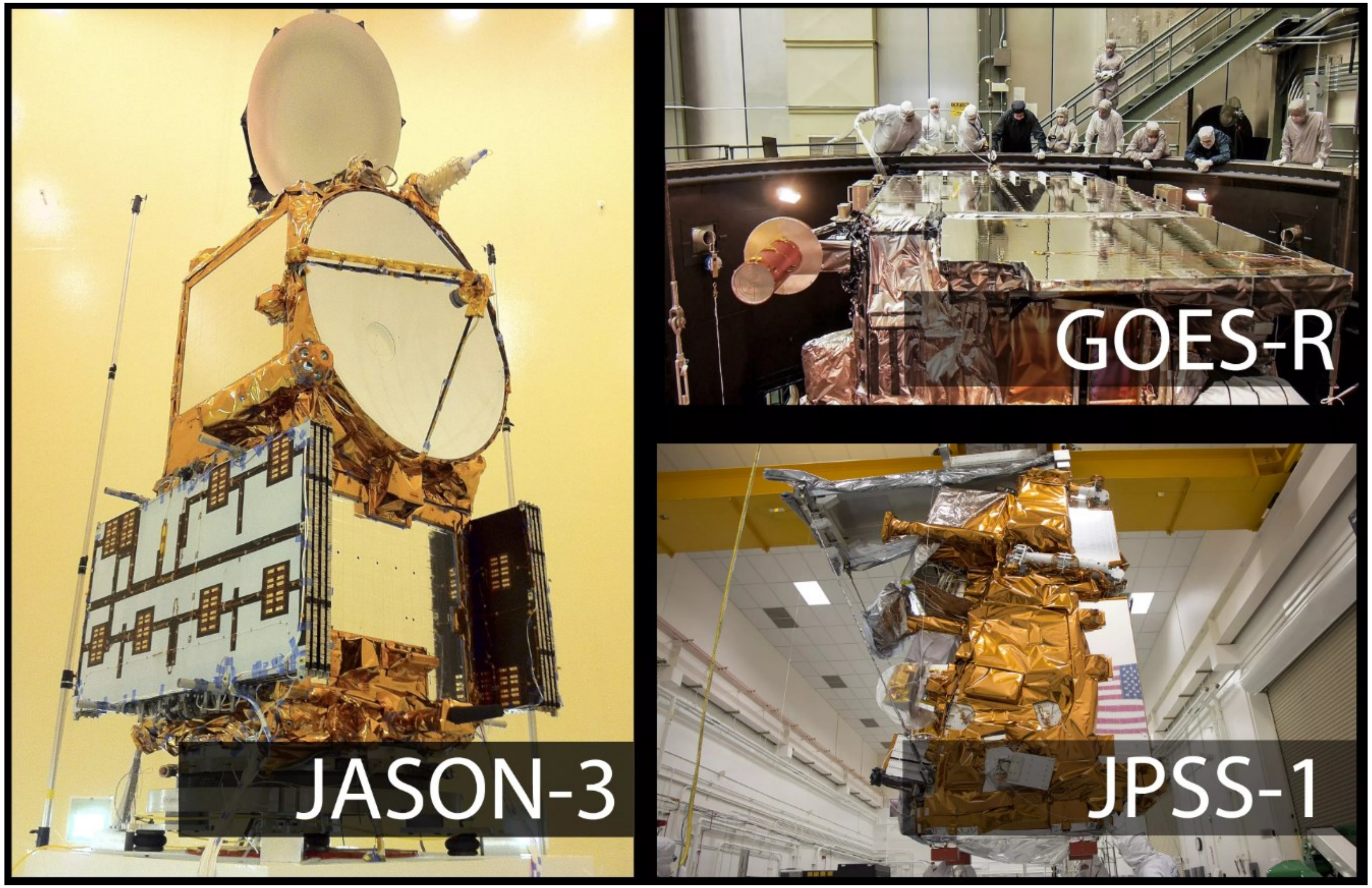
Extreme temperatures and thermal cycles

“Gold foils” on exposed surfaces are therefore used to protect the spacecraft from the harsh environment



# Spacecraft harsh conditions

Multi layer insulation - MLI



# Spacecraft harsh conditions

That is actually gold (coating)

# Spacecraft Loads

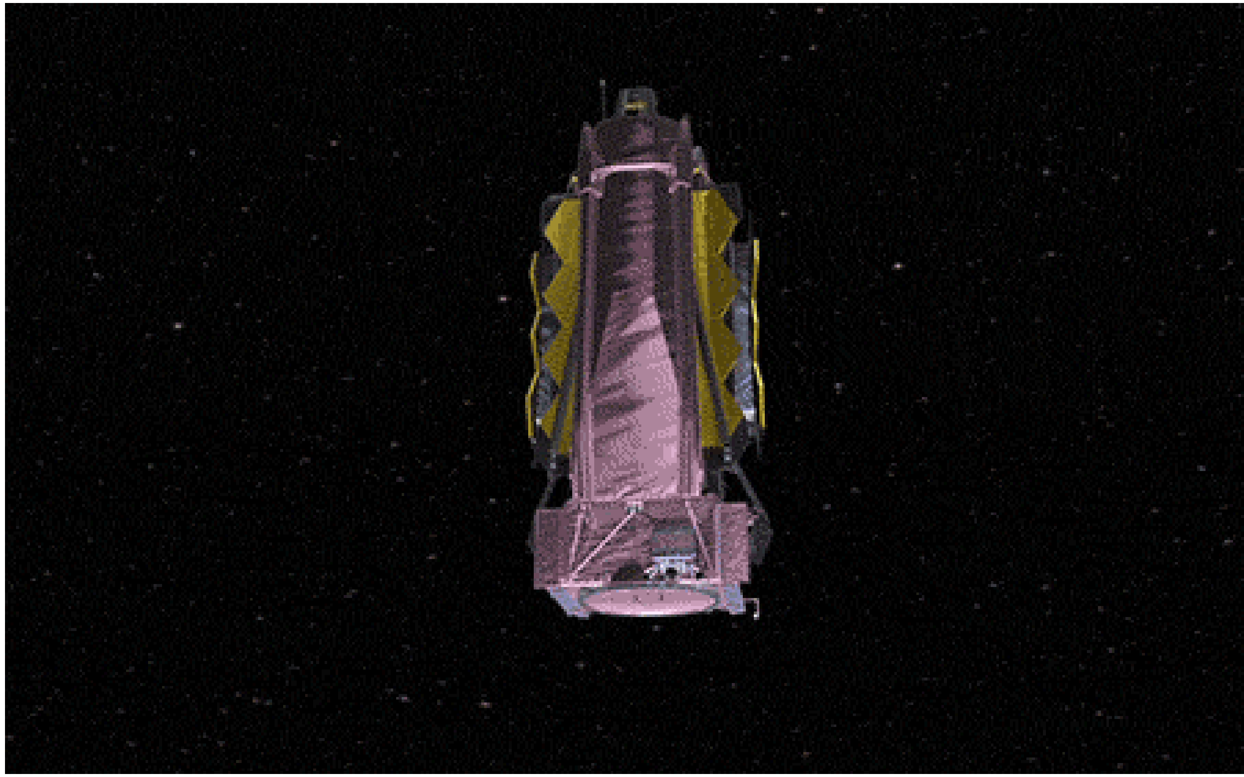
- Pre launch handling
- Transportation, test, and deployment
- Launch with axial and lateral accelerations
- Acoustics
- Staging separation
- Shock, and vibration and, on orbit vibration
- Thermal management and maneuvering


https://lightsinthedark.files.wordpress.com/2015/09/gif-33.gif

# Spacecraft Loads

Stringent packaging requirements during launch to orbit may result in **hinged** or **folded** **structural** arrangements for:

Solar cells or communication arrays that deploy on station



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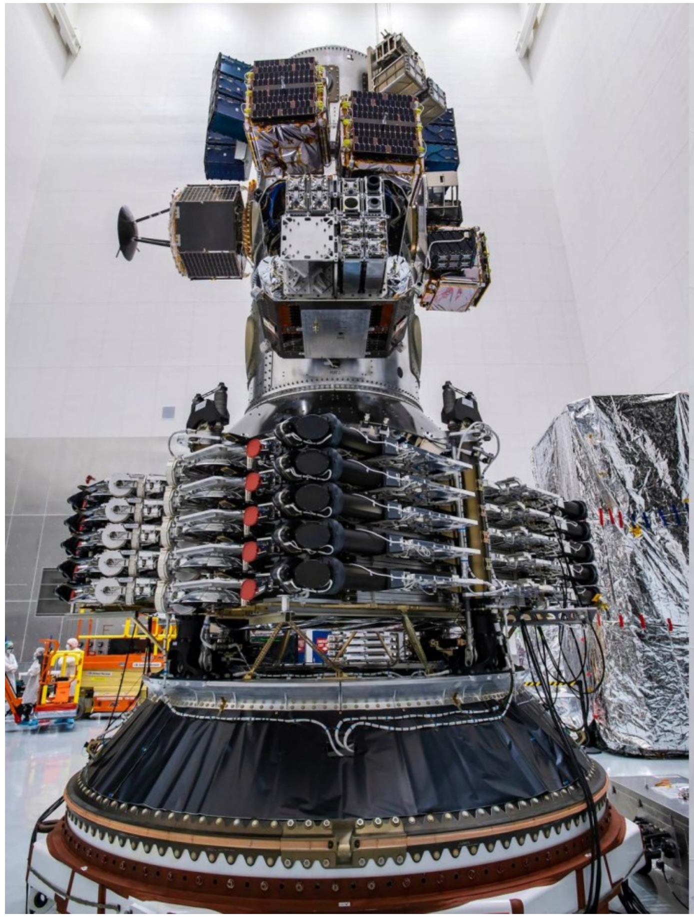
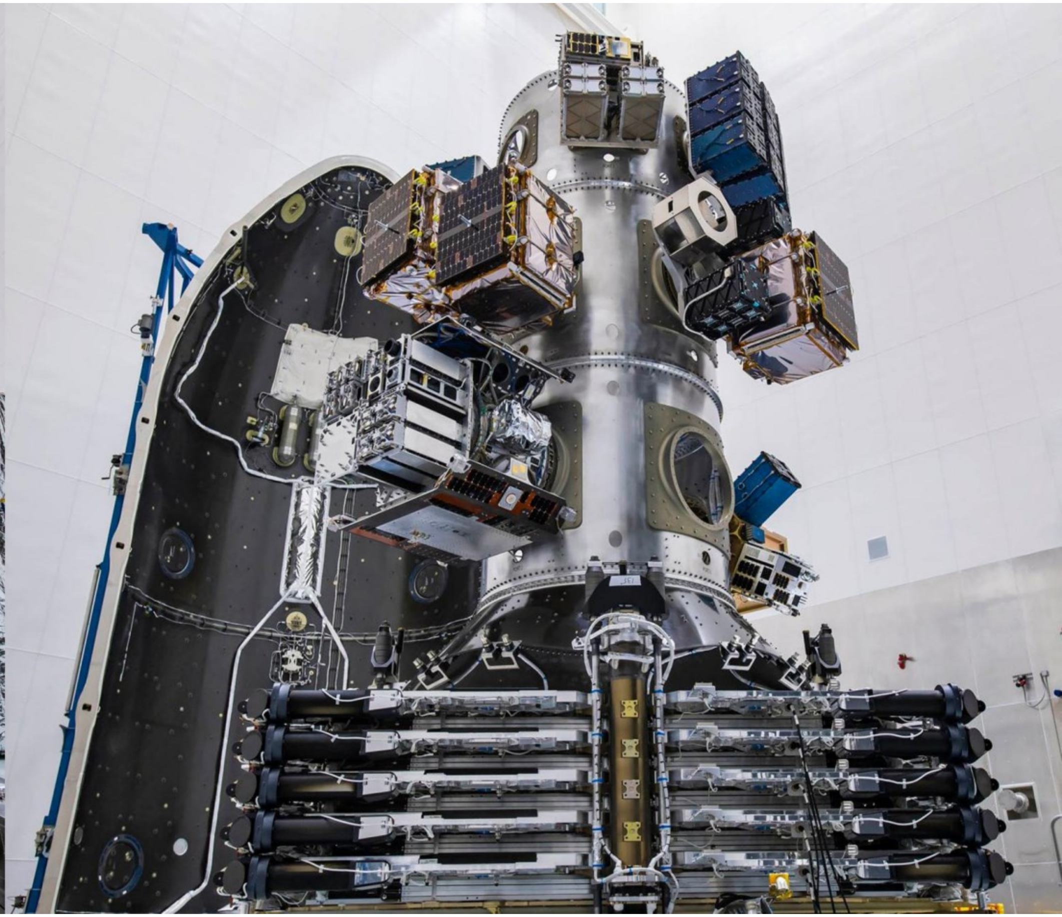
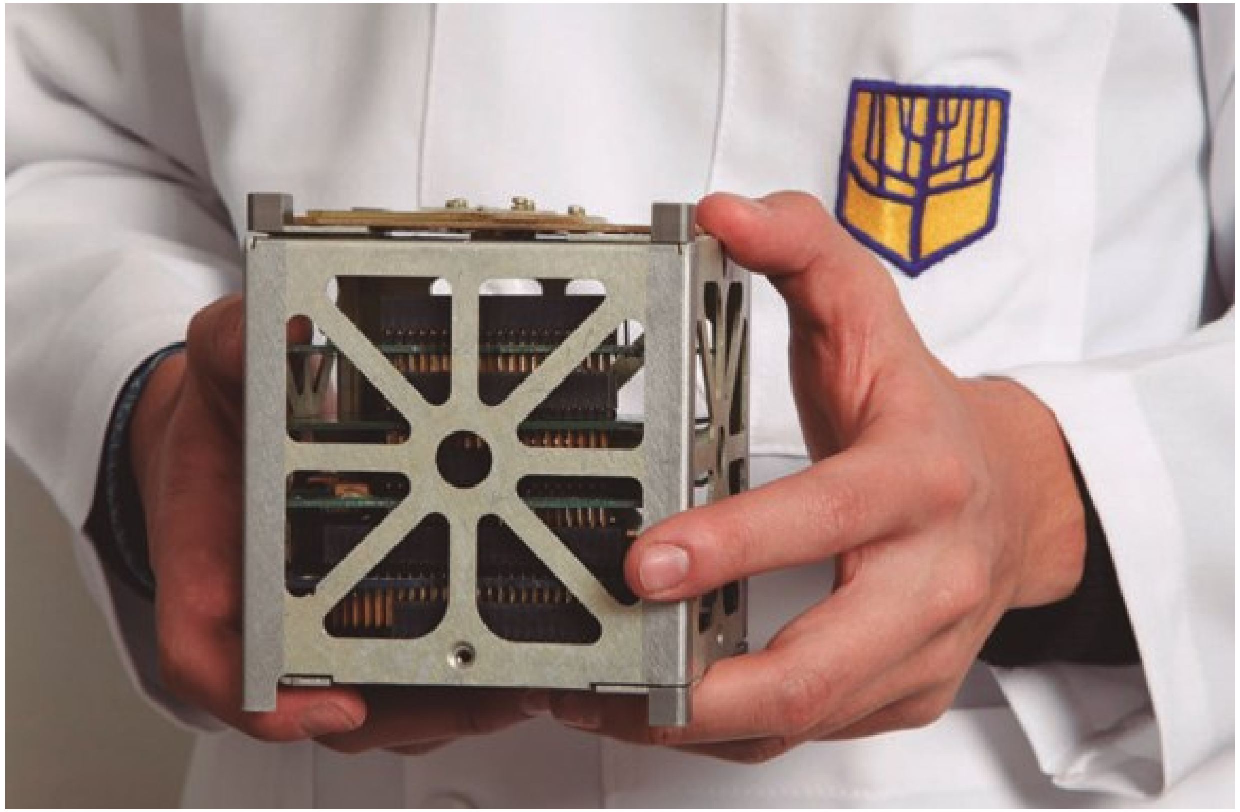




# Spacecrafts

The **satellite bus** is the spacecraft structure, usually providing locations for the payload

The main or “primary” bus structure transmits loads to and from the base of the satellite during launch through structural attachments and components such as tubes, honeycomb plates and panels and trusses



# Spacecrafts

The **satellite structure** is the **skeleton** that provides **support and alignment** for other sub systems

The bus structure defines and **maintains vehicle shape and the position of subsystems**. It covers and protects sensitive components

It transfers loads

# Spacecrafts

Both spacecraft and airplanes are subjected to acceleration that creates large stresses. These loads are commonly called “inertia loads”

Inertia loads = G forces (external loads)


https://j.gifs.com/aA52nY.gif

# Spacecrafts

Tests must be planned and conducted to **qualify the design of the spacecraft structure** and to accept the flight hardware

The qualification tests are used to prove that the structure can withstand the qualification or design limit loads