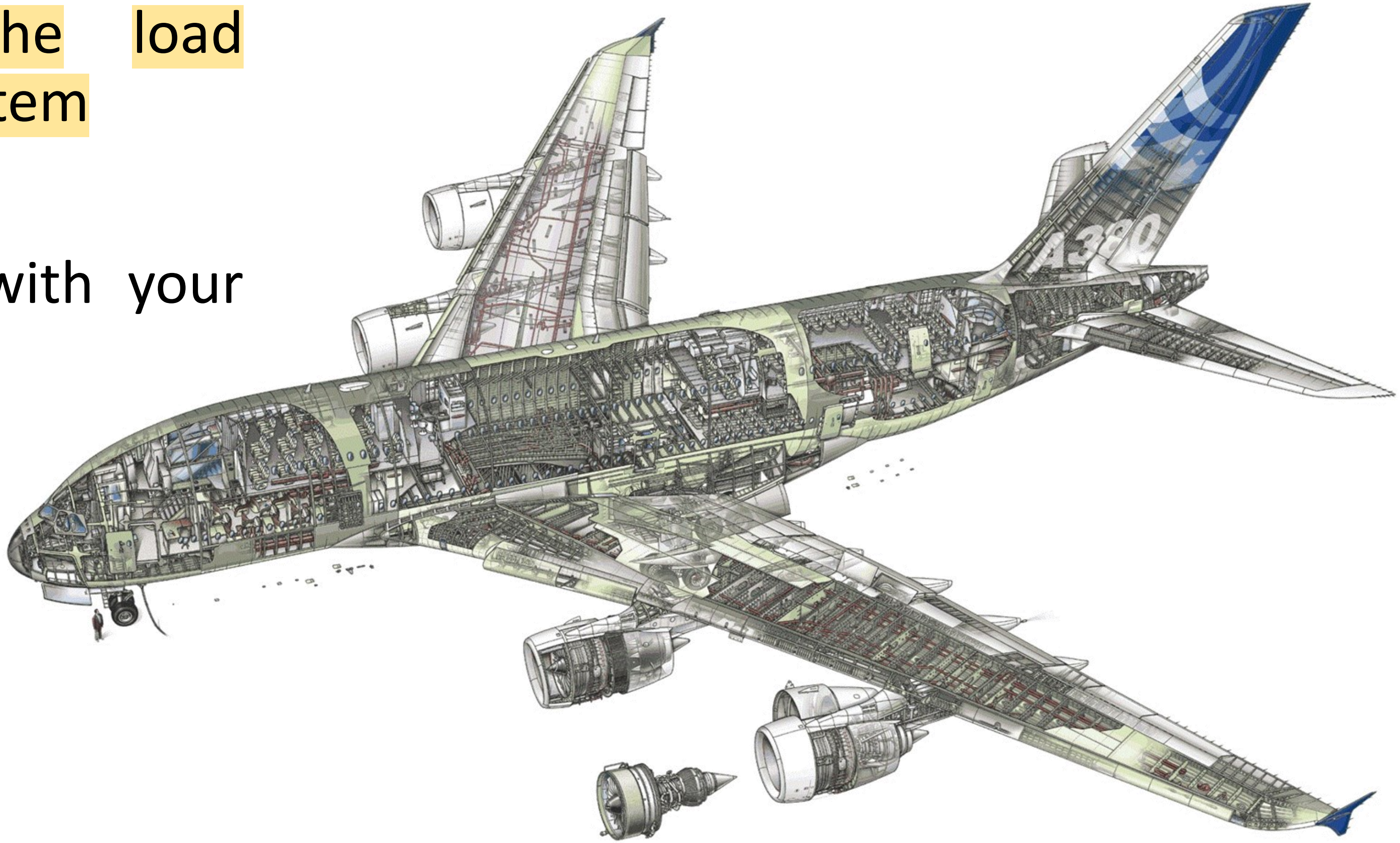
Aerospace Structures

M.Sc. Andrés Camilo Herrera Araujo

Structure

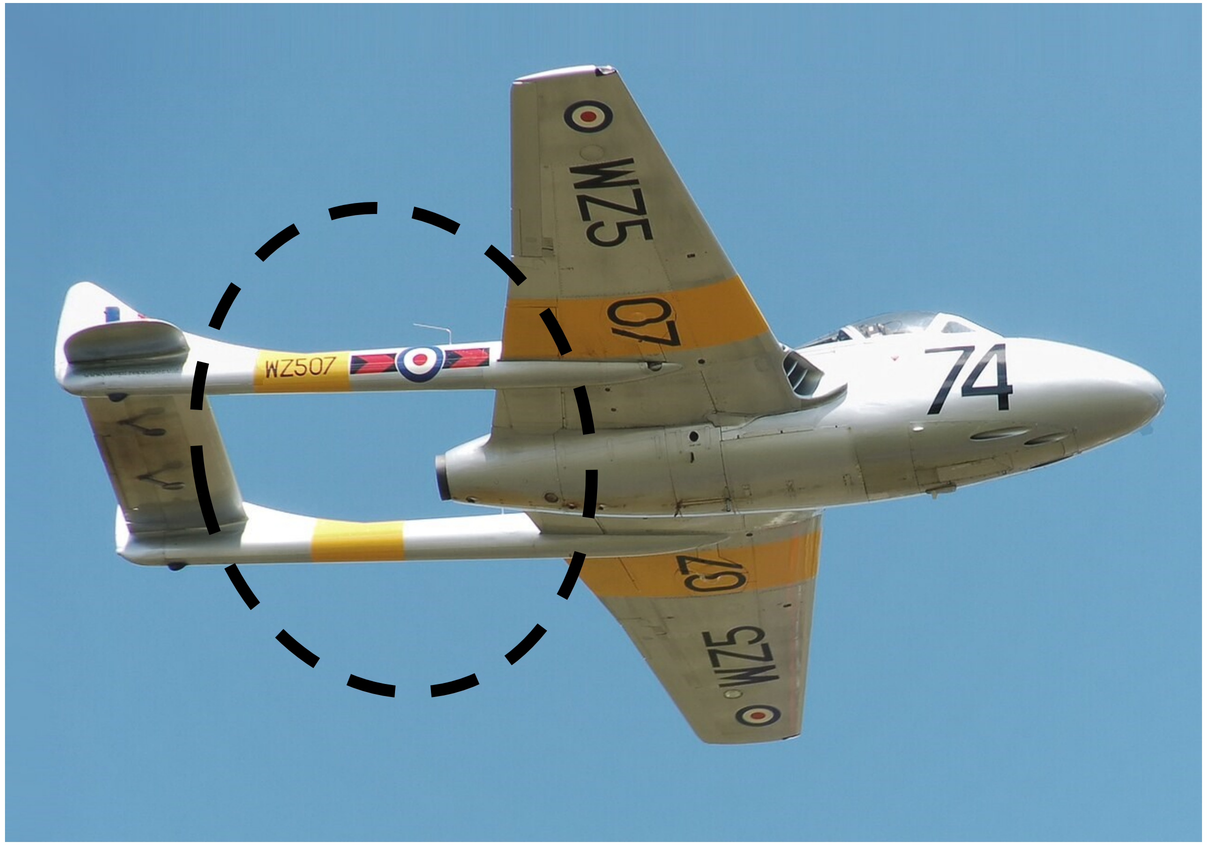
The structure is the load carrying part of the system

You can compare it with your body skeleton

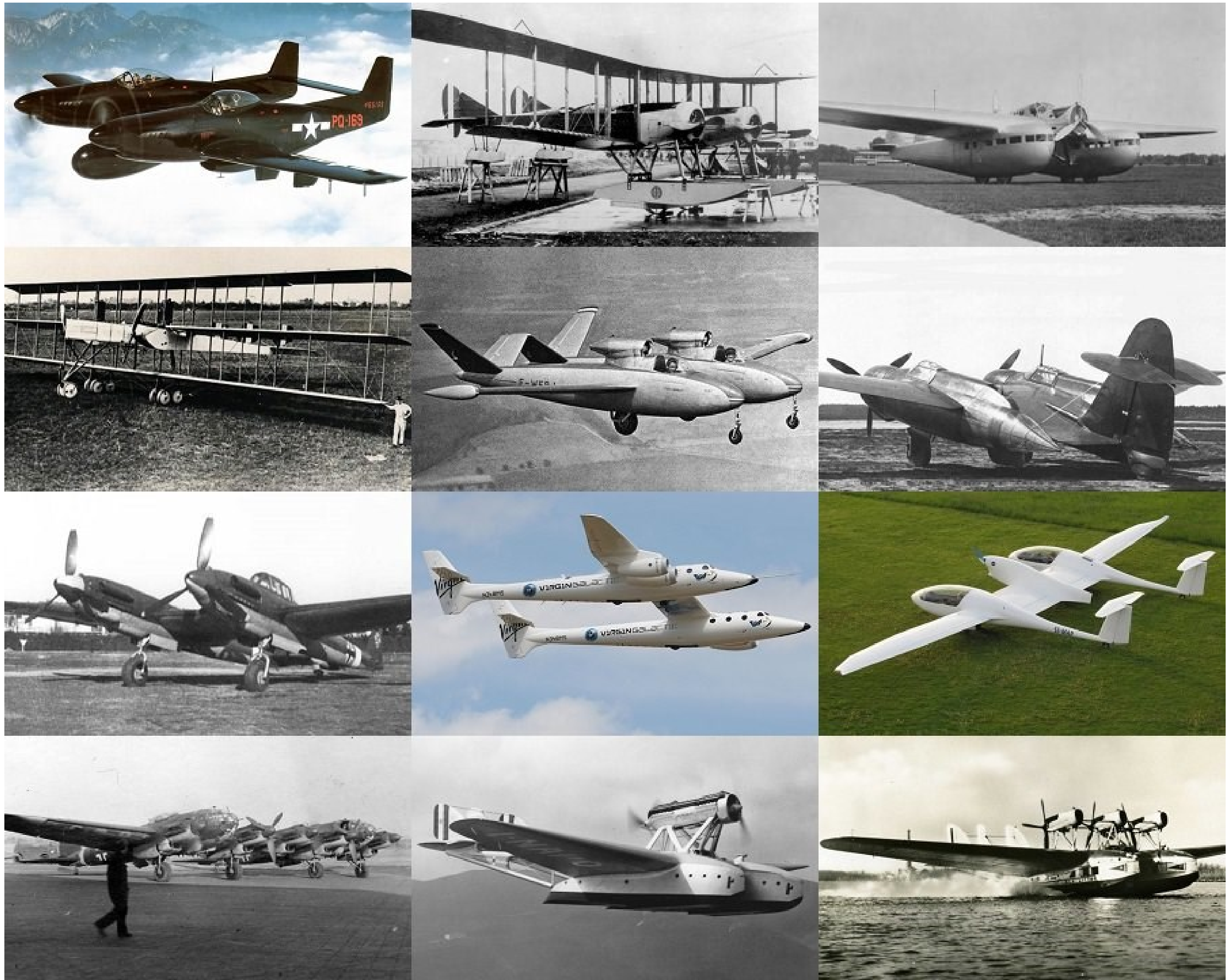



INTERNATIONAL CARGO
TRANSPORTER
ANTONOV 225
МРІЯ
UR-82060

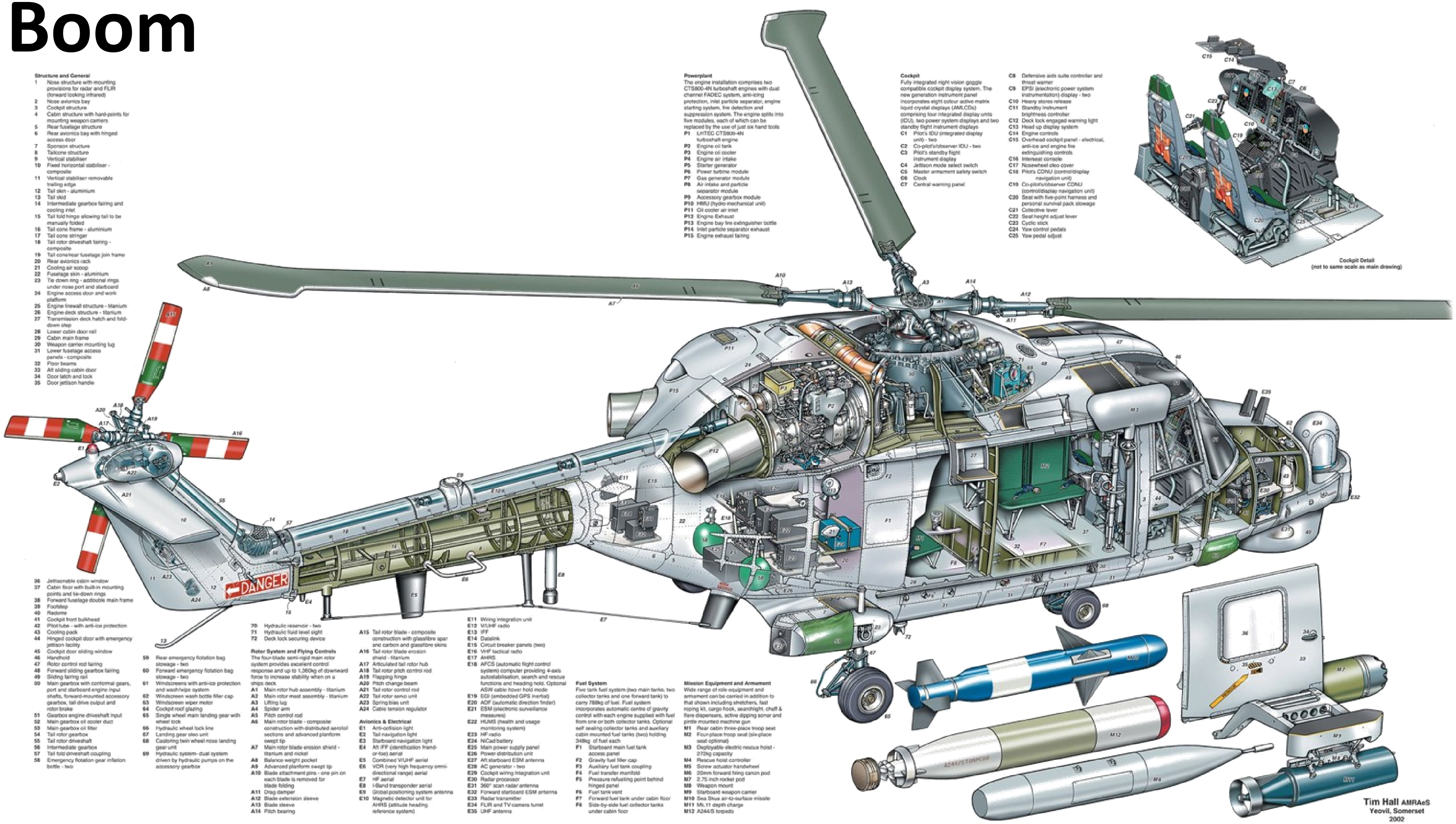
Booms



Twin fuselage

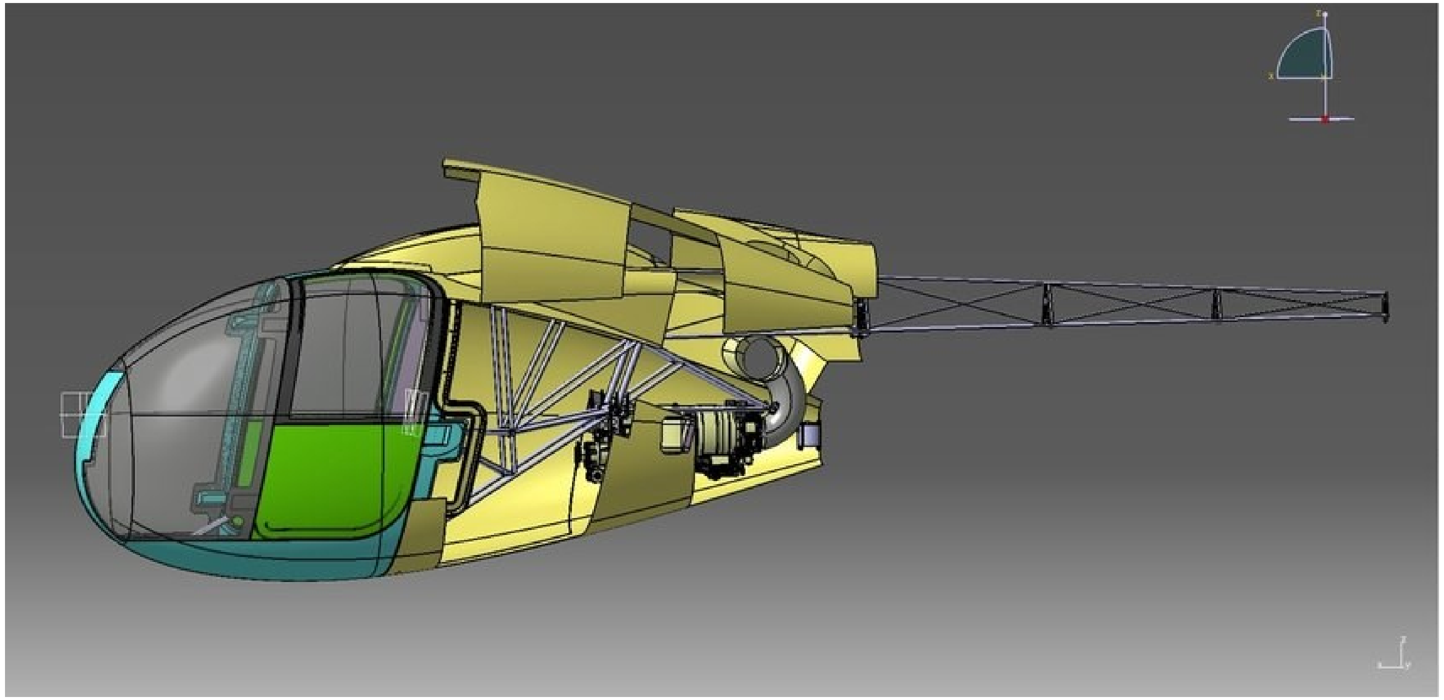


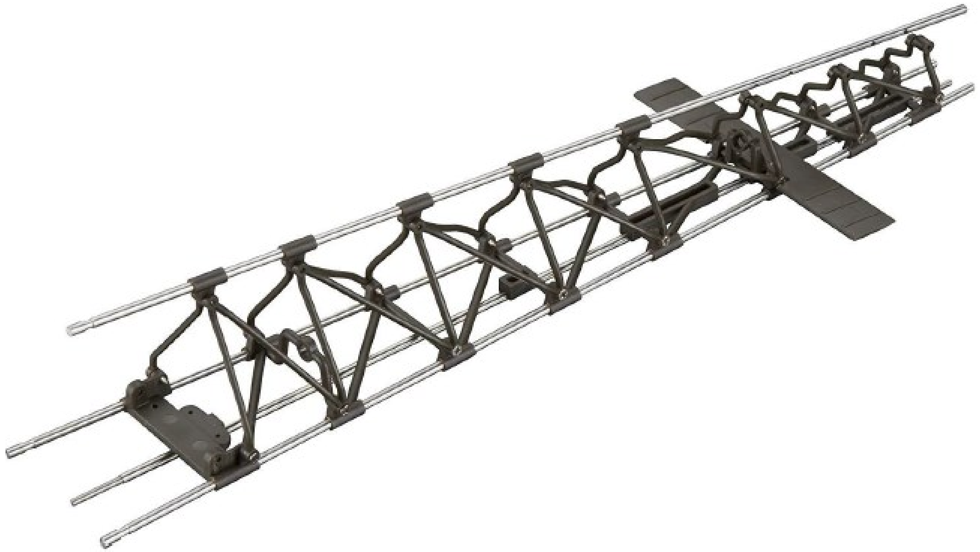
Boom

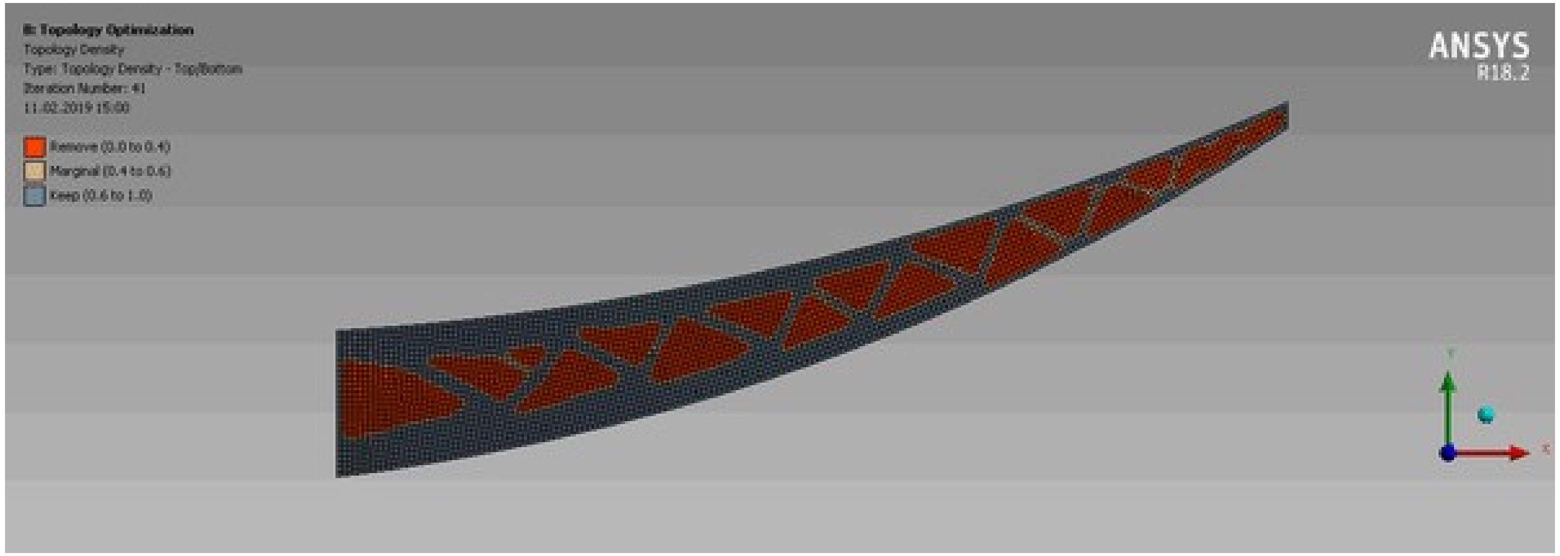


Cockpit Detail
(not to same scale as main drawing)
DANGER
Tim Hall AMRAeS
Yeovil, Somerset
2002

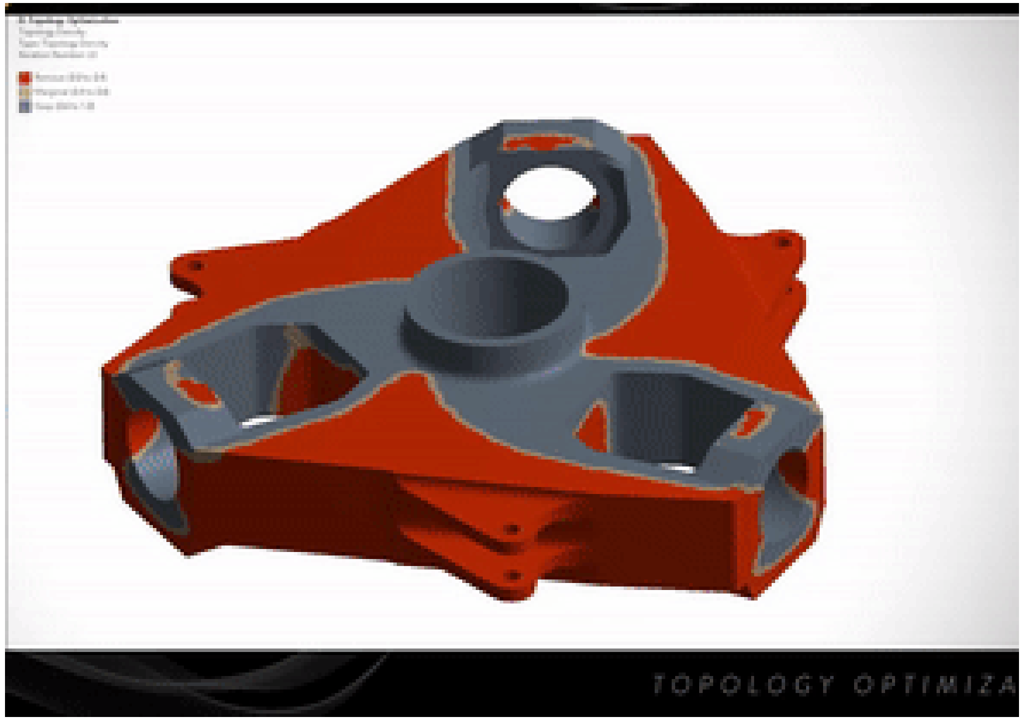
Boom





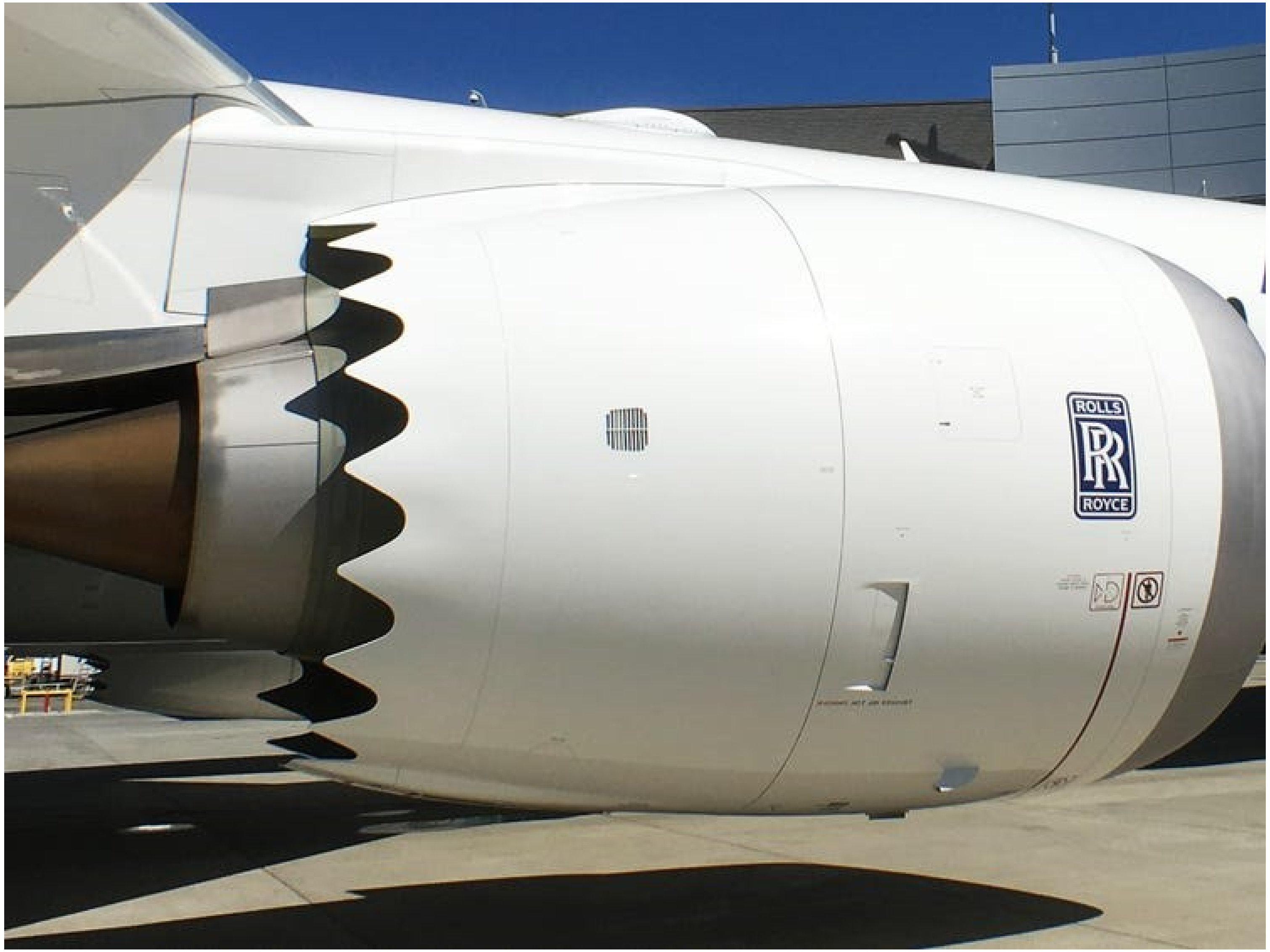


https://d2t1xqejof9utc.cloudfront.net/screenshots/pics/9587ecbaa2feef0dc136a3c800938a55/large.gif



https://i.makeagif.com/media/1-04-2018/U6v1Xf.gif

Nacelles, cowlings and pylons



Nacelles, cowlings and pylons

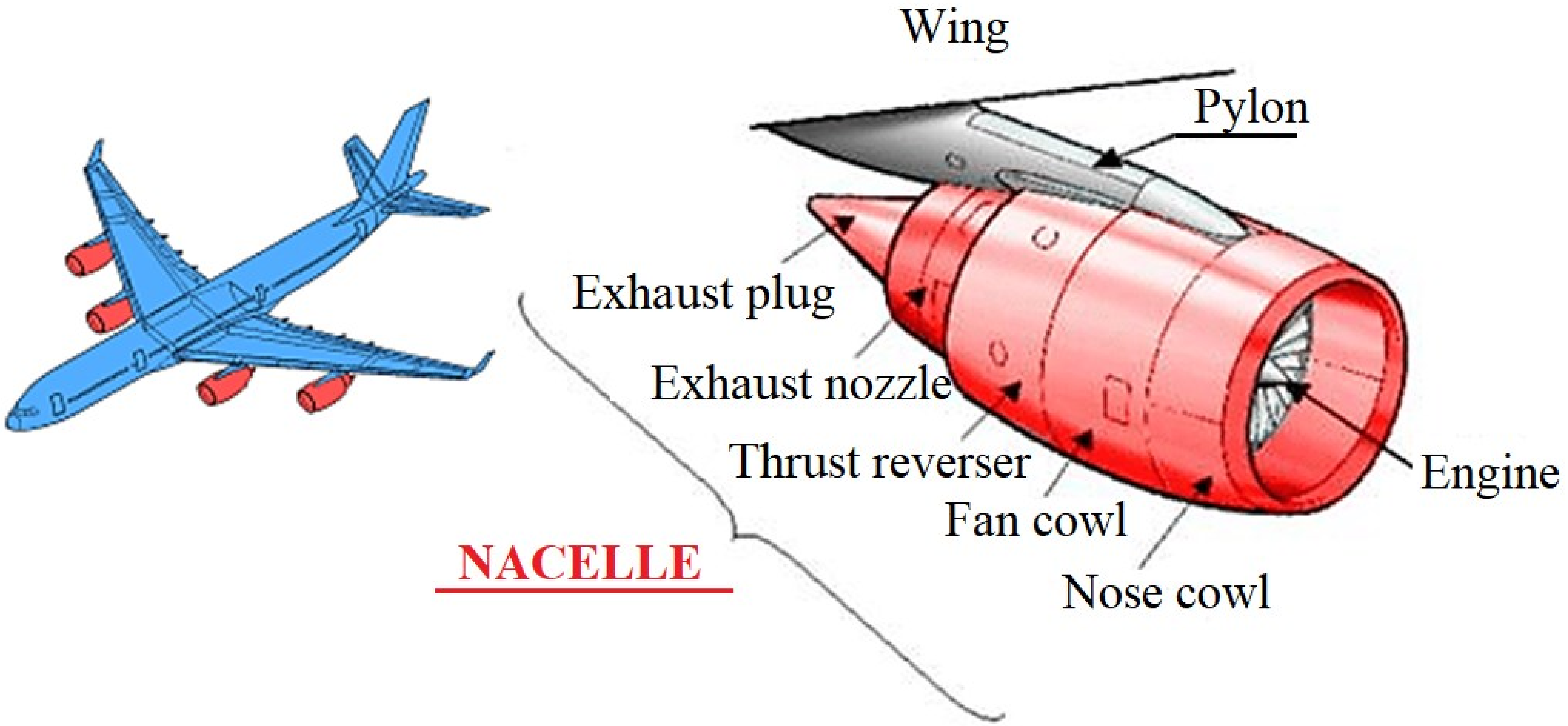
It’s a subtle difference to the untrained eye for nacelles and cowlings

A **nacelle** is the metal structure that supports the engine firewall, the engine mount, the loads induced into the airframe due to engine torque and thrust and is structurally attached to the wing. It’s relatively heavy.

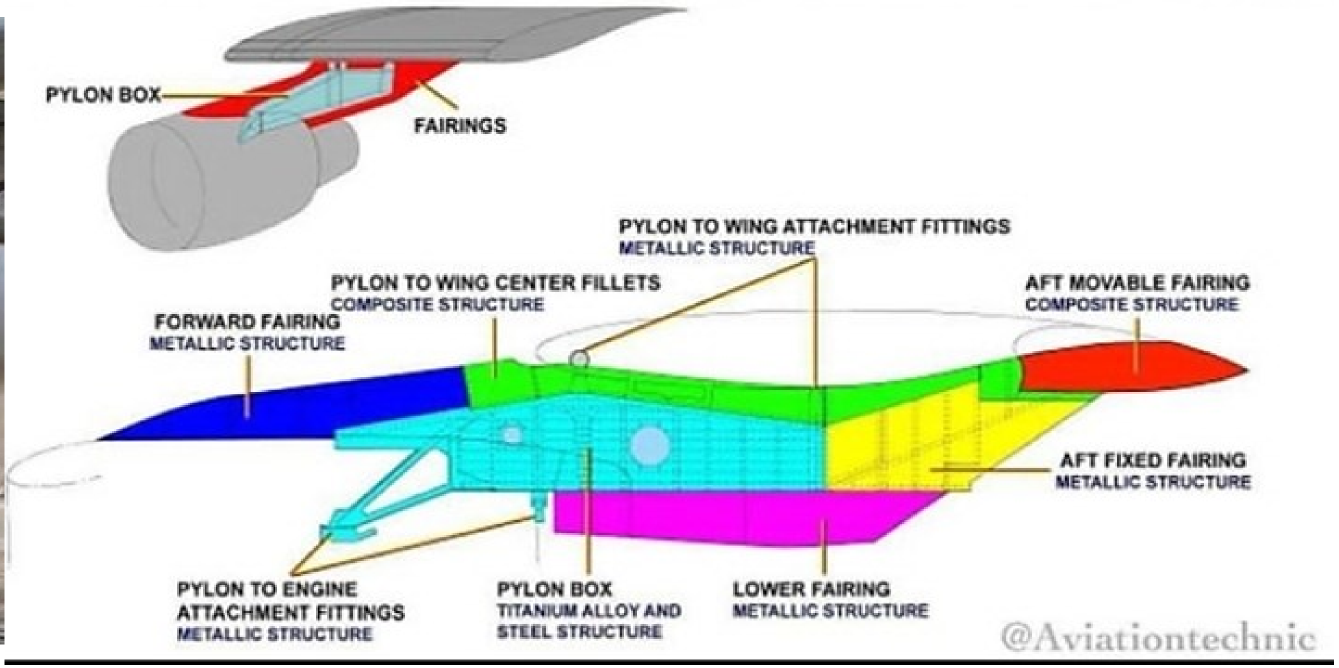
Attached to that nacelle structure is the **cowling**. This is sheet metal or fiberglass, or a combination of those and other materials, that streamline the shape of the engine to the nacelle.

A **pylon** connects the engine to the airframe of an aircraft.

Nacelles, cowlings and pylons



Nacelles, cowlings and pylons



Wings

Empennage

Landing gear

Landing gear

Structural classification

Primary structure is that structure which contributes significantly to carrying flight, ground and pressurization loads.

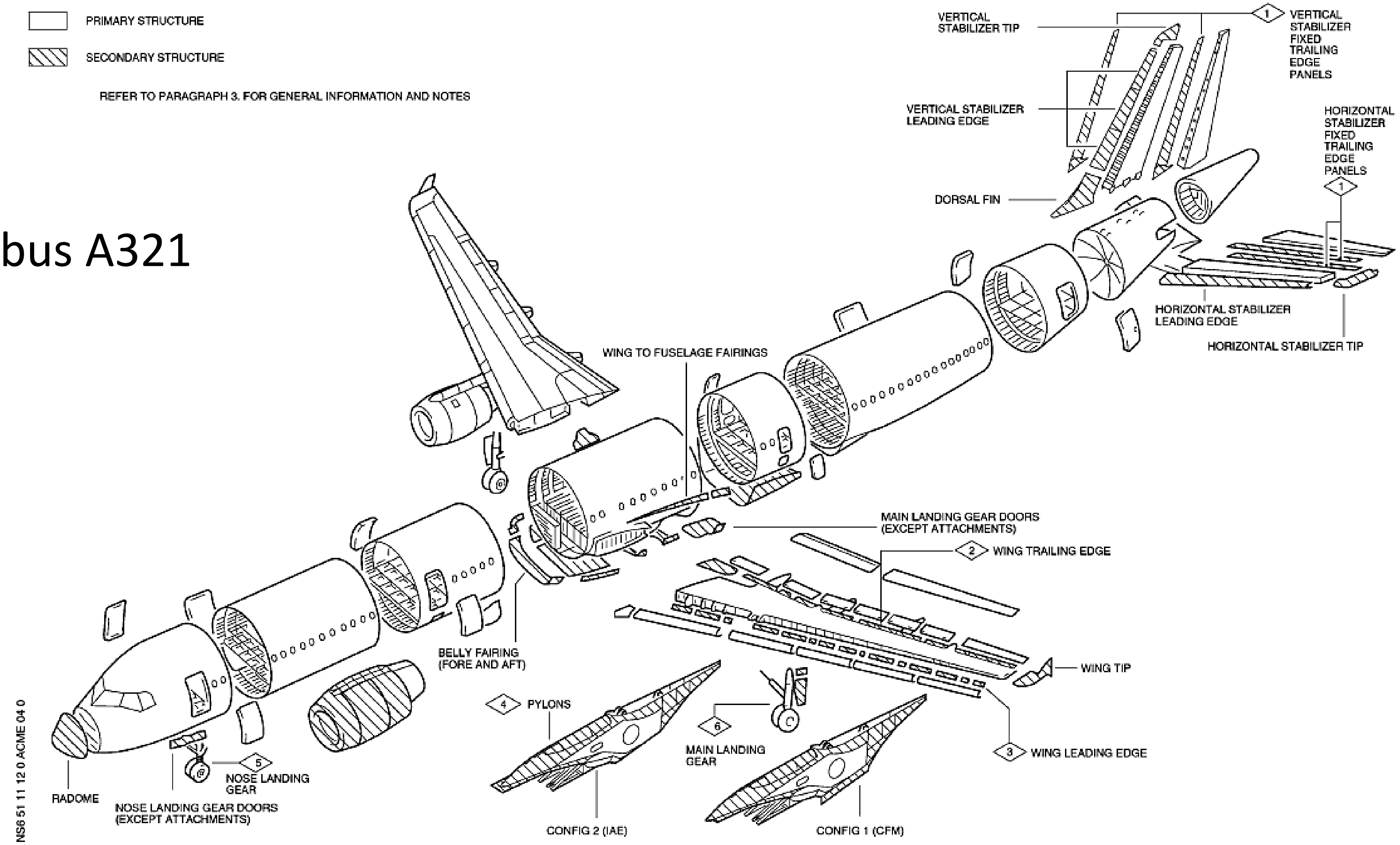
Secondary structure is that structure which carries only air or inertial loads generated on or within the secondary structure.

PRIMARY STRUCTURE

SECONDARY STRUCTURE

REFER TO PARAGRAPH 3. FOR GENERAL INFORMATION AND NOTES

Airbus A321



Primary and Secondary Structure - General Details
Figure 2

Airbus A320

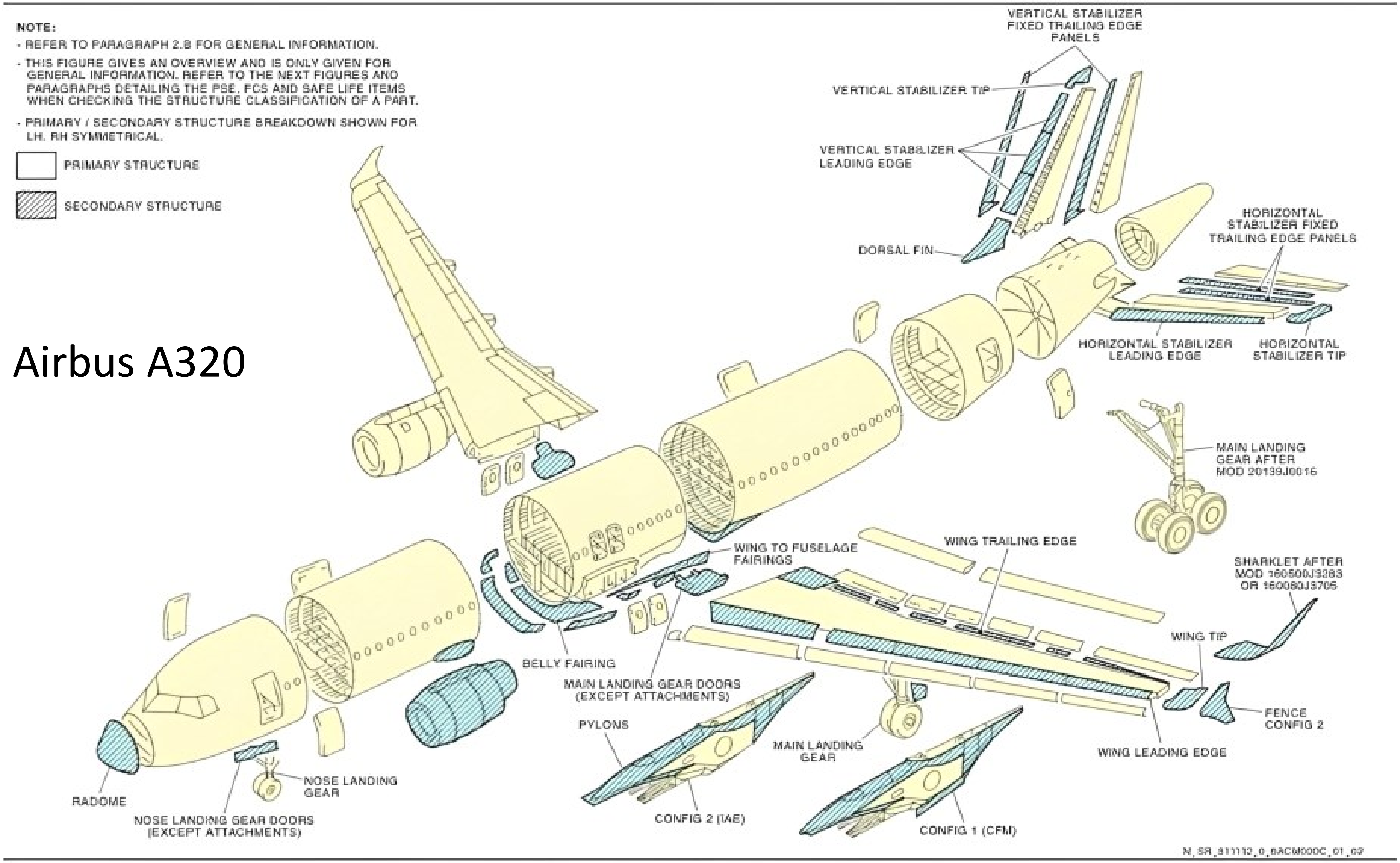
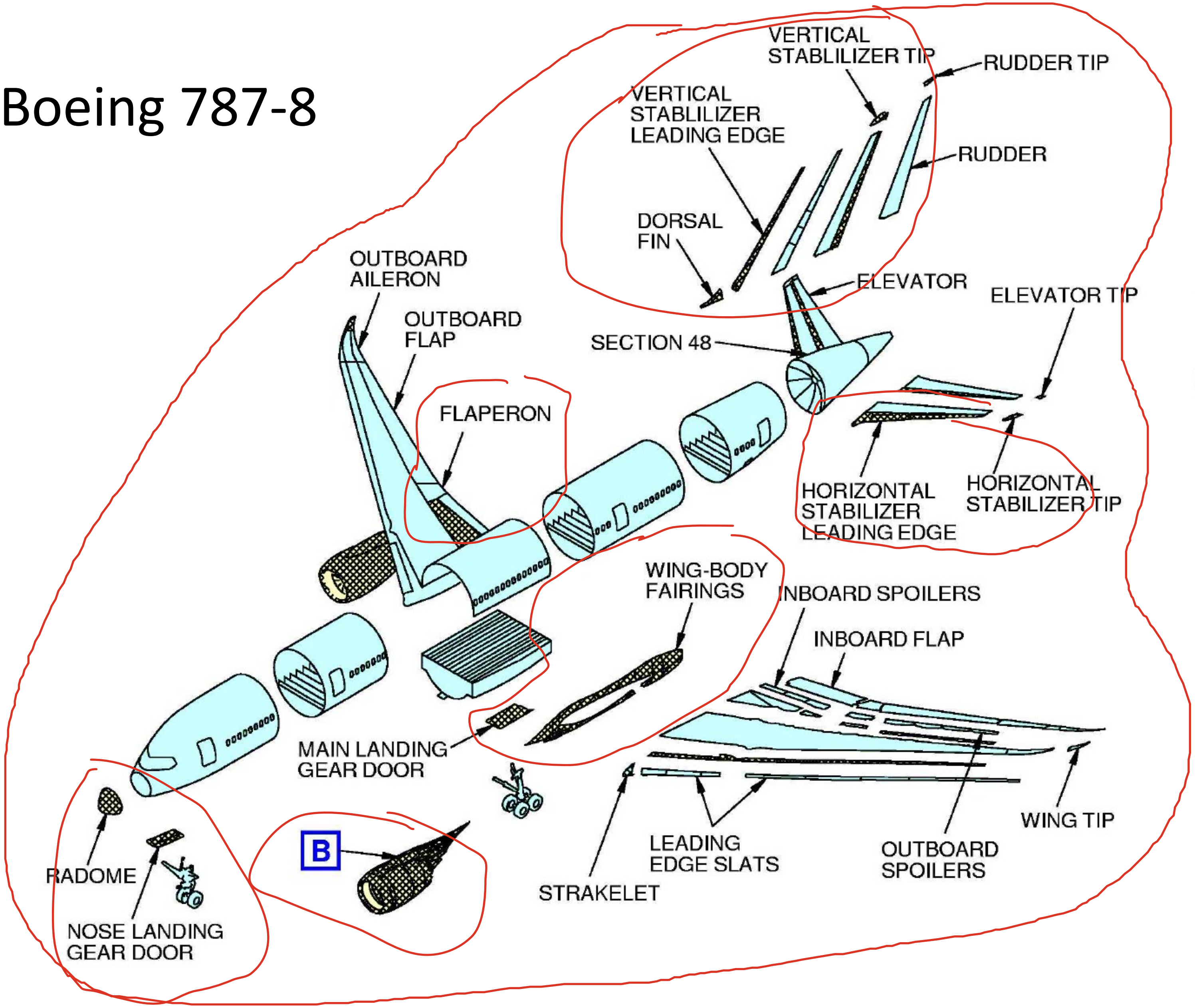
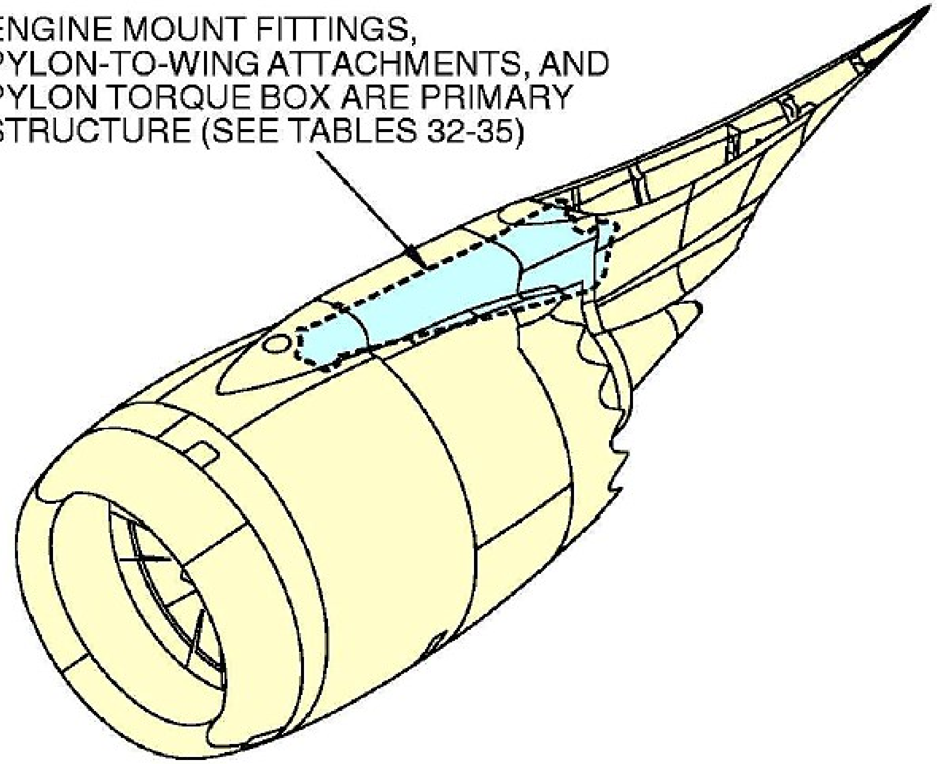


Figure 002 / 51-11-12 (SHEET 1) - Primary and Secondary Structure - General Details

Boeing 787-8

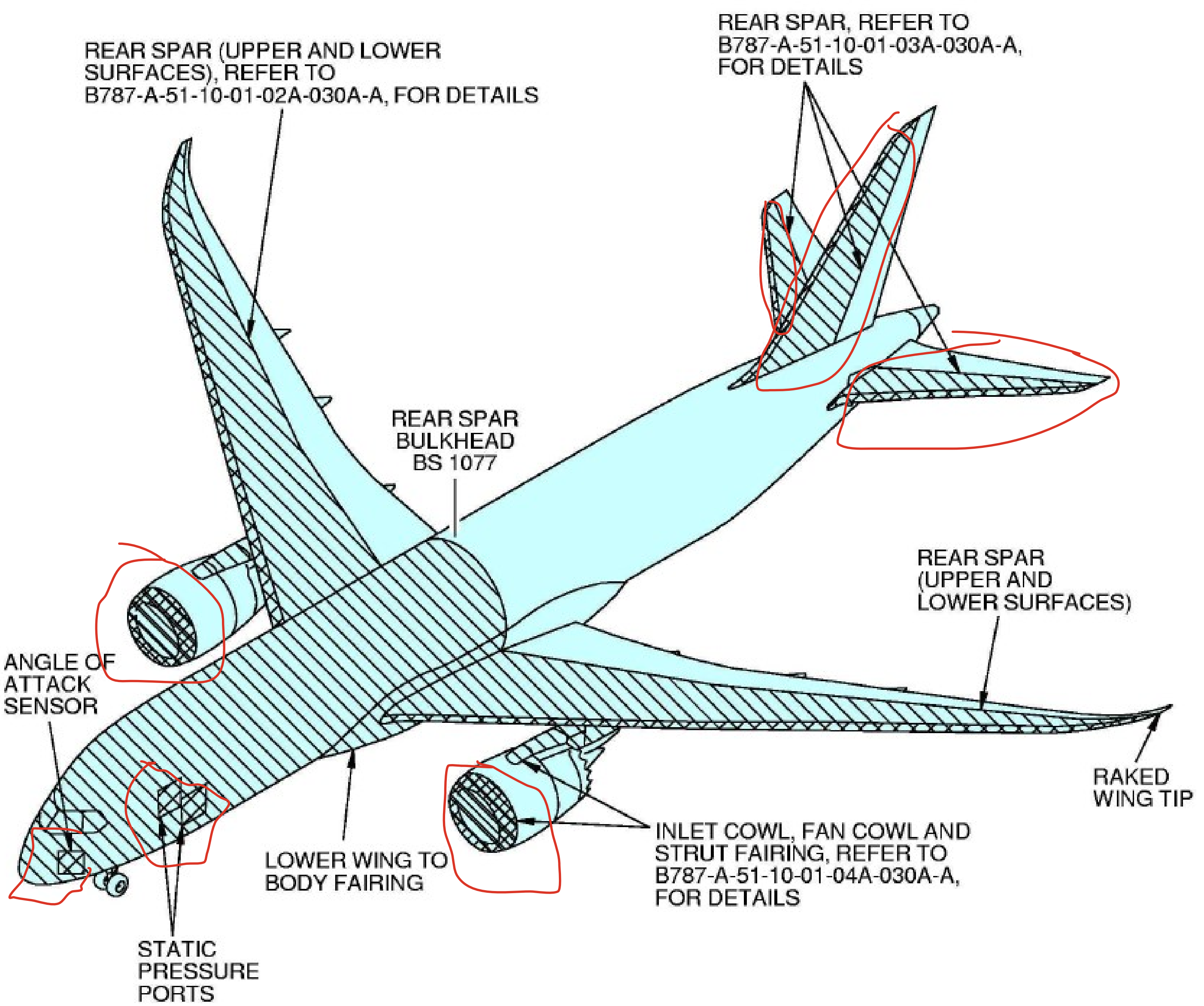




PRIMARY STRUCTURE (STRUCTURALLY SIGNIFICANT ITEMS) (SEE TABLES 1 - 69)

SECONDARY STRUCTURE (SEE TABLE 70)

Boeing 787-8



EXTRA CRITICAL AREA (EXTRA HIGH LEVEL OF AERODYNAMIC SMOOTHNESS IS NECESSARY)

CRITICAL AREA (A HIGH LEVEL OF SMOOTHNESS IS NECESSARY). INCLUDES INTERNAL NACELLE FLOW SURFACES AND THE LEADING EDGE (FIRST 20 PERCENT OF THE CHORD) OF ALL HIGH LIFT DEVICES AND CONTROL SURFACES.

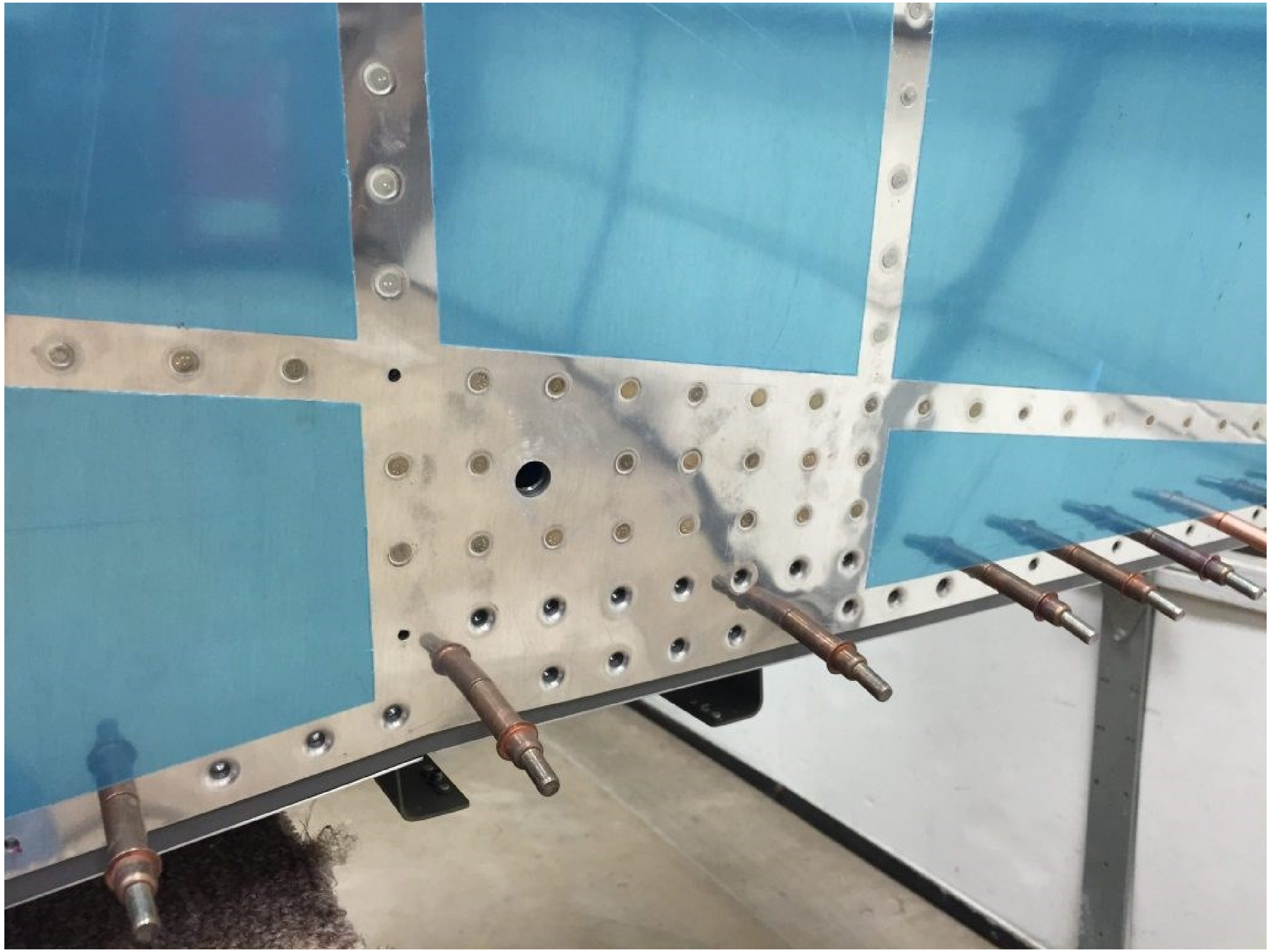
NON-CRITICAL AREA

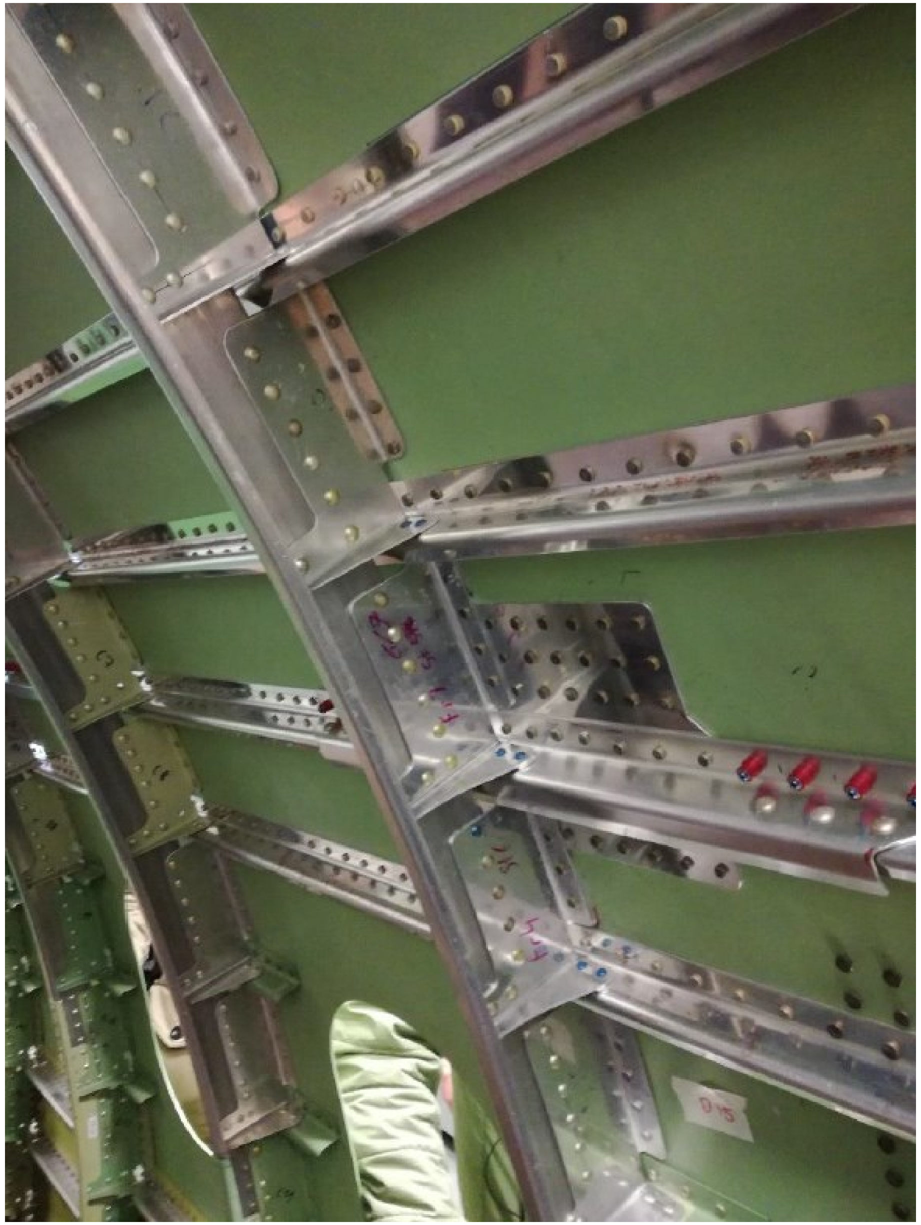
Typical structure arrangement

The main structure of the fuselage typical sections is primarily made by:

- Skin plates
- Frames
- Stringers, longerons
- Skin stiffeners

They are riveted together to make the fuselage shell



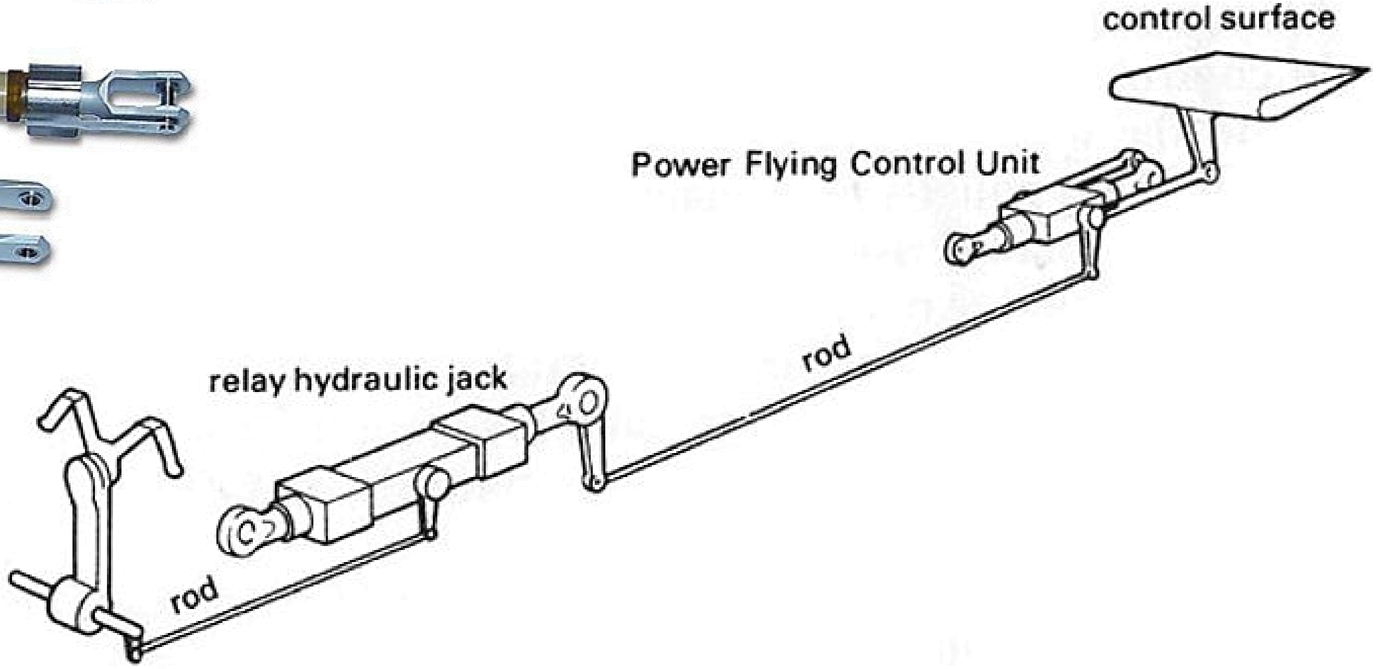


Standard construction shapes

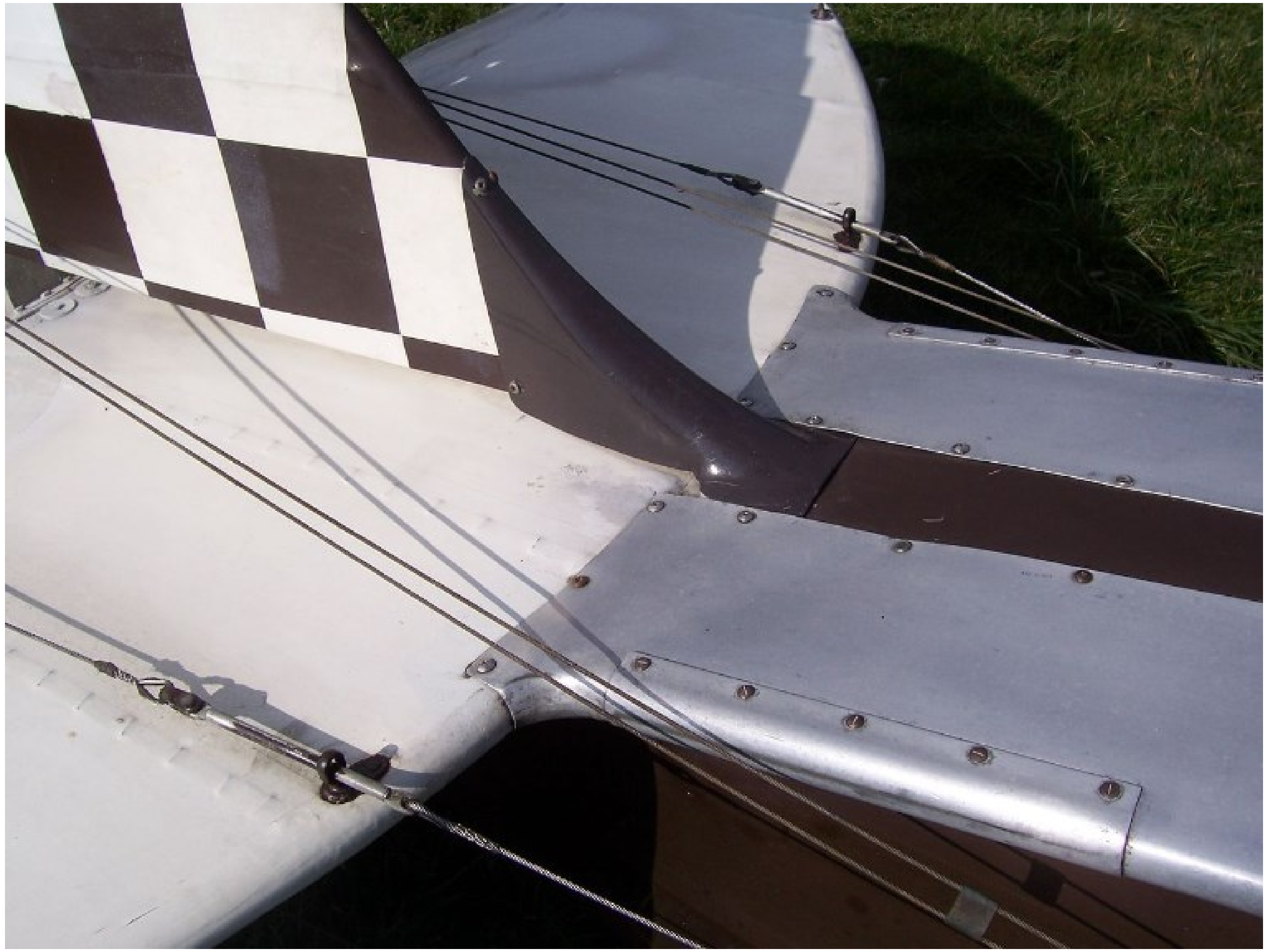
Wire: Solid section, square, rectangular or round, hexagonal or octagonal whose diameter, width or greatest distance between parallel faces is less than 3/8 in (9.525 mm)

Rod: a solid round section 3/8 in (9.525 mm) or greater in diameter

Standard construction shapes



Standard construction shapes



Aircraft control

- Fly by wire
- Fly by light (fly by optics)
- Fly by wireless
- Power by wire

Kawasaki P-1

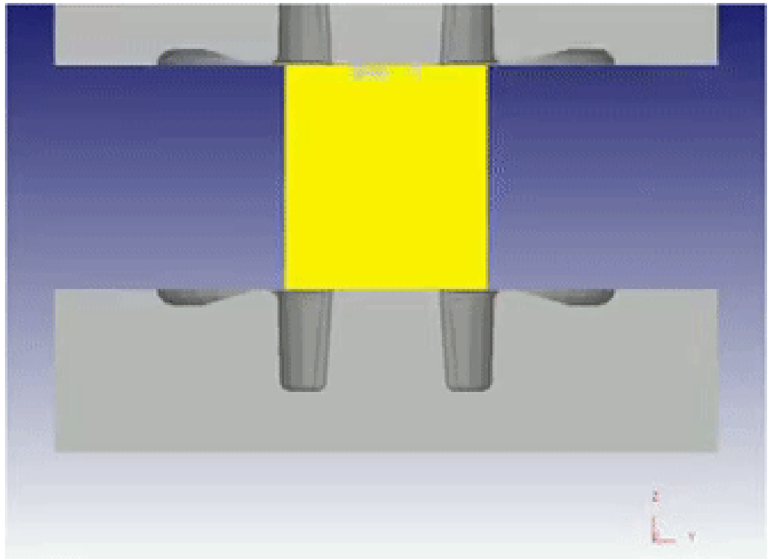
Standard construction shapes

Forging: a metal part worked to a predetermined shape by one or more such process as hammering, upsetting, pressing, rolling, etc.

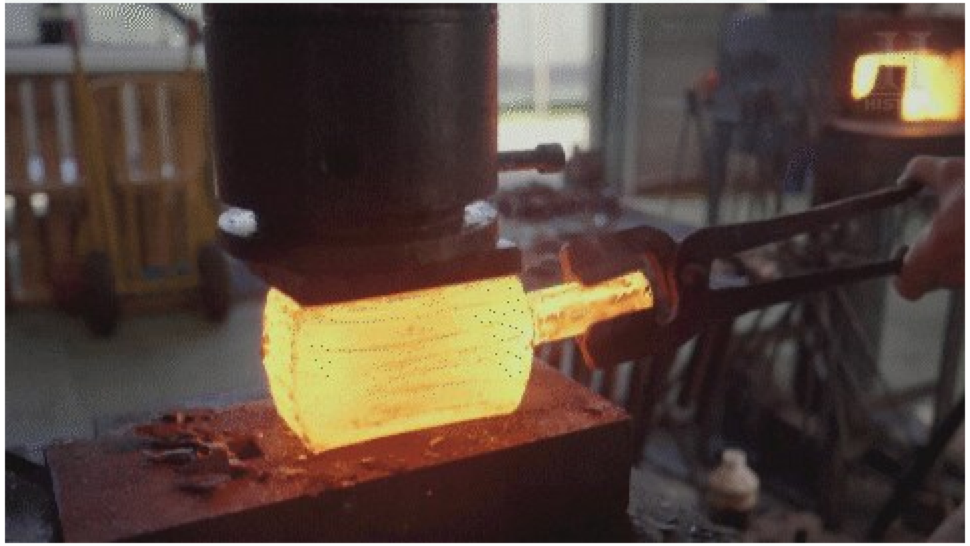
Die Forging: A forging formed to the required shape and size by working in impression dies.

Hand Forging: A forging worked between flat or simply shaped dies by repeated strokes or blows and manipulation of the piece.

Standard construction shapes



https://thumbs.gfycat.com/HandsomeHorribleBluebottlejellyfish-size_restricted.gif

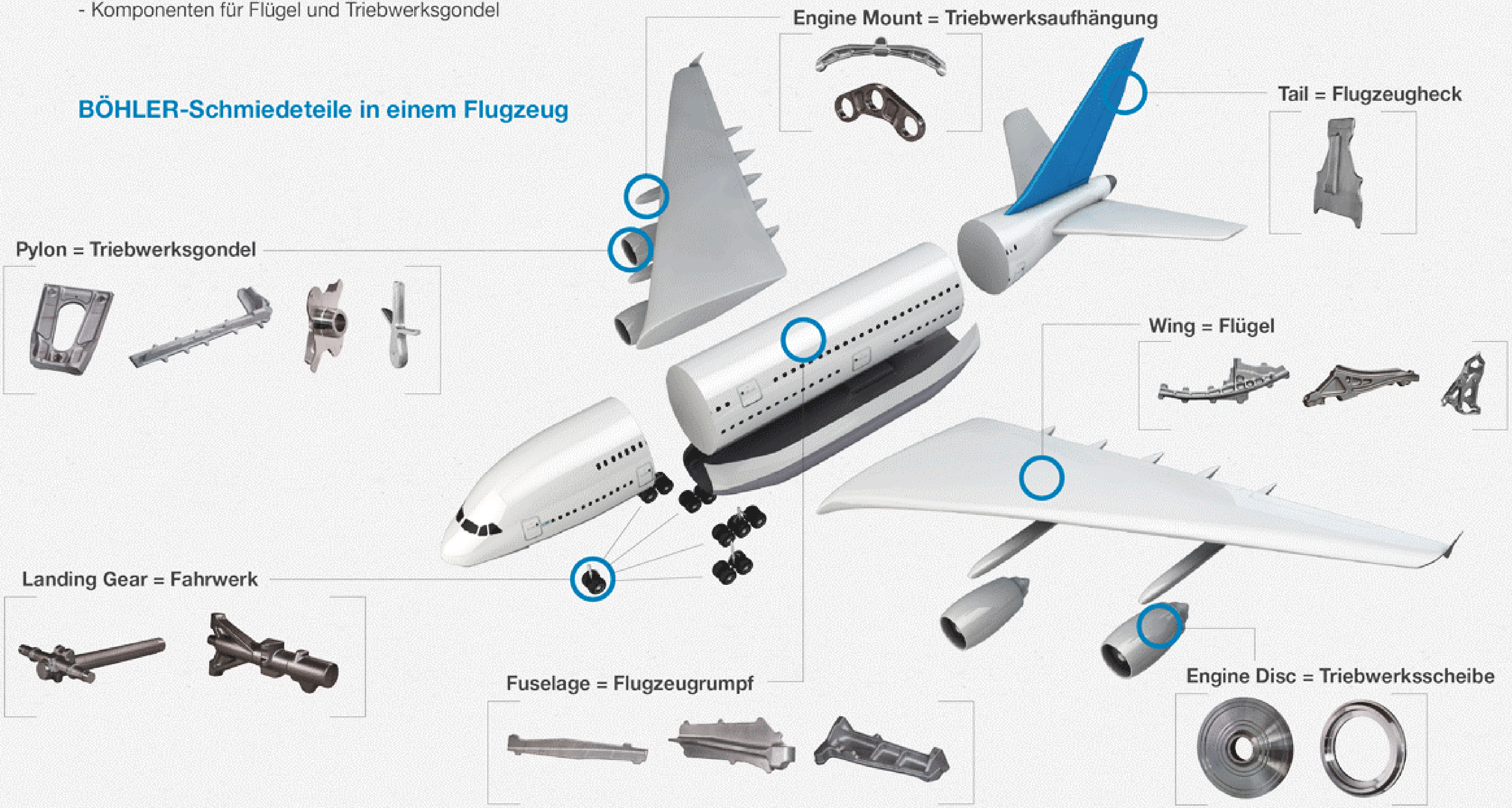


https://media1.giphy.com/media/v1.Y2lkPTc5MGI3NjExdmFkjF6OTVqbm80amVxbjRtbWcyMDBuOWQwbHYzaThxcXJxMGVpMyZlcD12MV9naWZzX3NlYXJjaCZjdD1n/33F9BfC9ZOUoYH04zu/giphy.gif

Spezialisiert auf das Hochqualitätssegment von schwer umformbaren Werkstoffen

- Triebwerksscheiben
- Verbindung Höhen-/Seitenleitwerk mit Rumpf
- Fahrwerkskomponenten
- Strukturteile für Flugzeugrumpf (z. B. Haupttrageelemente im Flügelkasten)
- Komponenten für Flügel und Triebwerksgondel

BÖHLER-Schmiedeteile in einem Flugzeug



Ein Airbus A380 besteht aus ca. 4 Mio. Teilen, ca. 1.000 davon sind Schmiedeteile.

Standard construction shapes

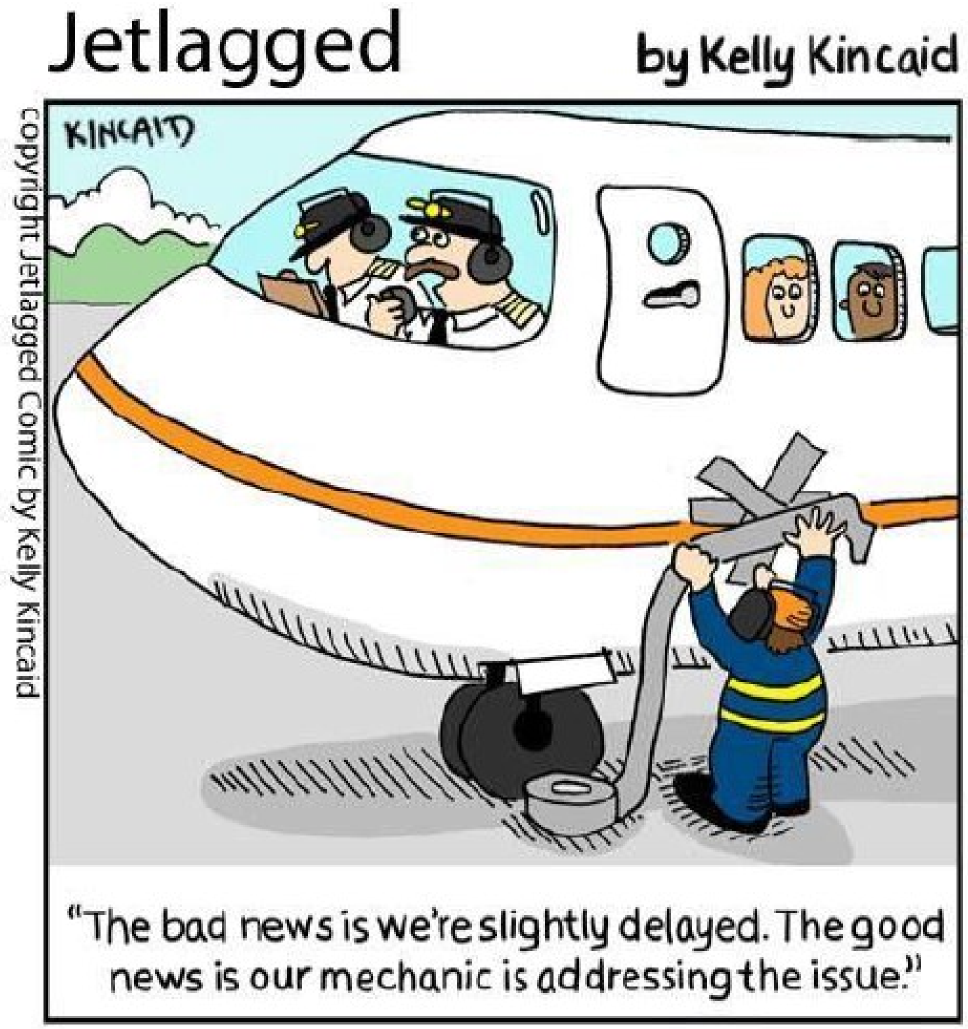
Foil: rolled section of less than t=0.15 mm (0.006 in).

Sheet: thickness greater than t=0.15 mm and less than t=6.35 mm (0,006 - 0,250 in)

Plate: thickness greater than t=6.35 mm (0.250 in)

All above have rectangular section

Foil

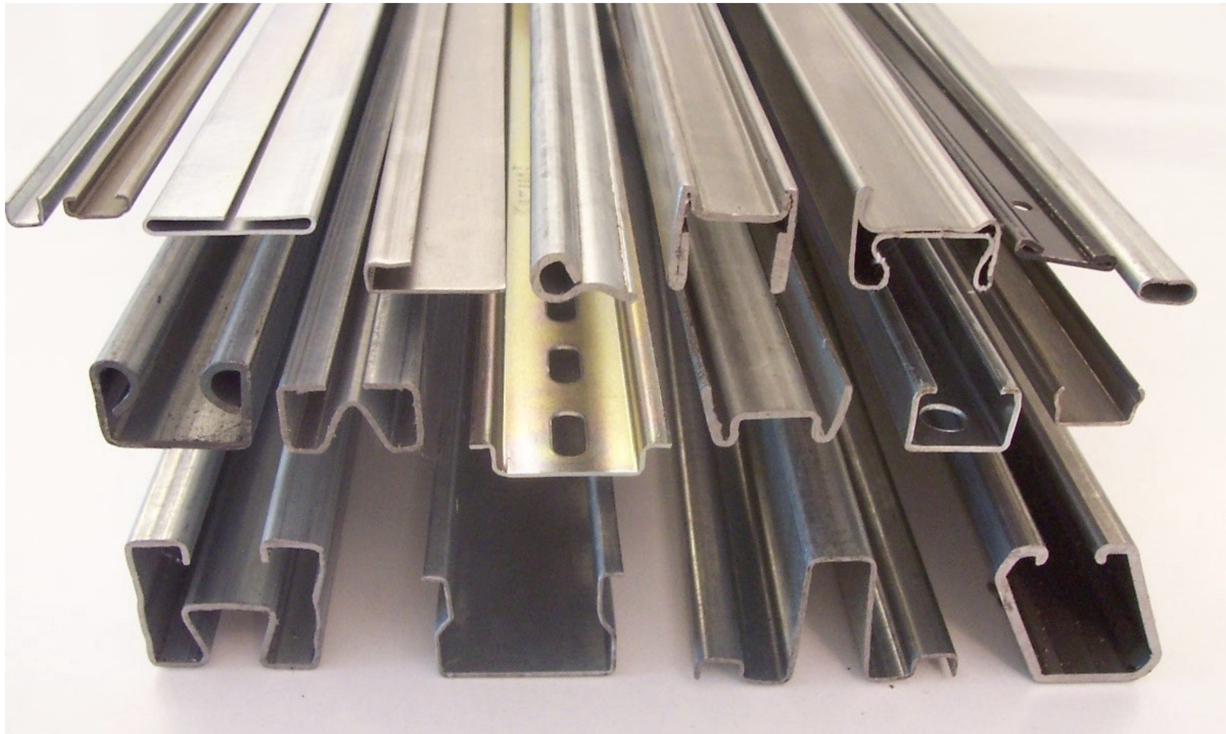

Jetlagged
by Kelly Kincaid
KINCAID
copyright Jetlagged Comic by Kelly Kincaid
"The bad news is we're slightly delayed. The good news is our mechanic is addressing the issue."

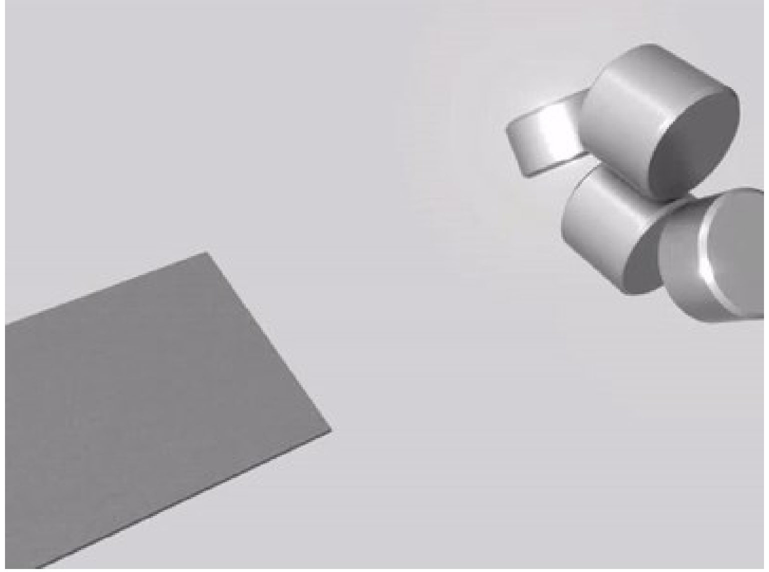

LYKEN

25 USD

Standard construction shapes

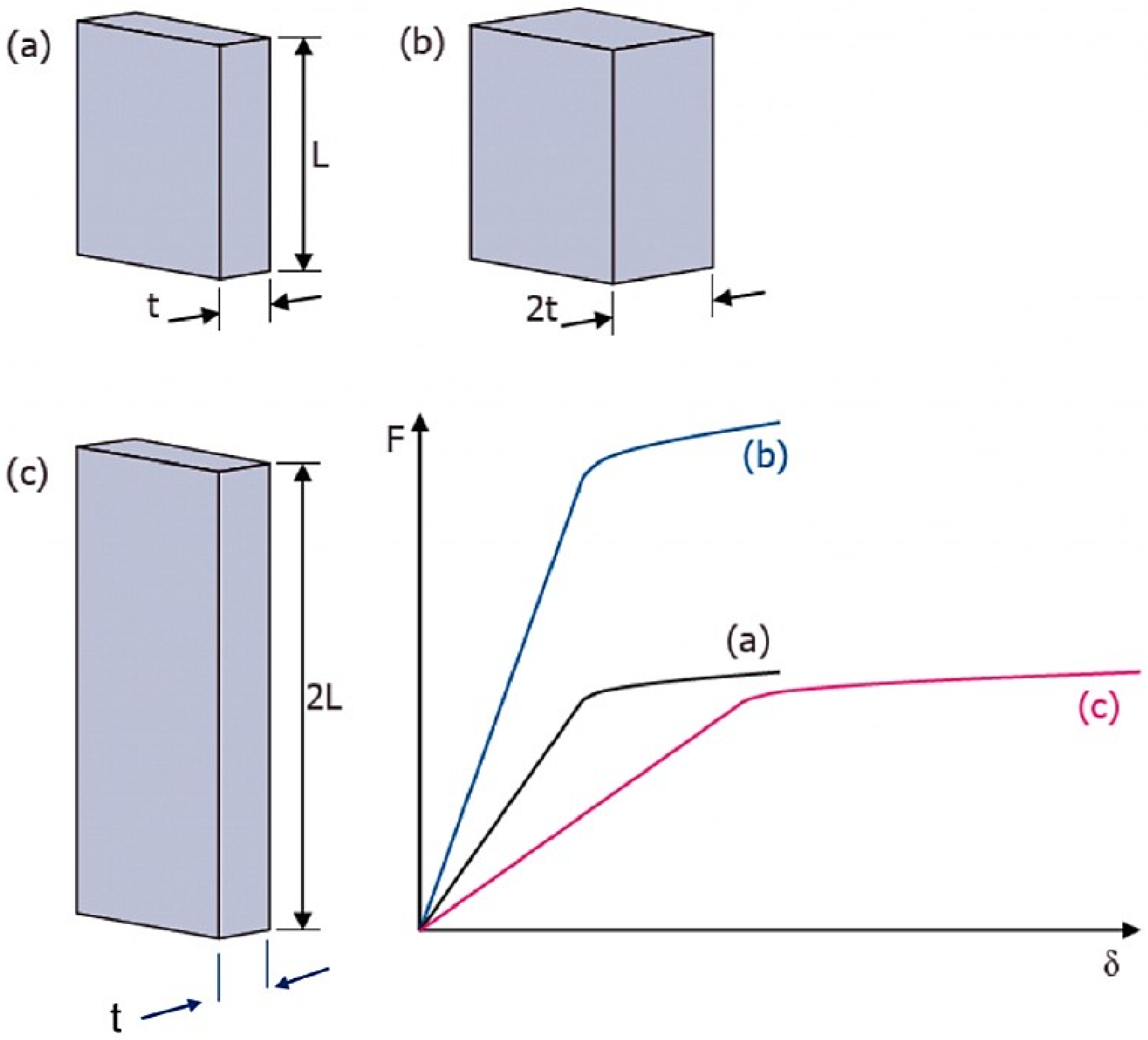
Formed sections: these are parts bent in a process by which metal material can be plastically deformed and therefore its shape also changes.

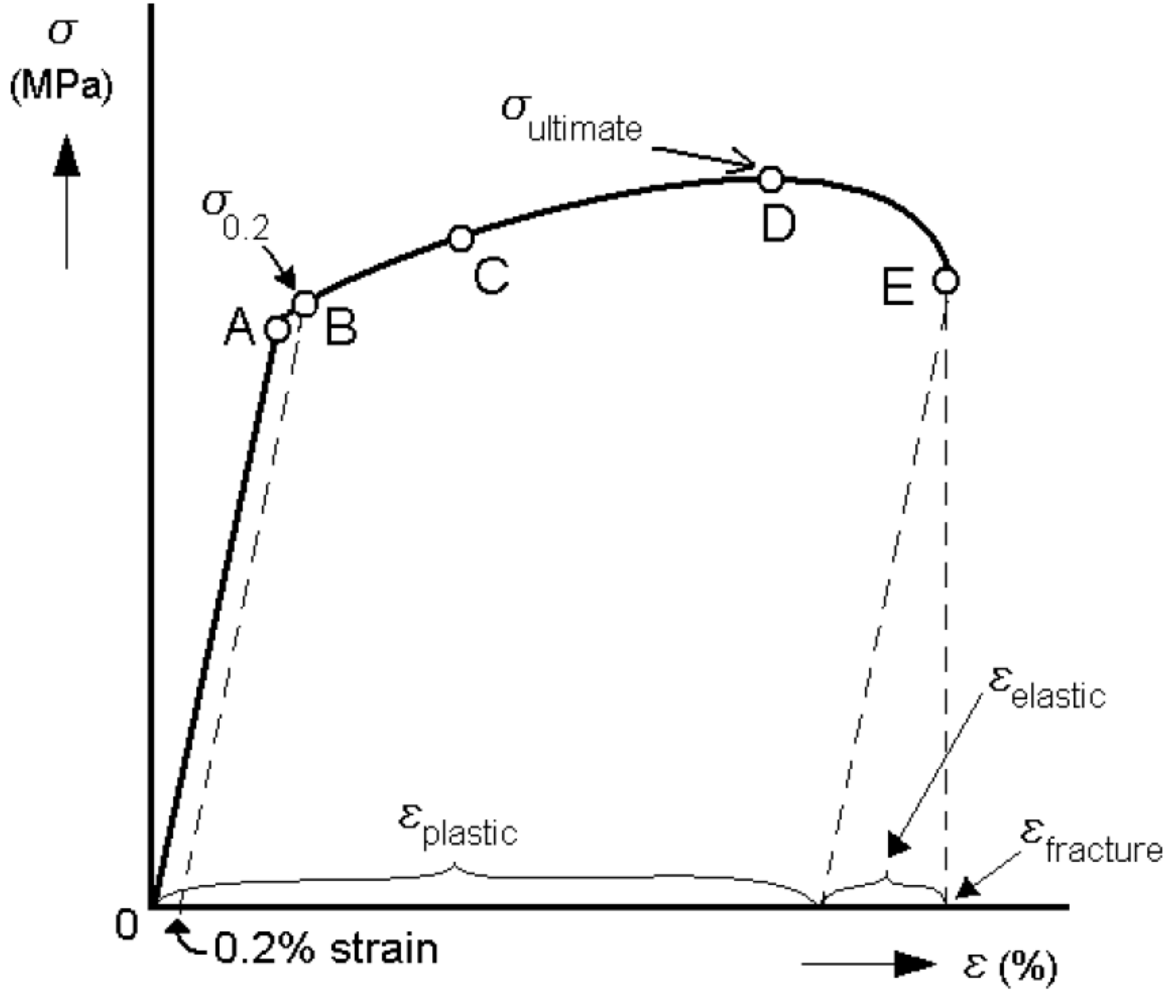


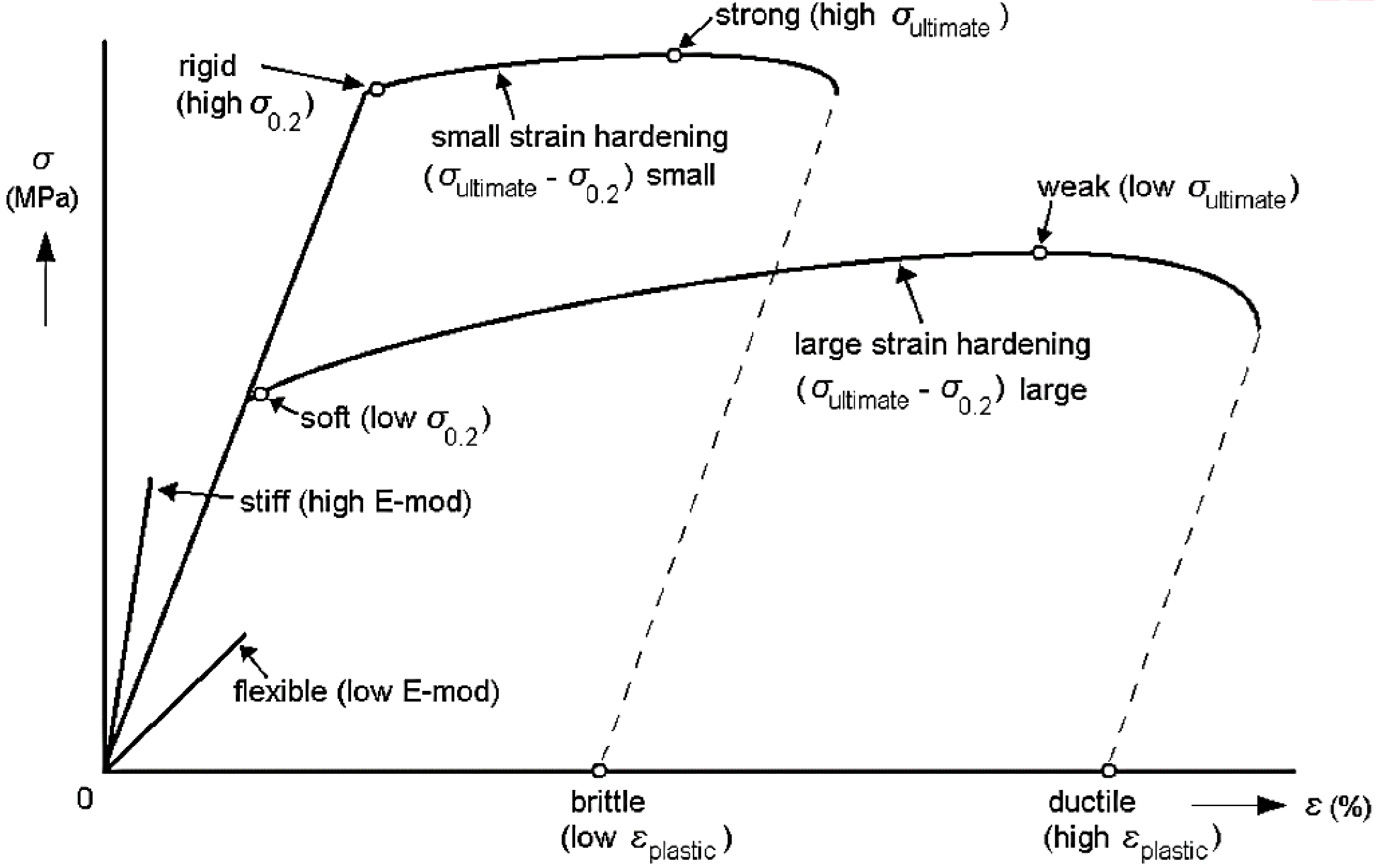


https://i.makeagif.com/media/11-01-2017/dITSeY.gif

Materials - Stress-Strain



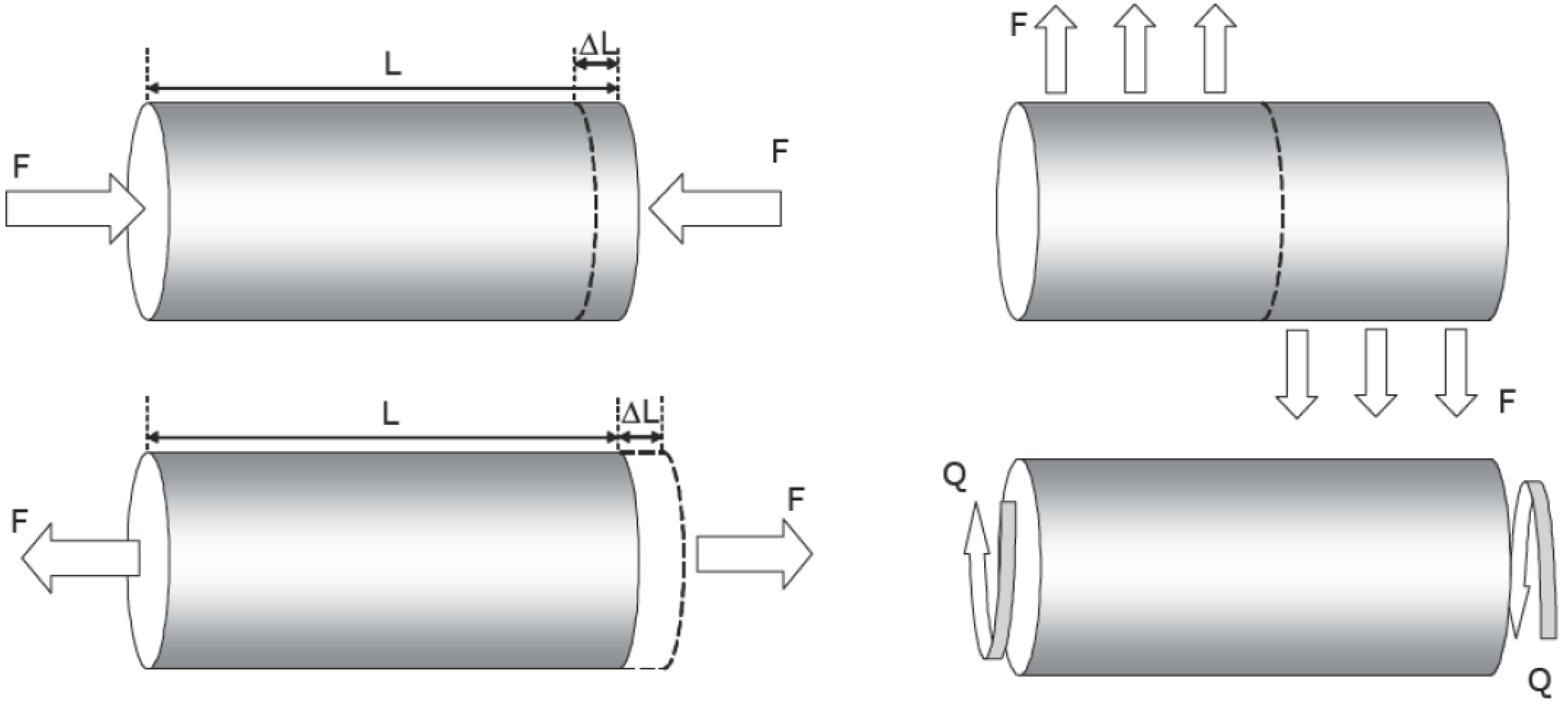



strong (high $\sigma_{ultimate}$)
rigid (high $\sigma_{0.2}$)
small strain hardening ($\sigma_{ultimate}$ - $\sigma_{0.2}$) small
σ (MPa)
weak (low $\sigma_{ultimate}$)
large strain hardening ($\sigma_{ultimate}$ - $\sigma_{0.2}$) large
soft (low $\sigma_{0.2}$)
stiff (high E-mod)
flexible (low E-mod)
0
brittle (low $\varepsilon_{plastic}$)
ductile (high $\varepsilon_{plastic}$)
ε (%)

Materials - Stress-Strain

NASA Aerovironment

Materials - Loading modes

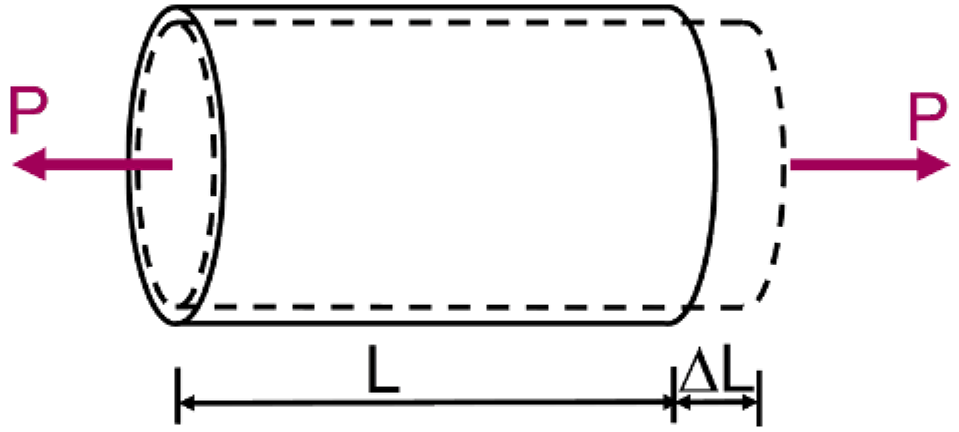


Materials

Normal Stress

$$\sigma = E\varepsilon$$

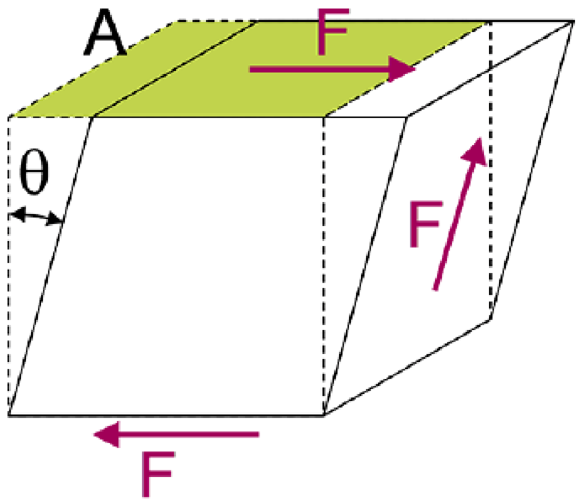
$$\varepsilon_t = -\upsilon\varepsilon_l = \nu\frac{\sigma_l}{E}$$



Shear Stress

$$\tau = G\gamma$$

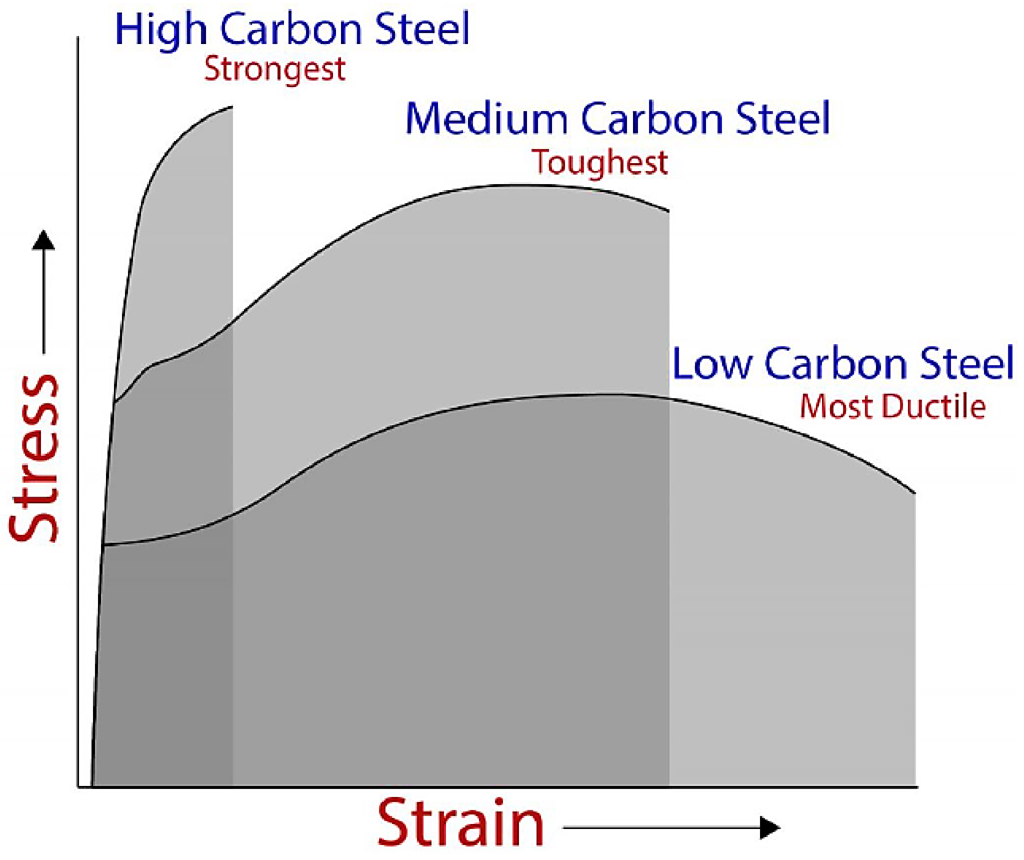
$$G = \frac{E}{2(1+\upsilon)}$$



Materials (Toughness)

In aerospace structures it represents the **material resistance to fracture, formation of damage** or **impact**.

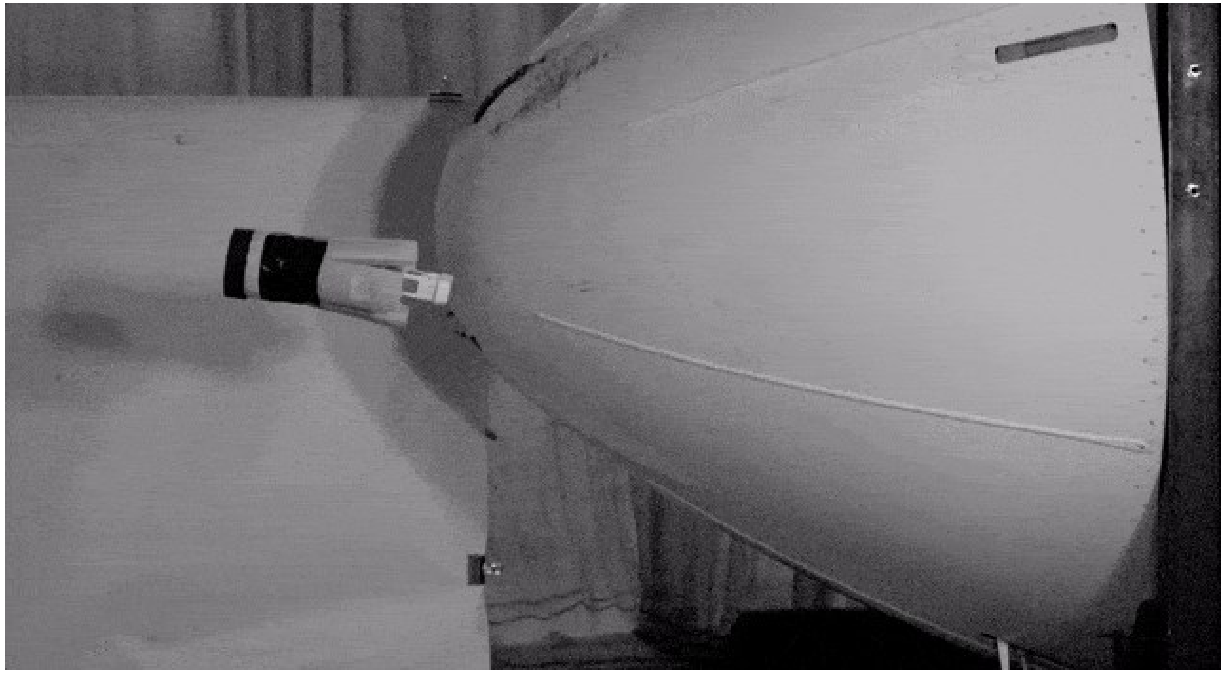
Toughness is represented by the area underneath the stress-strain curve. This area represents the mechanical deformation energy per unit volume prior to failure.



Materials (Toughness)

https://i-cdn.embed.ly/1/display?key=fd92ebbc52fc43fb98f69e50e7893c13&url=http%3A%2F%2Fi.imgur.com%2F4MH8XJX.gif%3Fnoredirect

Materials (Toughness)



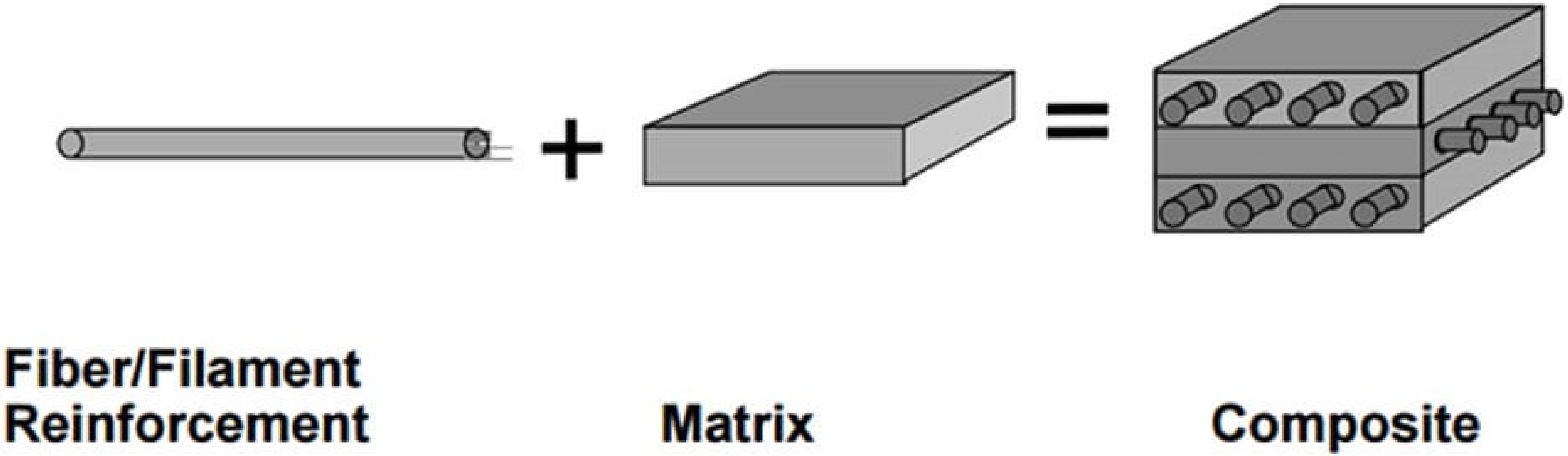
https://hips.hearstapps.com/pop.h-cdn.co/assets/16/51/640x351/gallery-1482423421-dronegif.gif?resize=1200:*

https://www.sciencealert.com/images/2018-10/026-drone-collision_600.gif

Composite Materials

A composite is a structural material that consists of **two or more combined constituents** that are combined at a macroscopic level and are **not soluble in each other**.

One constituent is called the **reinforcing phase** and the one in which it is embedded is called the **matrix**.

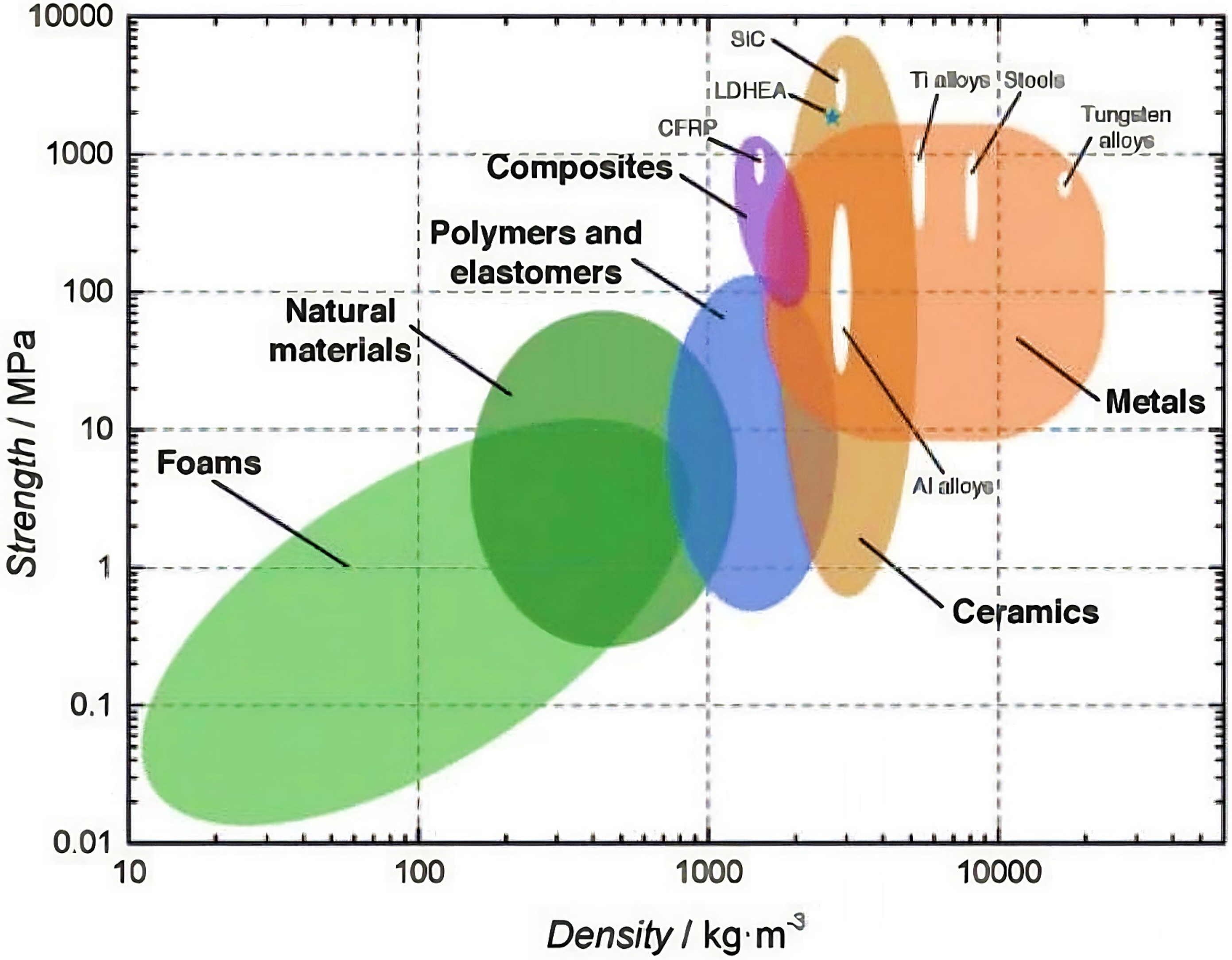


Composite Materials

The reinforcing phase material may be in the form of **fibers, particles, or flakes**.

The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and epoxy reinforced with graphite fibers, etc.

Composite Materials

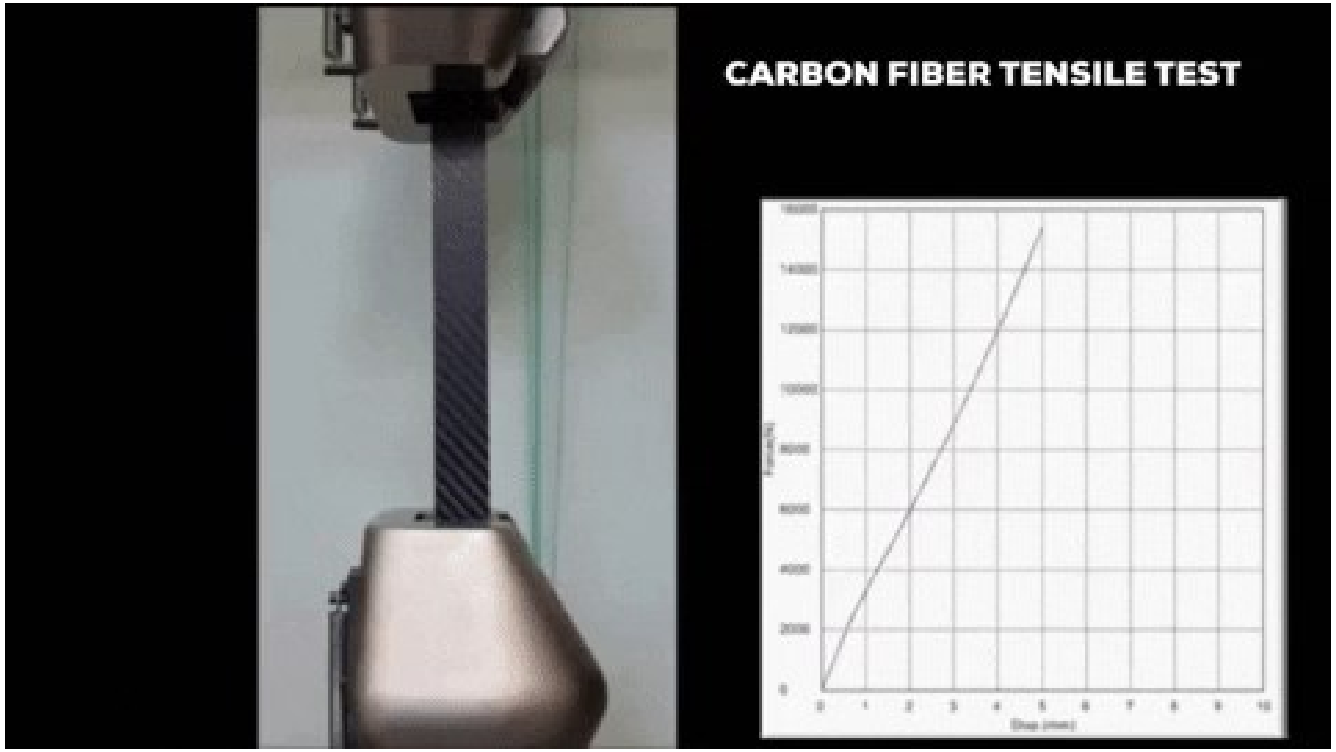


Composite Materials

Mechanical advantage

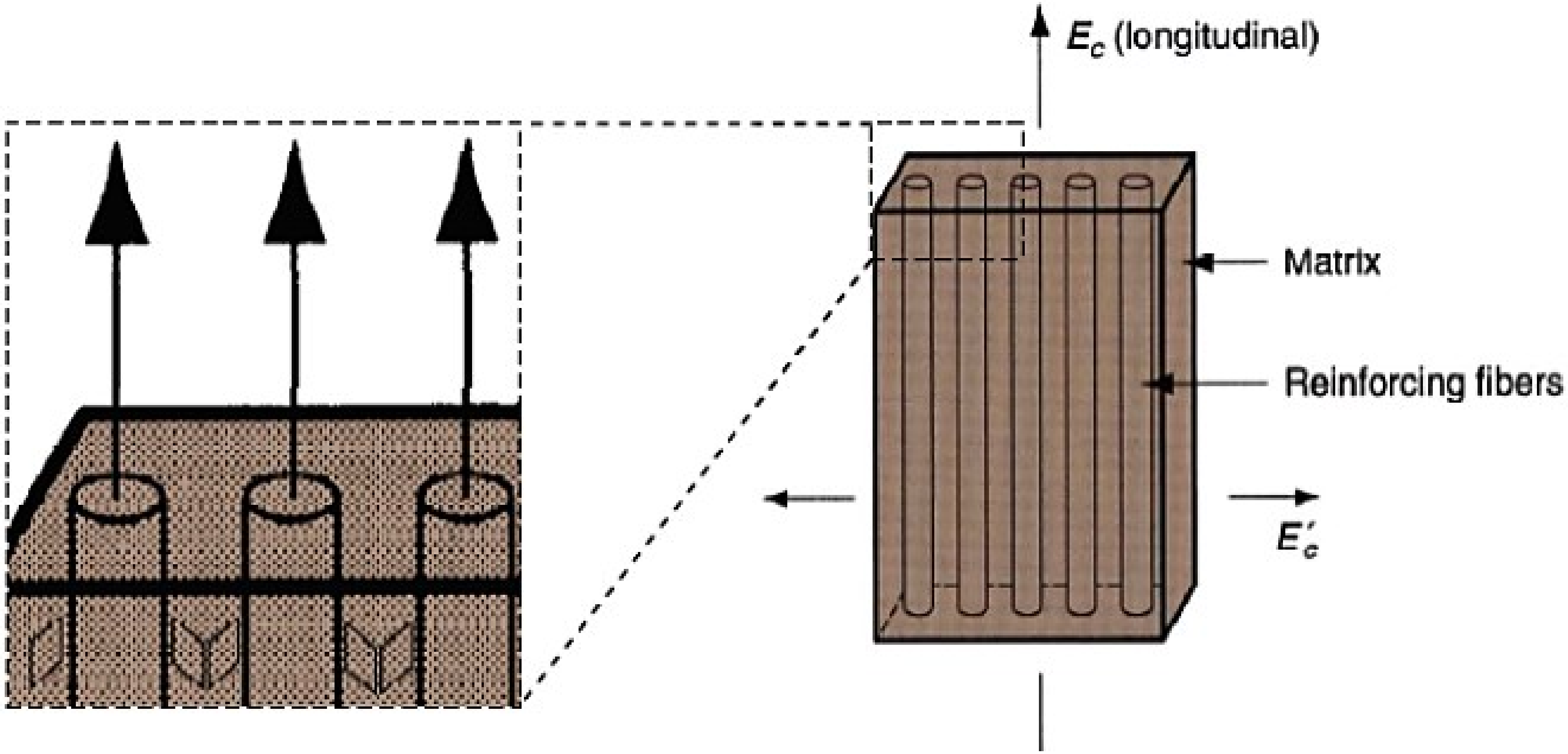
$$Specific\ modulus = \frac{E}{\rho}$$

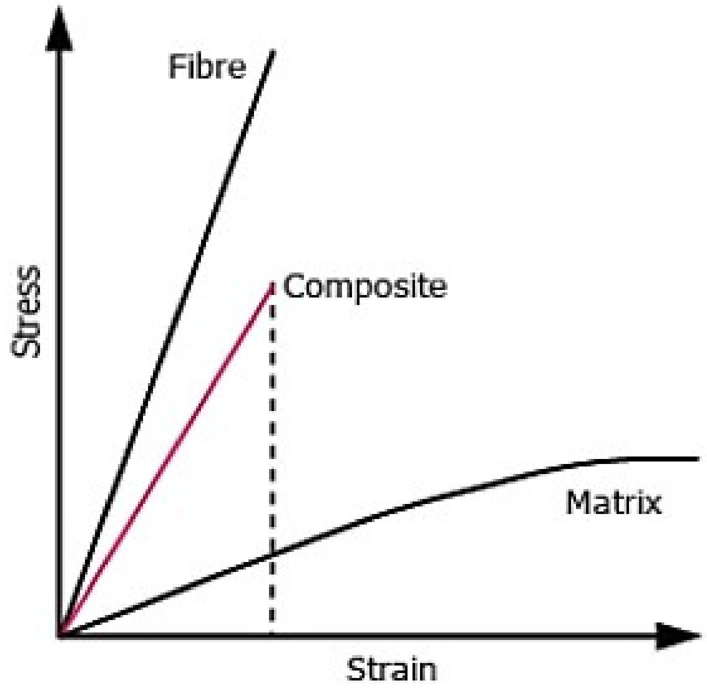
$$Specific\ strength = \frac{\sigma_{ult}}{\rho}$$



https://media.giphy.com/media/v1.Y2lkPTc5MGI3NjExZHVlampyaWY2MWp0ejN6Zm9nY3VjamVvZTY4cHlmdzVxeXRoZXd2ZCZlcD12MV9pbnRlcm5hbF9naWZfYnlfaWQmY3Q9Zw/aF8Yis3MEat56evLhR/giphy.gif

Composite Materials





Composite Materials

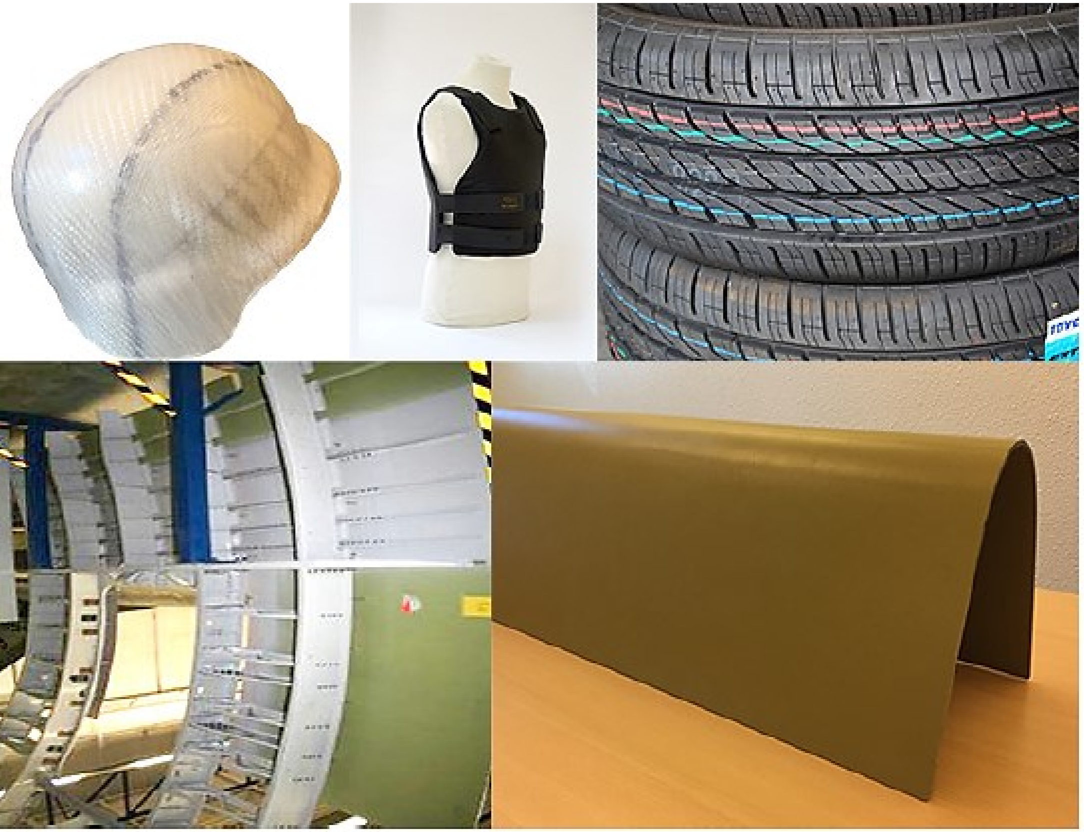
Glass fibre composites
- Wind turbine blades
- Sail planes
- Pressure tanks & vessels

Carbon fibre composites
- Automotive components
- Aerospace components
- Sailboats
- (motor) bikes
- Sport equipment

Composite Materials

Aramid/kevlar composites

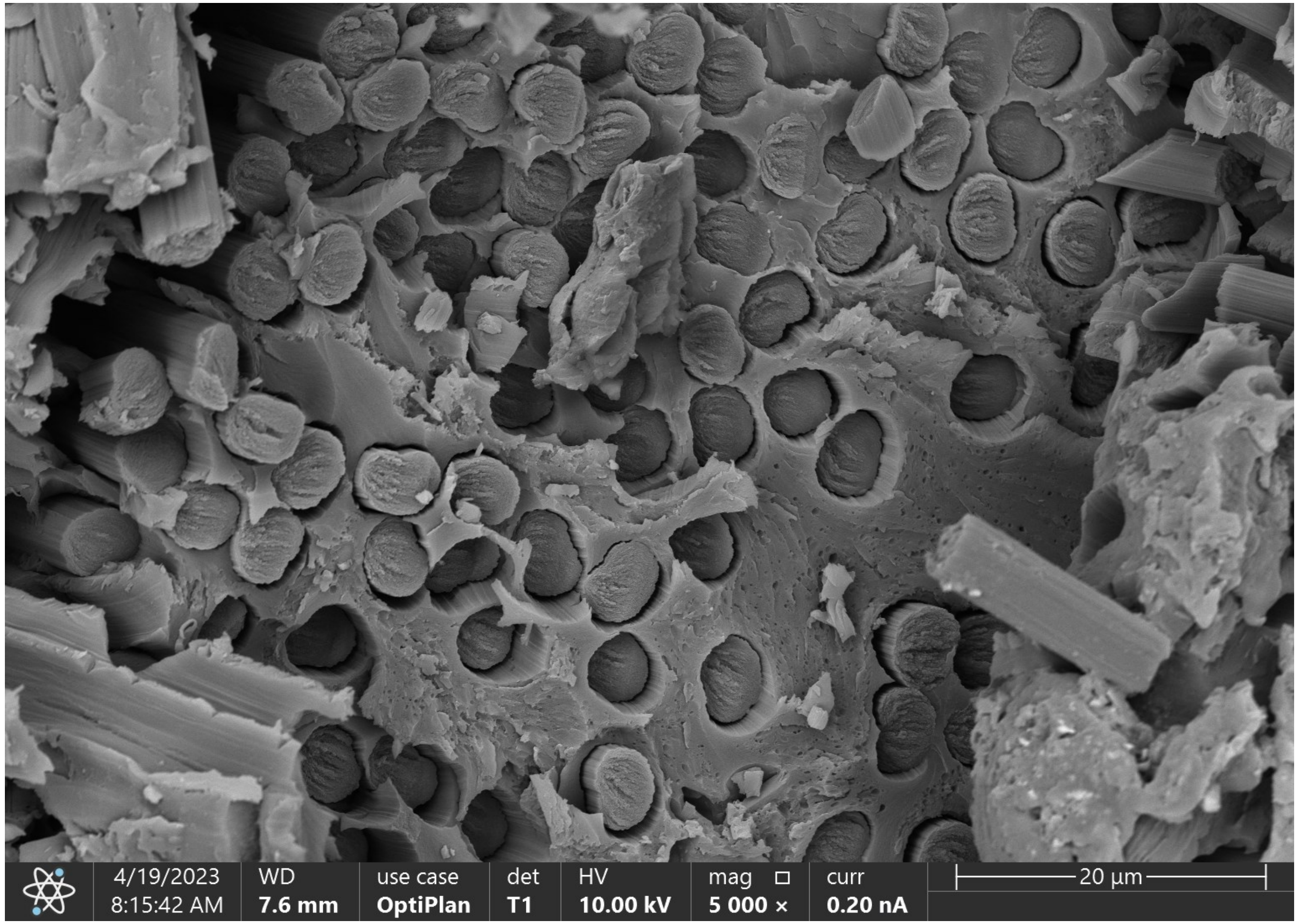
- Armor & bullet proof products
- Impact and penetration resistant products

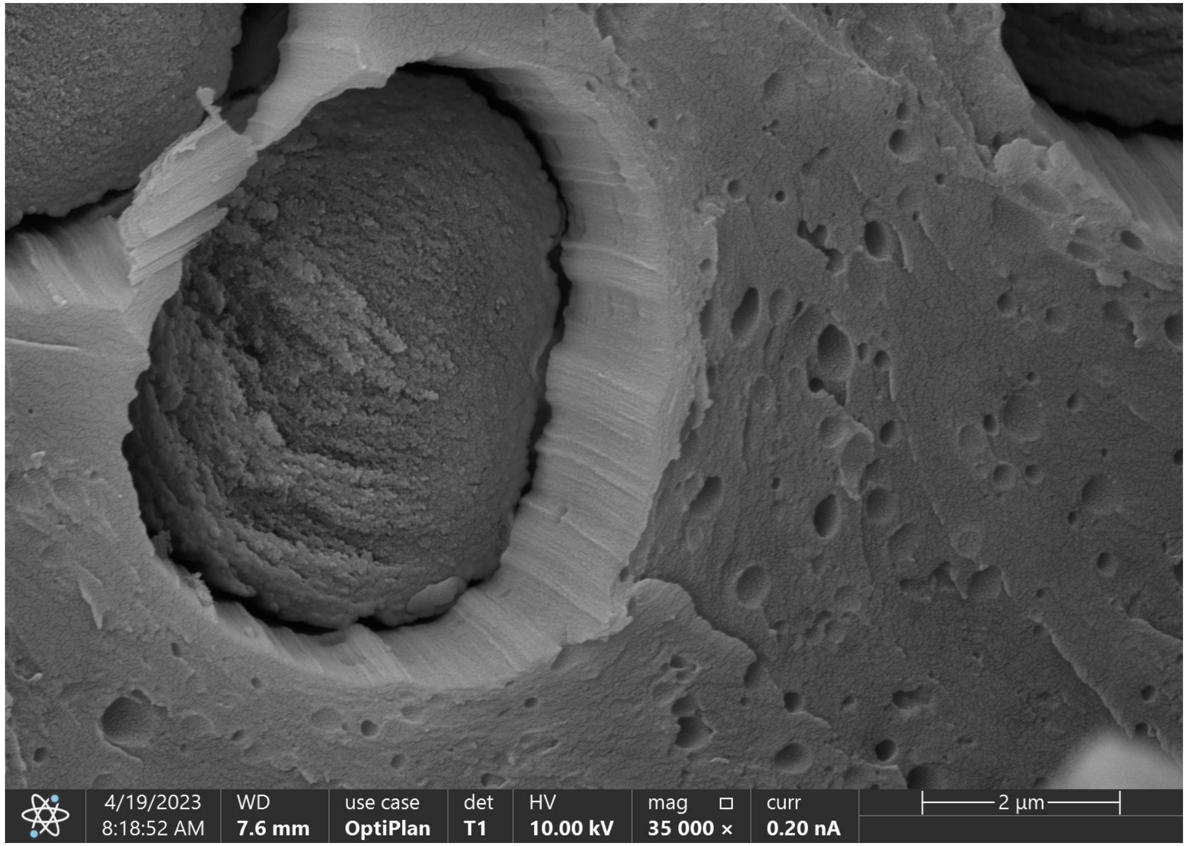


Fibre Metal Laminates

- Upper fuselage skin panels
- Impact resistant leading edges
- Critical joint straps
- Lower wing panels

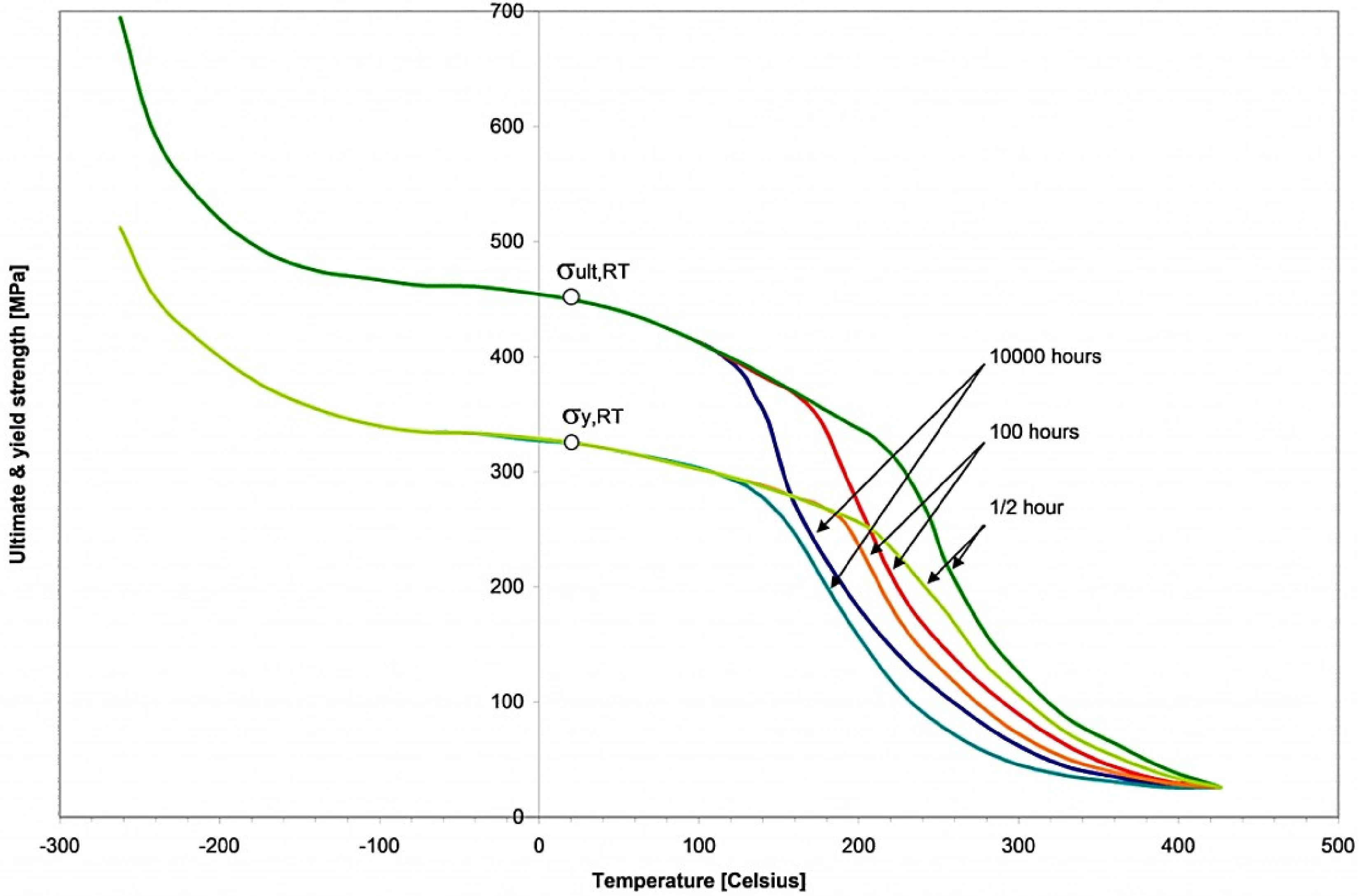
Composite Materials





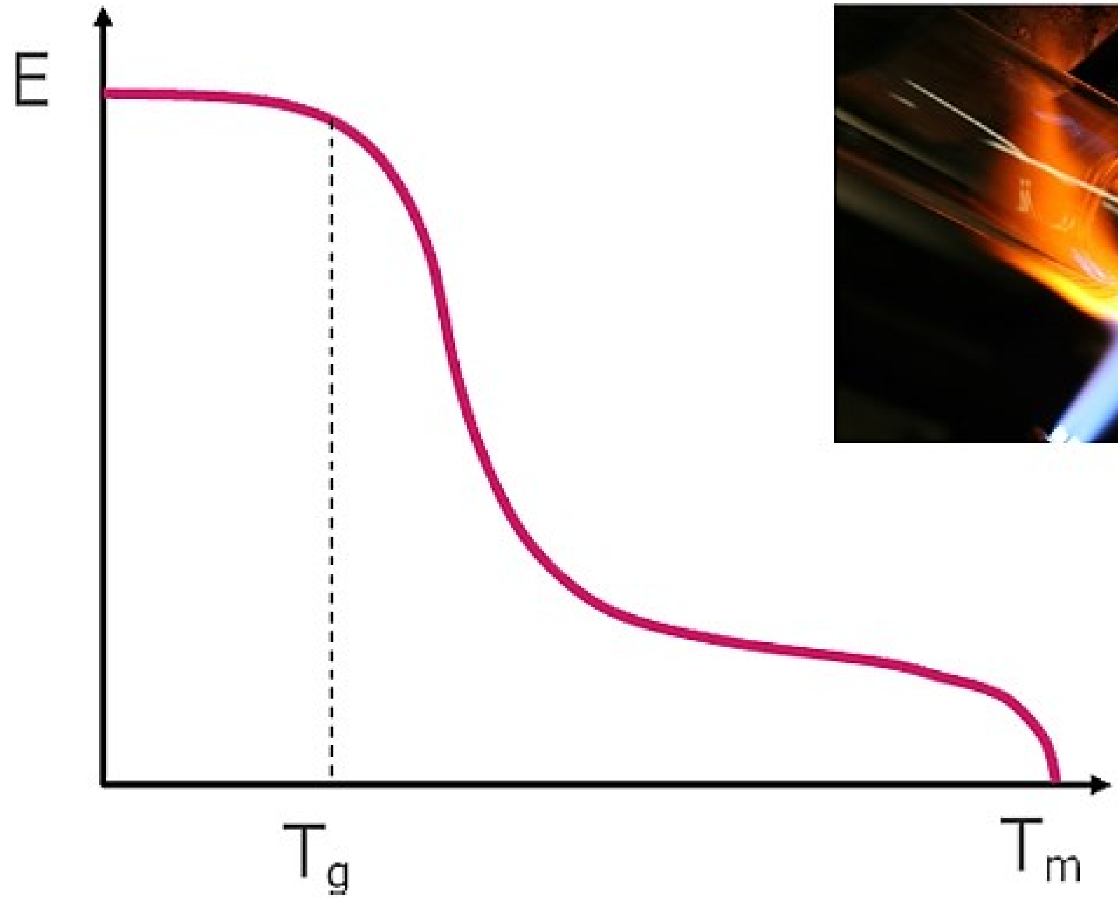
Environment and durability

Temperature



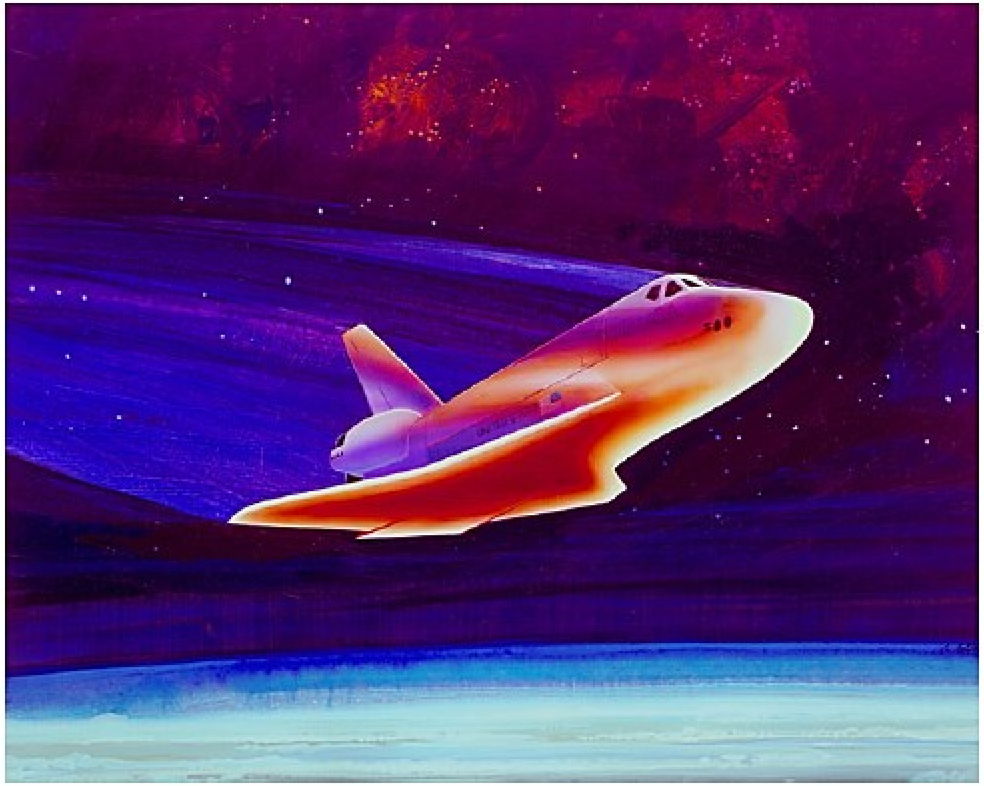
Environment and durability

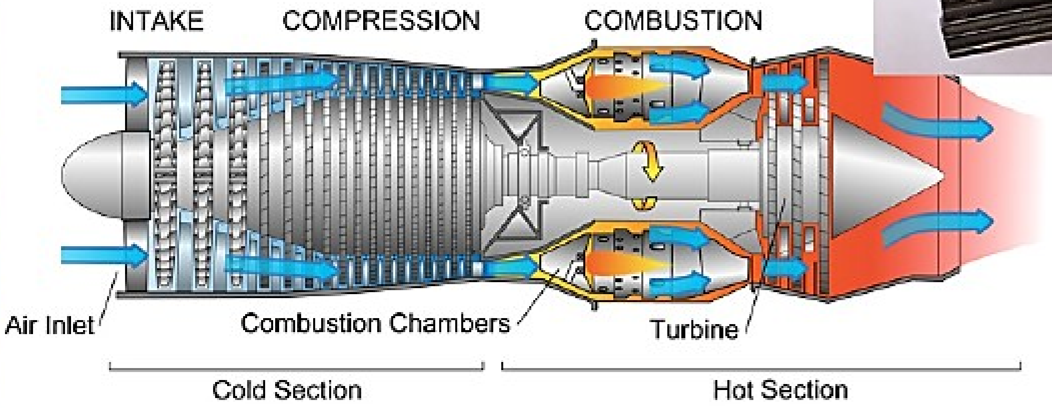
Temperature



Environment and durability

Temperature





Environment and durability

Temperature

Concord

Nose temp: 127 °C

Tail temp: 90 °C

Airframe stretched by 12 to 30 centimeters

Environment and durability

Humidity

Moisture

Corrosion

Salty environment

Fuel exposure

Exposure to hydraulics

Exposure to cleaning agents

Environment and durability

In aerospace industry **corrosion** levels must be kept **low or null**

Environment and durability

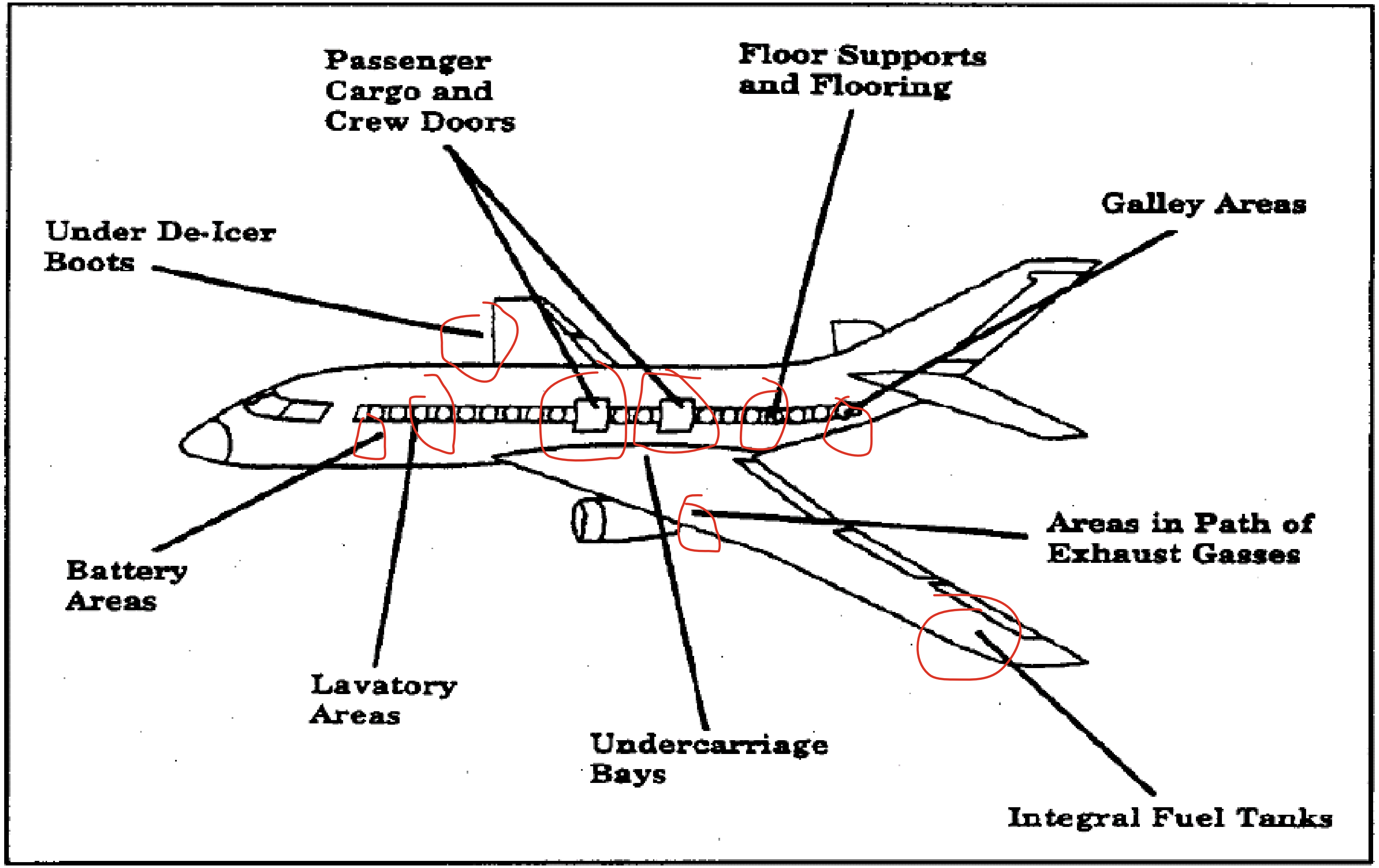


FIGURE 1-5. AREAS MOST SUSCEPTIBLE TO CORROSION

Allowable basis (MMPDS)

MMPDS stands for "Metallic Material Properties Development and Standardization"

A-Basis: The lower of either a statistically calculated T_{99} value, or the specification minimum (S-Basis). The T_{99} value indicates that at least 99 percent of the population is expected to equal or exceed it, with a confidence of 95 percent.

B-Basis: Based on the calculated T_{90} at least 90 percent of the population of values are expected to equal or exceed the B-Basis mechanical property allowable with a confidence of 95 percent.

Allowable basis (MMPDS)

S-Basis: The S-value represents or is based on the minimum property value specified by the governing industry specification (as issued by standardization groups such as SAE Aerospace Materials Division, ASTM, etc.) or federal or military standards for the material.

For certain products heat treated by the user (for example, steels hardened and tempered to a designated F_{tu}), the S-value may reflect a specified quality-control requirement. Statistical assurance associated with this value is not known.

The S-Basis value may also represent downgraded derived properties where reduced ratios were questionable, even though the primary tensile values have A- and B-Basis allowables.

Allowable basis (MMPDS)

Typical basis: A typical property value is an average value and has no statistical assurance associated with it.

For aerospace application of mechanical properties:

- A-Basis values are generally used for single loadpath applications (like lugs) and
- B-Basis values for redundant loadpath applications (like skins, stringers and frames).

Allowable basis (MMPDS)

Use of B-Values

“The use of B-Basis design properties is permitted in design by the Air Force, the Army, the Navy, and the FAA, subject to certain limitations specified by each agency. Reference should be made to specific requirements of the applicable agency before using B-values in design”

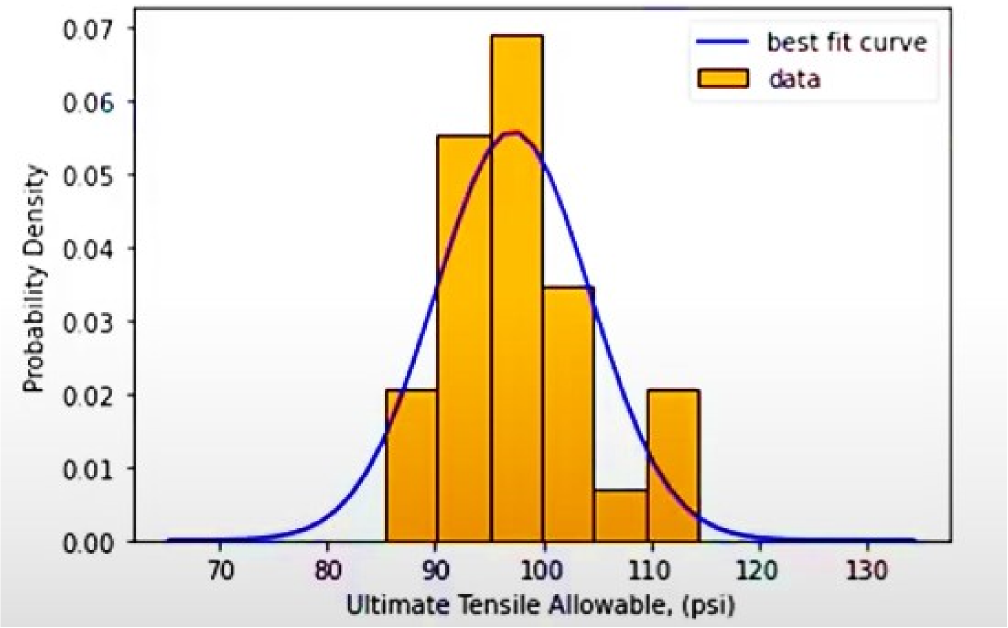
Allowable basis (MMPDS)

The design of aerospace metallic structures must be approved by certifier (i.e., FAA, EASA, UAEAC)

FAA accepts "A-Basis" and "B-Basis" values published in MIL-HDBK-5, and now MMPDS as meeting the regulations of FAR 25.613.

If a designer wants to use different “Basis” values (apart from MMDPS), the designer must have sufficient data to verify the allowables used

Allowable basis (MMPDS)



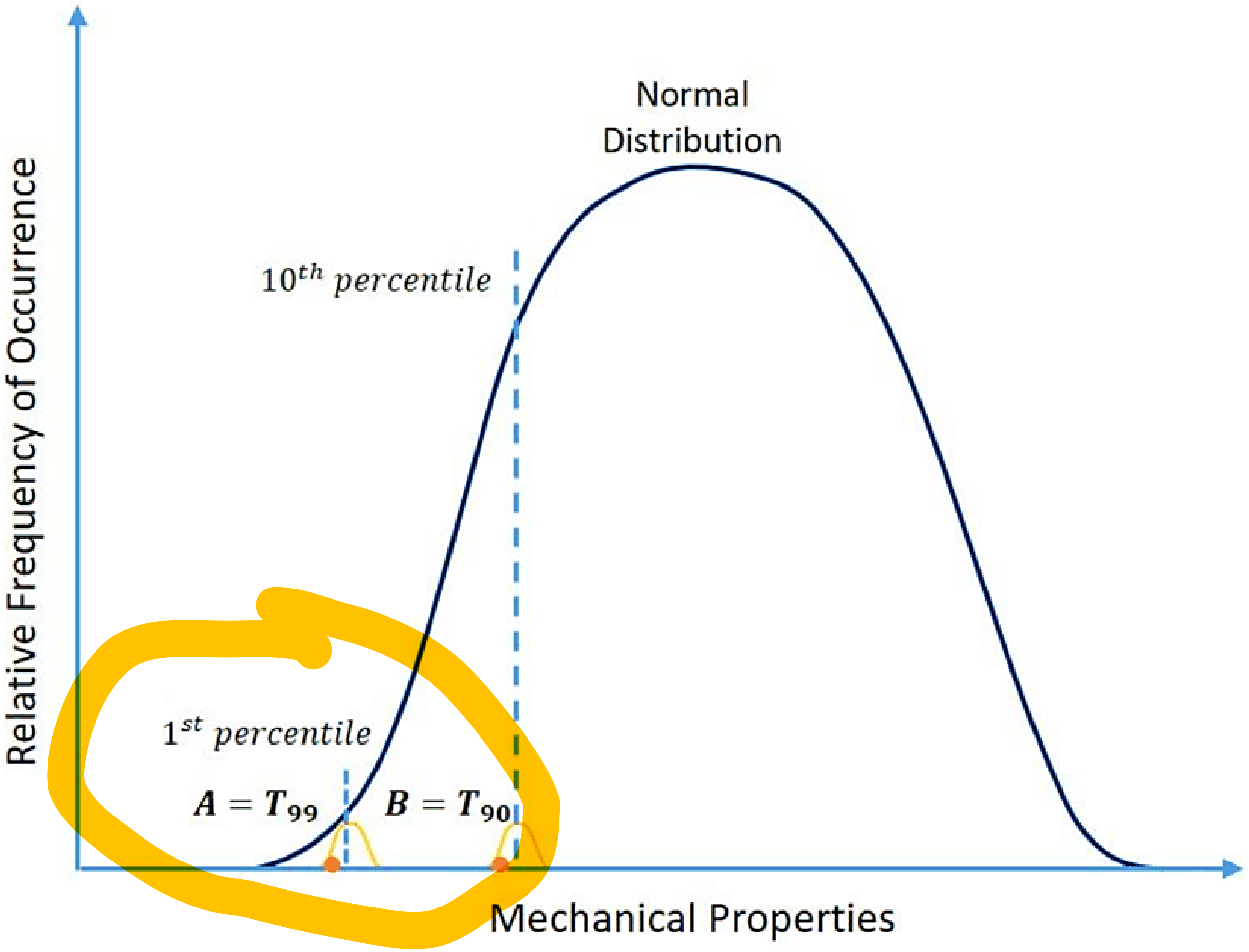


Table 3.2.4.0(b_1). Design Mechanical and Physical Properties of 2024 Aluminum Alloy Sheet and Plate.

Specification	AMS 4037[a]					AMS 4269[a]		
Form	Sheet					Sheet		Plate
Temper	T3					T361		
Thickness, in.	0.008-0.009	0.010-0.128		0.129 - 0.249		0.020-0.062	0.063-0.249	0.250-0.500
Basis	S	A	B	A	B	S	S	S
Mechanical Properties:								
F_{tu}, ksi:								
L	64	64	65	64	66	68	69	67
LT	63	63	64	63	65	67	68	66
F_{ty}, ksi:								
L	47	47	48	47	48	56	56	54
LT	42	42	43	42	43	50	51	49
F_{cy}, ksi:								
L	39	39	40	39	40	47	48	46
LT	45	45	46	45	46	53	54	52
F_{su}[b], ksi	39	39	40	40	41	42	42	41
F_{bru}[b,c], ksi:								
(e/D = 1.5)	104	104	106	106	107	111	112	109
(e/D = 2.0)	129	129	131	131	133	137	139	135
F_{bry}[b,c], ksi:								
(e/D = 1.5)	73	73	75	73	75	82	84	81
(e/D = 2.0)	88	88	90	88	90	97	99	96
e, percent (S-Basis):								
LT	10	[d]	...	[d]	...	8	9	9[e]
E, 10^3 ksi	10.5							10.7
E_c, 10^3 ksi	10.7							10.9
G, 10^3 ksi	4.0							4.0
μ	0.33							0.33
Physical Properties:								
ω, lb/in.^{3}	0.100							
C, K	See Figure 3.2.4.0(a)							
a	See Figure 3.2.4.0(b)							

Table 8.1.3.1.2(d_2). Static Joint Strength of Blind Protruding Head Locked Spindle Aluminum Alloy Rivets in Aluminum Alloy Sheet

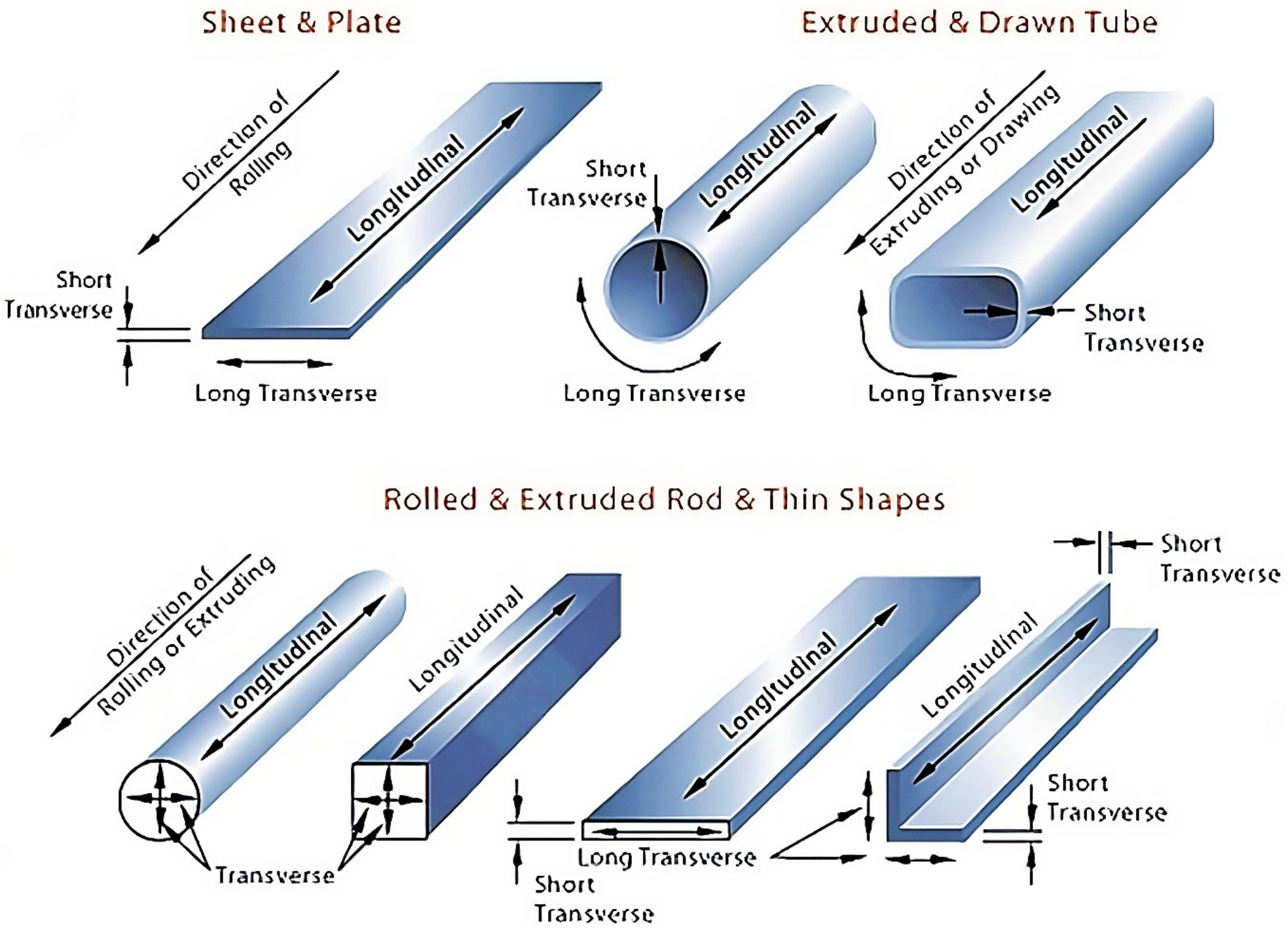
Rivet Type	NAS1738B and NAS1738E[a] (F_{su} = 34 ksi)		
Sheet Material	Clad 2024-T3		
Rivet Diameter, in. (Nominal Hole Diameter, in.)	1/8 (0.144)	5/32 (0.178)	3/16 (0.207)
	Ultimate Strength, lbs. (Estimated Lower Bound)		
Sheet thickness, in.:			
0.025	267	305[b]	330[b]
0.032	368	428	473[b]
0.040	427	567	636
0.050	480	650	815
0.063	547[c]	735	912
0.071	554[c]	785[c]	976
0.080	...	837[c]	1042[c]
0.090	...	...	1115[c]
0.100	...	...	1128[c]
Rivet shear strength[d]	554	837	1128
	Yield Strength[e], lbs. (Conservatively Adjusted Average)		
Sheet thickness, in.:			
0.020	185	213	228
0.025	242	285	317
0.032	298	386	433
0.040	321	453	568
0.050	336	489	625
0.063	336	508	680
0.071	336	508	684
0.080	...	508	684
0.090	...	...	684
0.100	...	...	684

Material grain direction

Longitudinal – L

Long transverse – LT

Short transverse – ST



Aluminum sheet materials

The most common sheet metal used in the aerospace industry is the aluminum alloy (7000 and 2000 series)

Condition: Sheet metals can be worked to obtain desired properties. The basic conditions are:

- **Annealed**: Refers to metal that are not heat treated. This is usually specified by a "-O", following the alloy code. Annealed parts can be formed into shapes more easily than heat treated parts

- **Wrought**: Metals that have been heat treated and quenched but have not reached their final stable condition. It is specified by a W" following the aluminum code

Sheet metal materials

Heat treated (Tempering): It refers to metals that have been reheated to a specified temperature, quenched and aged to a stable condition. Aluminum, steel and titanium each use different coding systems to specify the heat treatment.

The **-TXXX** code identifies the type of heat treatment applied to the part, the most common **types for aluminum** are:

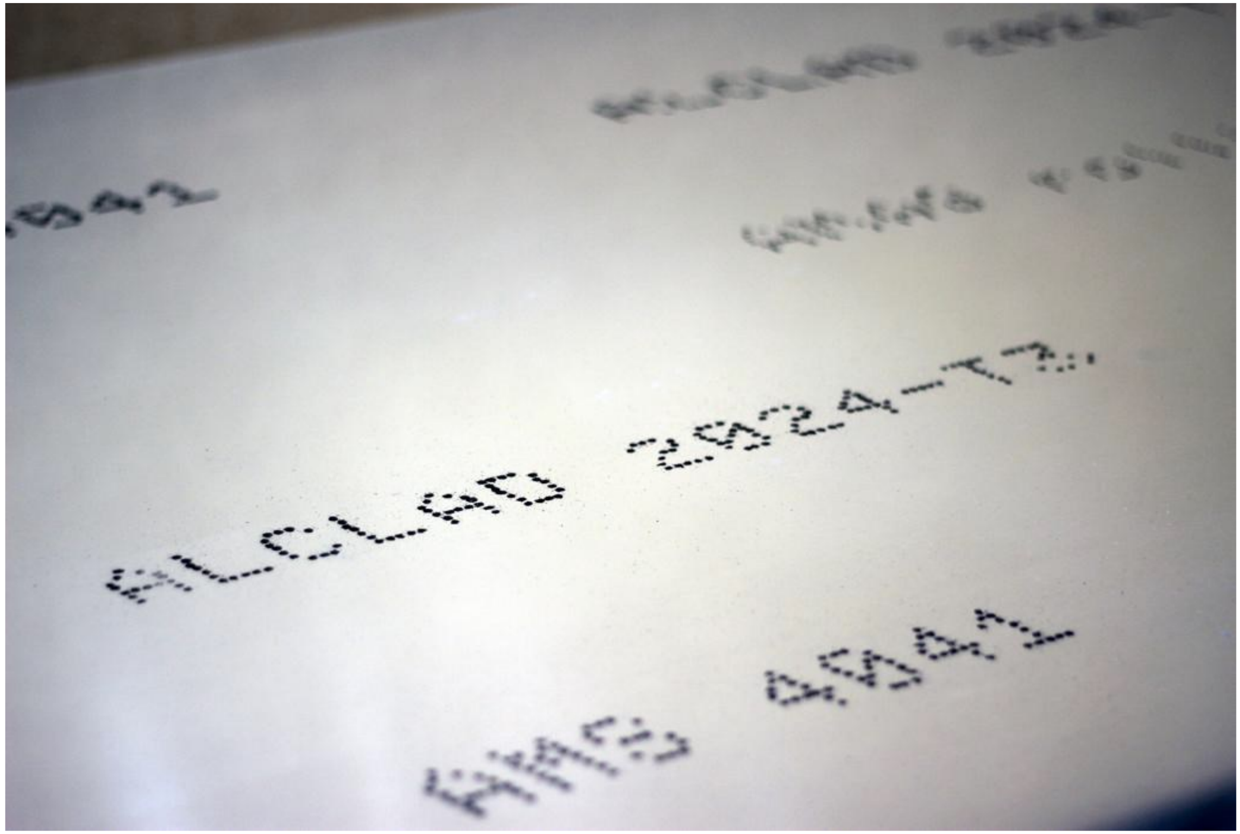
- **T3 Solution heat treated, naturally aged and cold worked**
- T4 Solution heat treated and naturally aged
- **T6 Solution heat treated and artificially aged**
- T73 Solution heat treated and artificially over aged

Other digits following the previous ones, are “2” for heat treatment after forming and “5” which indicates stress relieved

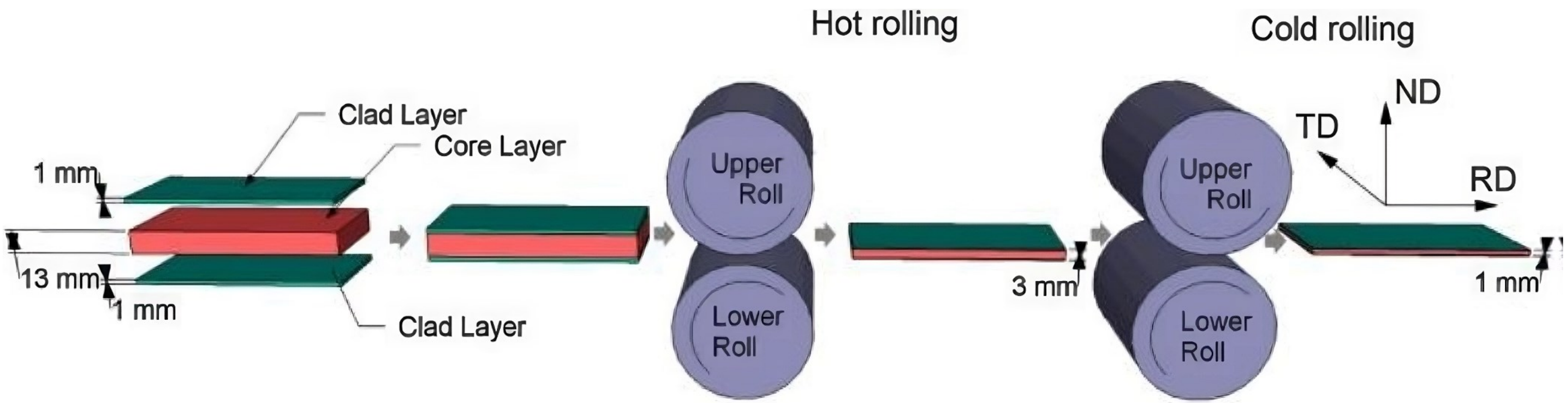
Sheet metal materials

The word **clad/Alclad** before sheet alloy identification shows that the sheet has a **thin layer of almost pure aluminum on it** to give maximum corrosion protection to the primary metal

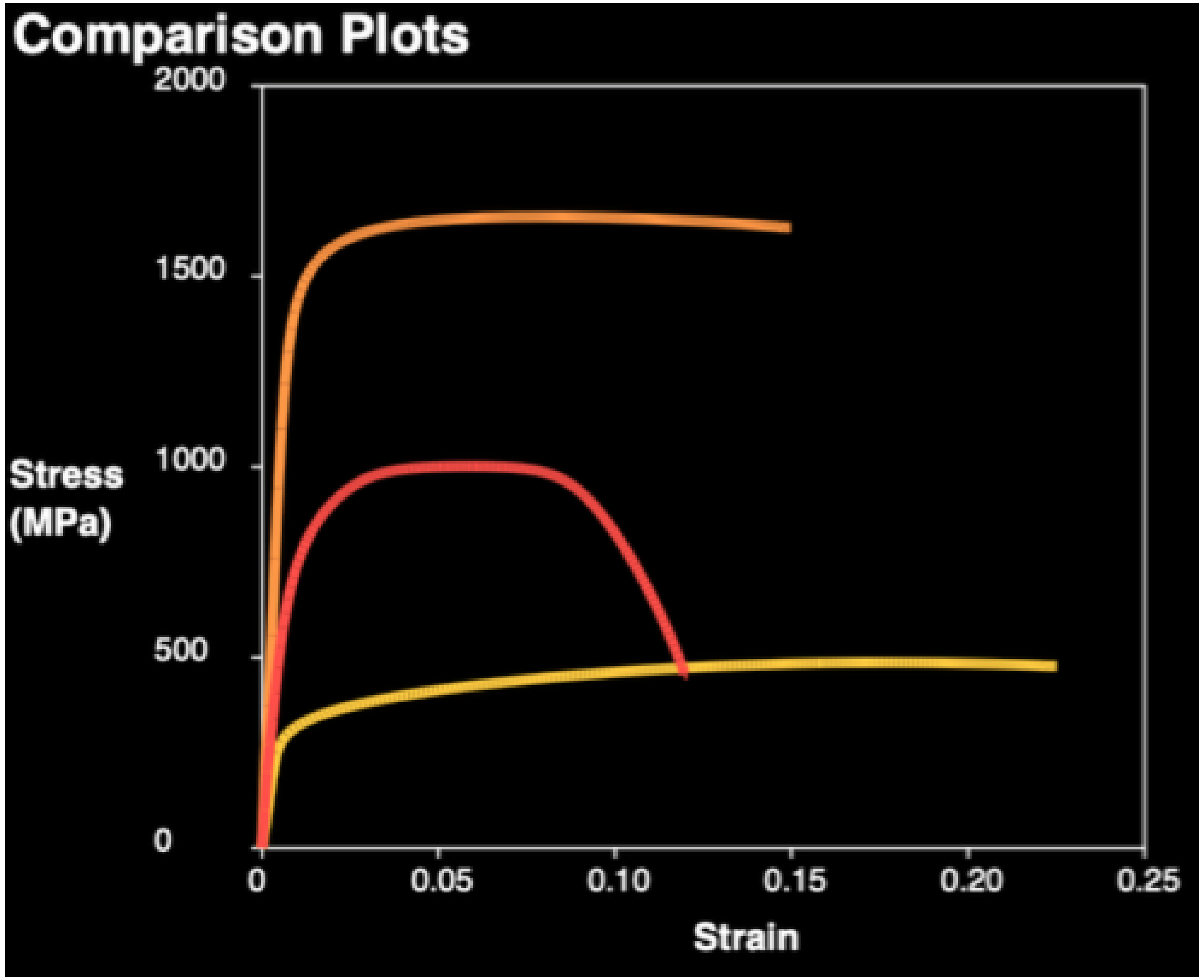
Nominal thickness of Clad changes from **2.5% to 5%** of the total thickness **per side** for different alloys and for their different thicknesses



Sheet metal materials



Exercise



Stress – Strain

Orange: Steel

Red: Ti

Yellow: Al

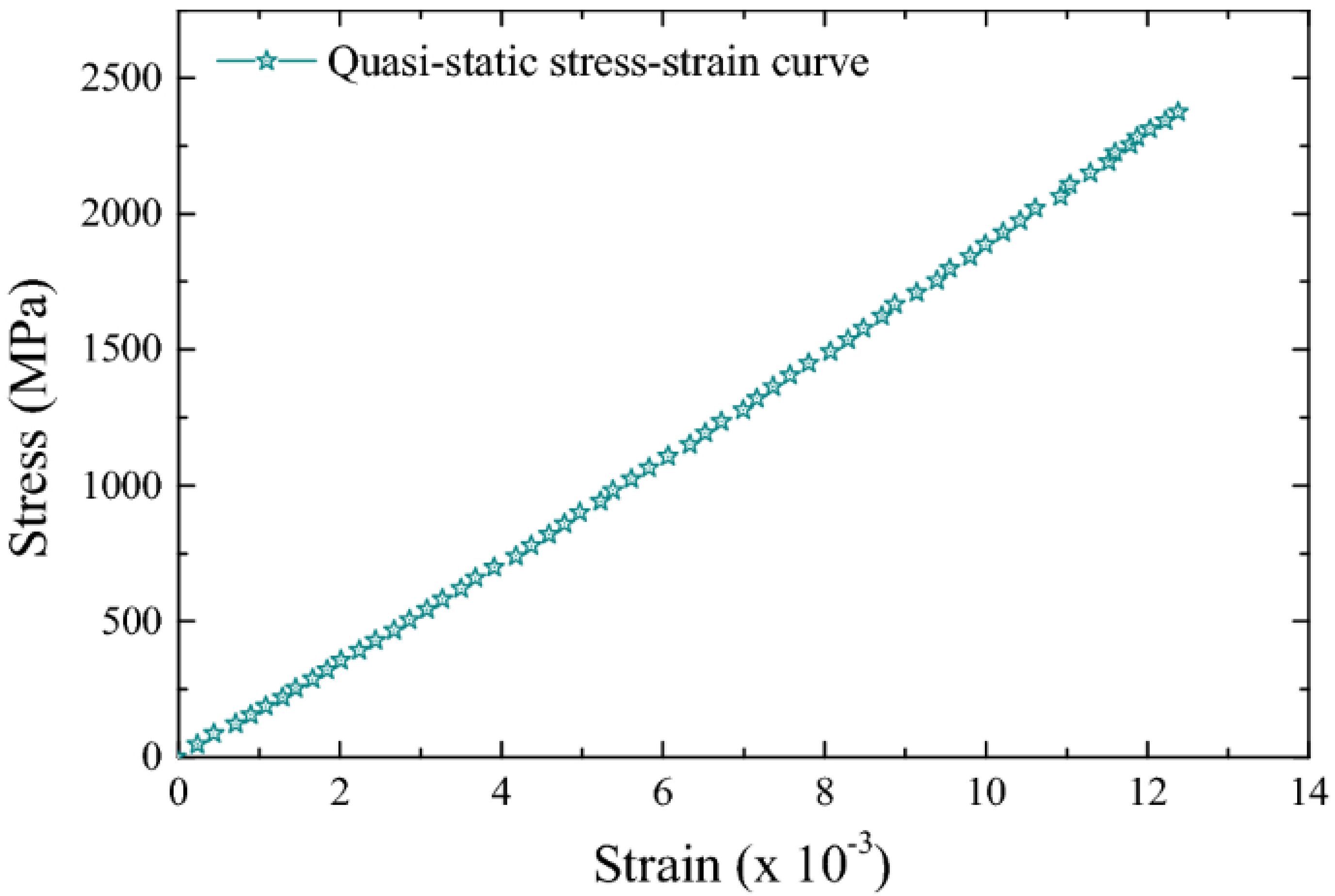
Melting points

Steel: 1425 – 1540 °C

Ti: 1668 °C

Al: 660.3 °C

Exercise



CFRP

Melting point ??

Work temperatures must not exceed 200 °C

Thermoset composites

Exercise

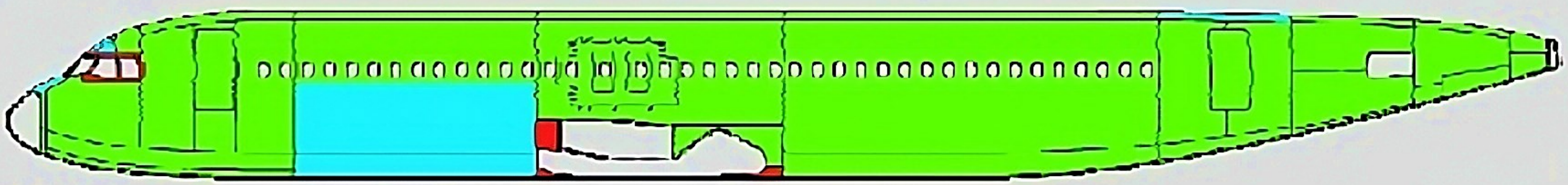
Choose the best material for the following applications:

1. Fan blades for subsonic aircraft
2. Skin panels for supersonic aircraft
3. High pressure turbine blades
4. Spacecraft heat shield for reentry
5. UH-60 HUB

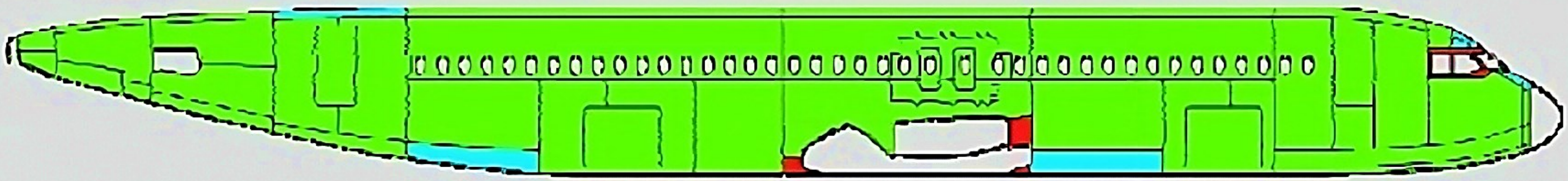
Briefly explain your material selection

SKIN PANELS

MATERIALS SUMMARY



SKIN A320



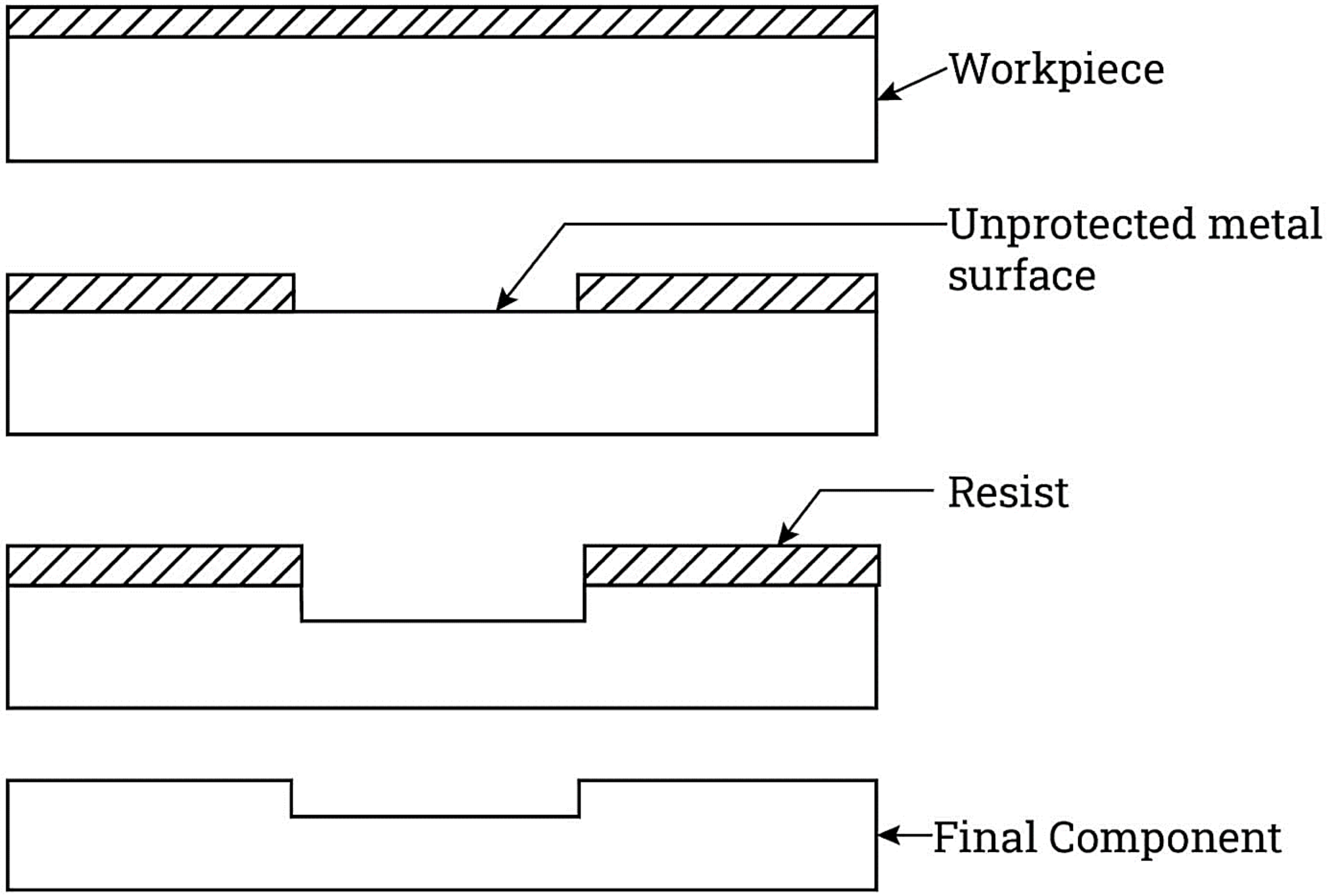
- Stretch - Formed or rolled plates
- Stretch - Formed or rolled plates chemically milled
- Integrally-machined parts

METALLIC MATERIALS

Skins			
- single curvature	sheet	2024	T3/T351C
- double curvature	sheet	2024	T42
- machined	plate	7075	T7351
Stringers			
	sheet	2024	T351
	extrusion	2024	T351X
Frames			
- standard	sheet	2024	T351/T42
- machined	plate	7010/7050	T73651
		2024	T351
		7075	T7351
		7175	T7351
FWD Bulkhead			
- skin	sheet	2024	T3
- stringers	extrusion	7175	T7310
Rear Bulkhead			
- frame	plate	7010/7050	T73651
- segments	sheet	2024	T42

Window frame	forging	7175	T73
Floor beams	extrusion	7050	T76511
		7175	T73511
Floor struts	extrusion	7075	T76511
Seat tracks	extrusion	7075	T76511
		7175	T6511
Windscreen frame	forging	7175	T73XX
	or plate	7010	T73651
		7175	T7351
NLG bay	plate	2024	T351
		7175	T7351
Keel beam elements	sheet	2024	T351
	extrusion	7050	T76511
	sheet	7475	T7611
THS actuator fitting	plate	7075	T7351
Vert. Stab. Attach. Fittings	forgings	7010/7050	T735

Chemical milling (or etching)



https://www.youtube.com/watch?v=2HR7qtbXM_4&ab_channel=PrecisionMicro

Titanium (Sheet metal materials)

Titanium alloy looks almost the same as CRES and is almost as strong. However, titanium alloy is approximately **56% the weight of steel**. Titanium is very resistant to atmospheric corrosion but it must be isolated from magnesium, aluminum, or alloy steel.

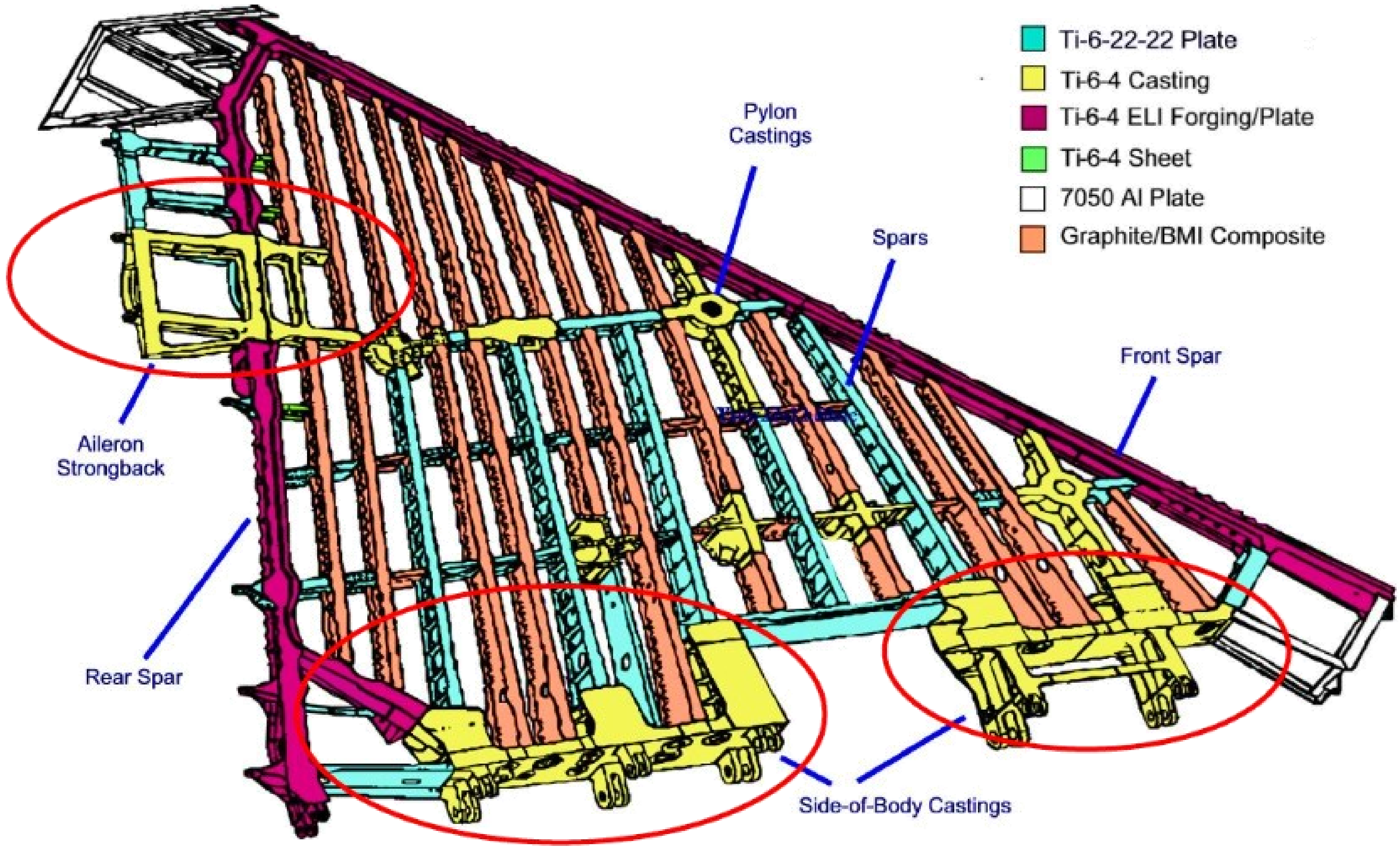
Some aircraft parts use formed 6 AL 4 V annealed titanium sheet

Titanium (Sheet metal materials)

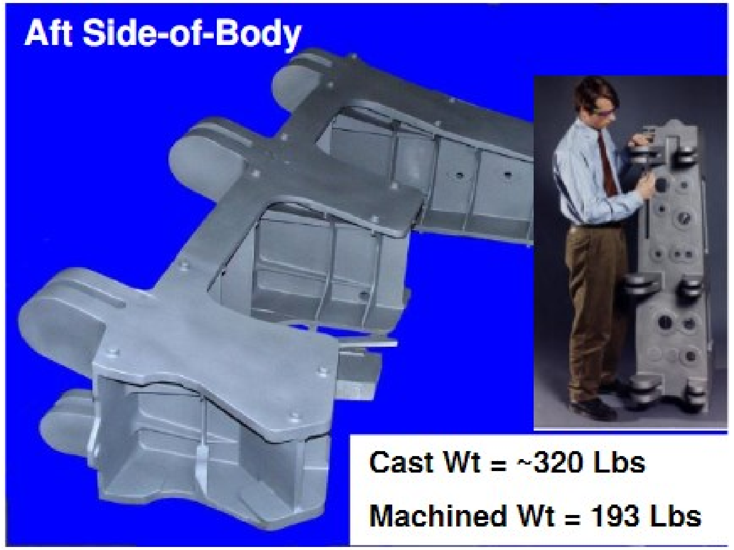
F22 Raptor, USAF

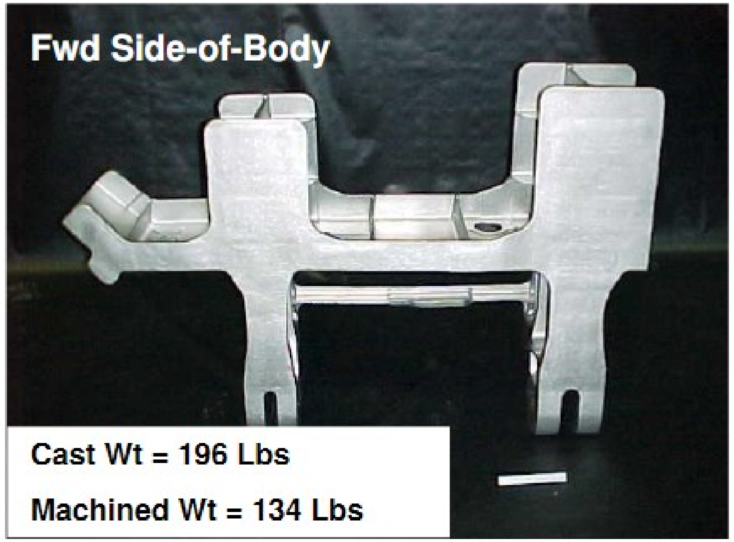
- Mid fuselage: 35% titanium
- Aft fuselage: 67% titanium
- Wings: 42% titanium

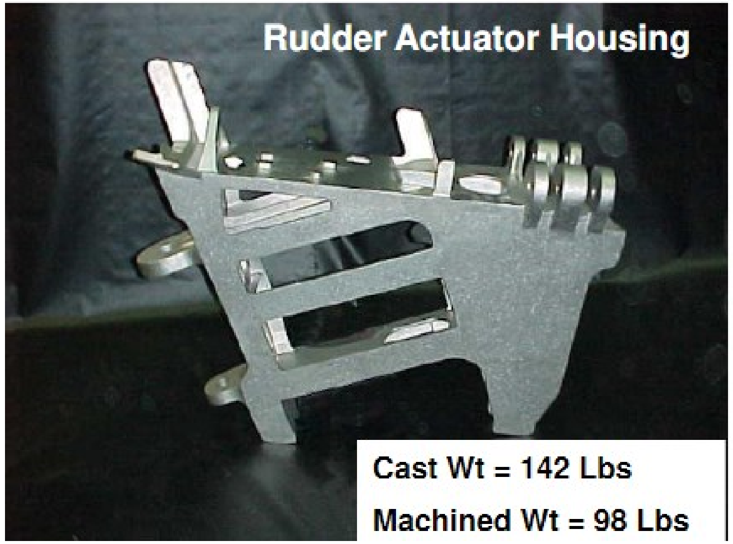
F-22 Wing Structural Arrangement



Titanium (F-22)

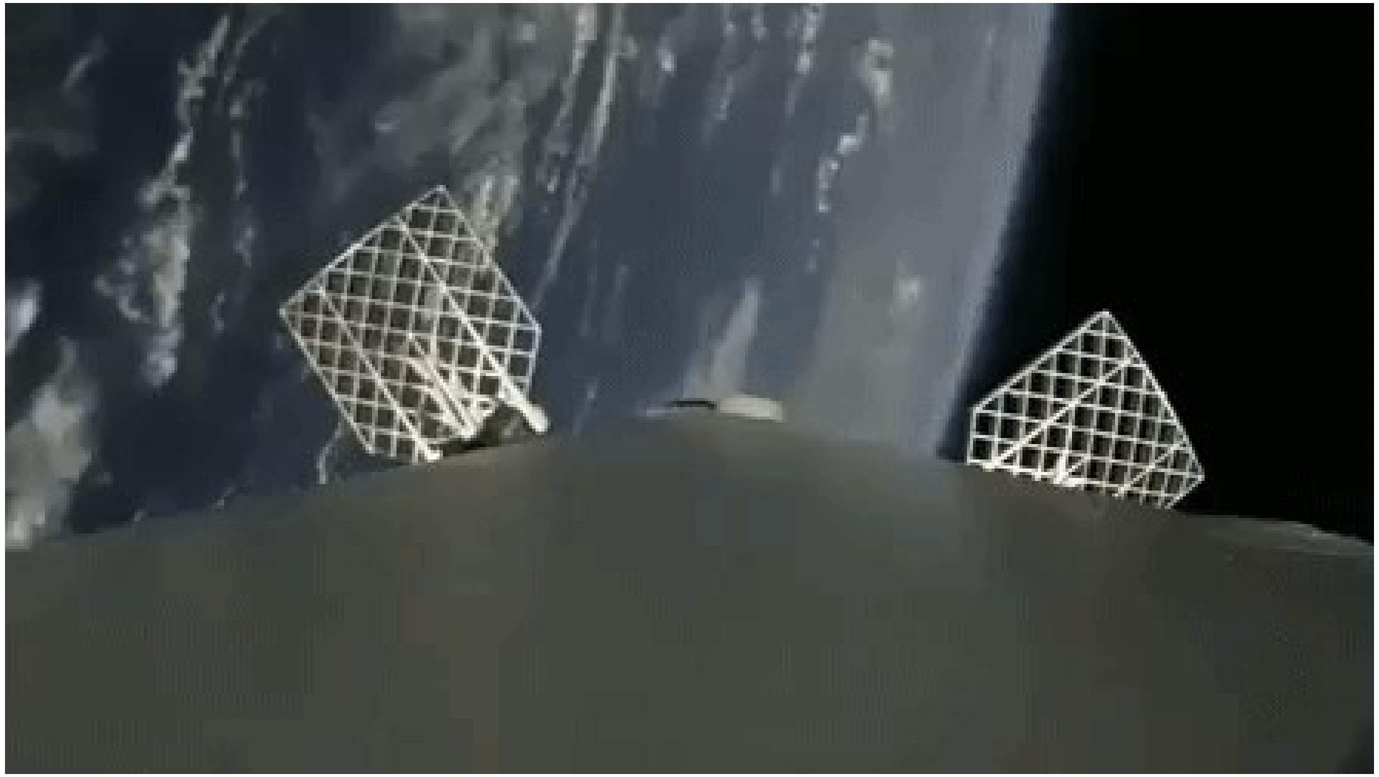






Titanium

SpaceX Falcon 9 Grid Fins

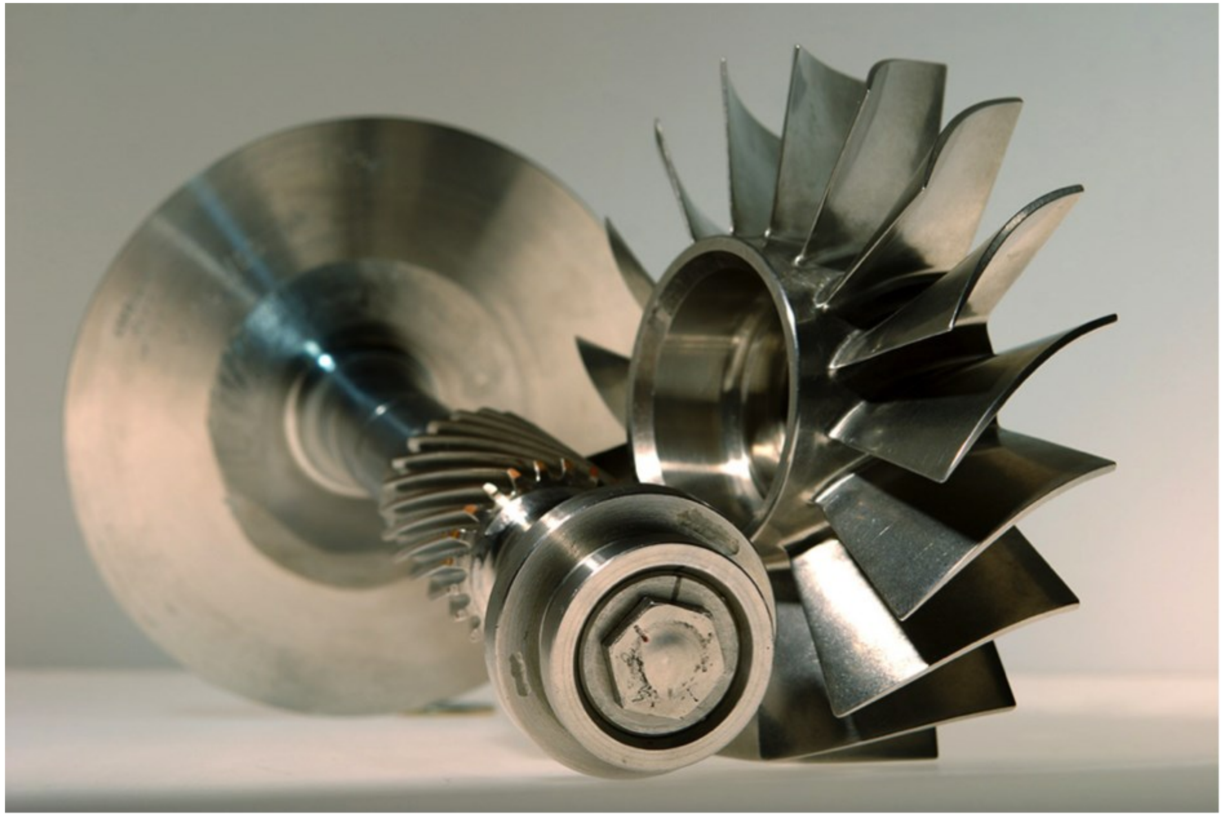


Titanium

The use of titanium is relatively new (1970-1980)

Titanium is a **lightweight, strong, corrosion resistant metal**. Recent developments make titanium ideal for applications where aluminum alloys are too weak and stainless steel is too heavy.

Additionally, titanium is unaffected by long exposure to seawater and marine atmosphere



Aluminum

Aluminum alloys are widely used in modern aircraft construction. Aluminum alloys are valuable because they have a high strength to weight ratio.

Aluminum alloys are corrosion resistant and comparatively easy to fabricate. **The outstanding characteristic of aluminum is its lightweight**.

Aluminum

Groups*

2000 series: **4.4 Cu – 0.6 Mg – 1.5 Mn**

6000 series: **0.6 Si – 1 Mg – 0.25 Cu – 0.2 Cr**

7000 series: **5.6 Zn – 2.5 Mg – 1.6 Cu – 0.23 Cr**

*Just a reference. Values may change depending the alloy

Steel

Corrosion resistant steel (CRES): sheet is used on some parts when high strength is necessary. CRES must be isolated from magnesium and aluminum

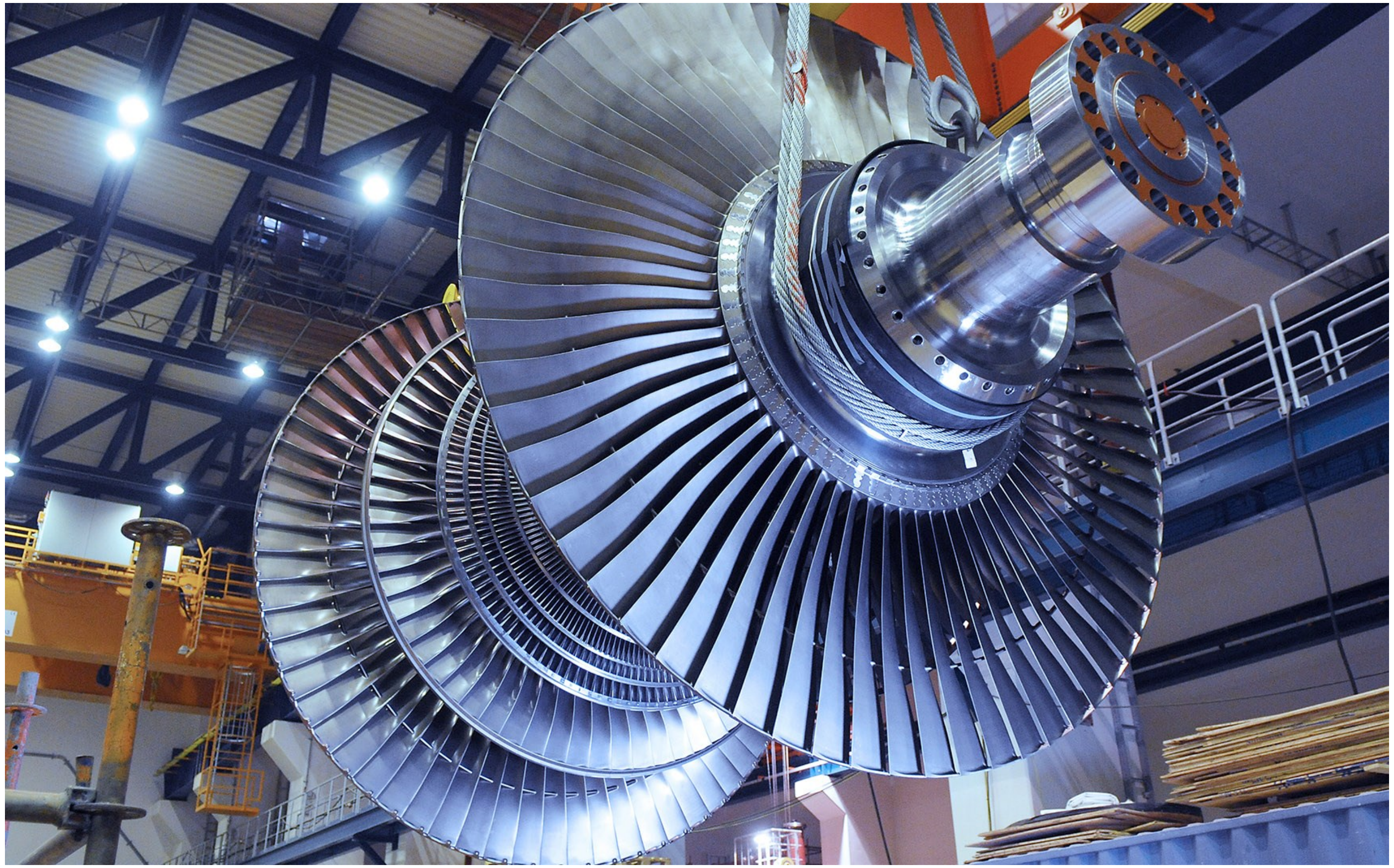
Steel

Alloy steels used in aircraft construction have **great strength** more so than other fields of engineering would require. These materials must withstand the forces that occur on today's modern aircraft

These steels contain small percentages of carbon, nickel, chromium, vanadium, and molybdenum

- 301 stainless steel austenitic
- Inconel aleación Ni Cr

Steel



Inconel material

Inconel alloy 625 and 718 are nickel chromium alloys. Those alloys are corrosion resistant and stays strong at high temperatures

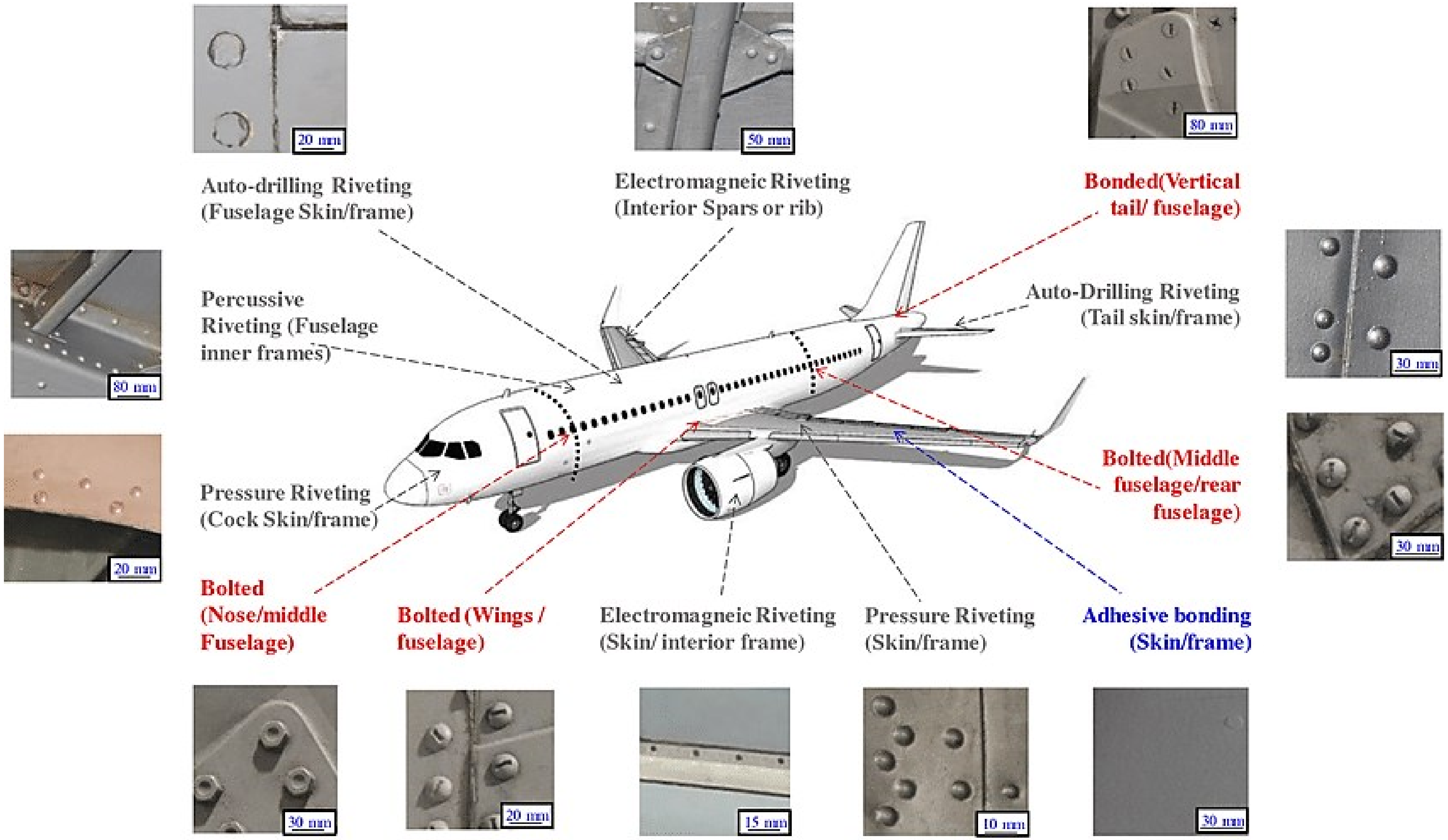
Structural joints

A complete aircraft is manufactured from many parts. **These parts must be joined together**

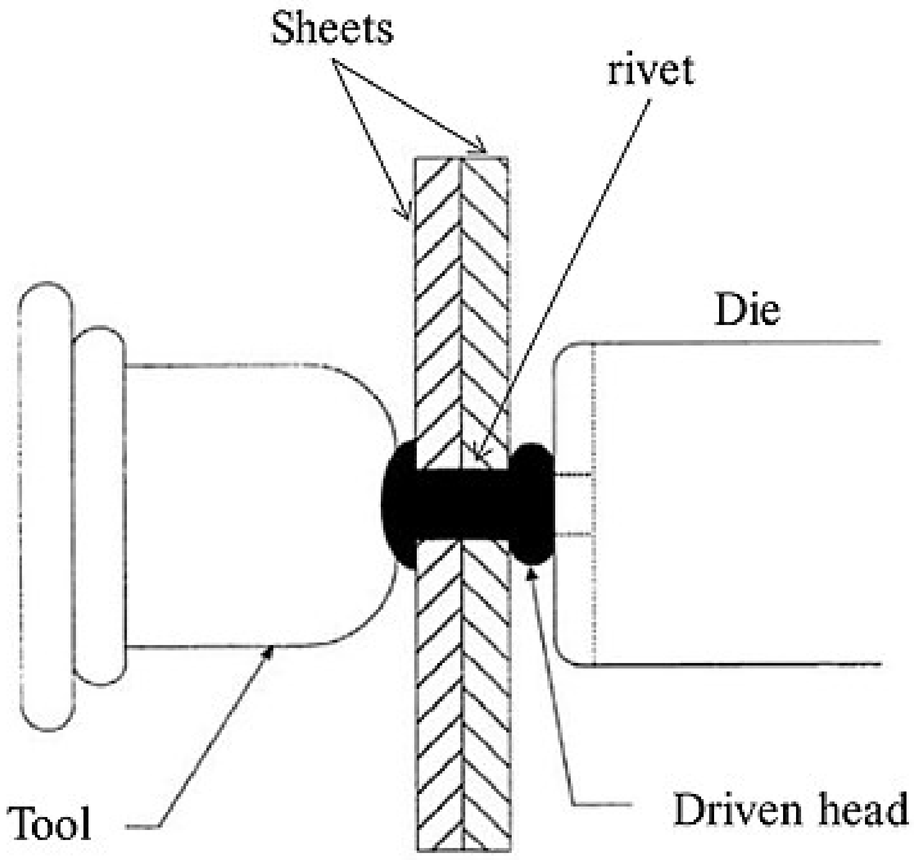
The subassemblies must then be joined together to form **larger assemblies** and then finally becoming a complete aircraft

Many parts of the aircraft must be disassembled for shipping repair, inspection or replacement

Structural joints



Structural joints



(b)

Primary Failure Modes

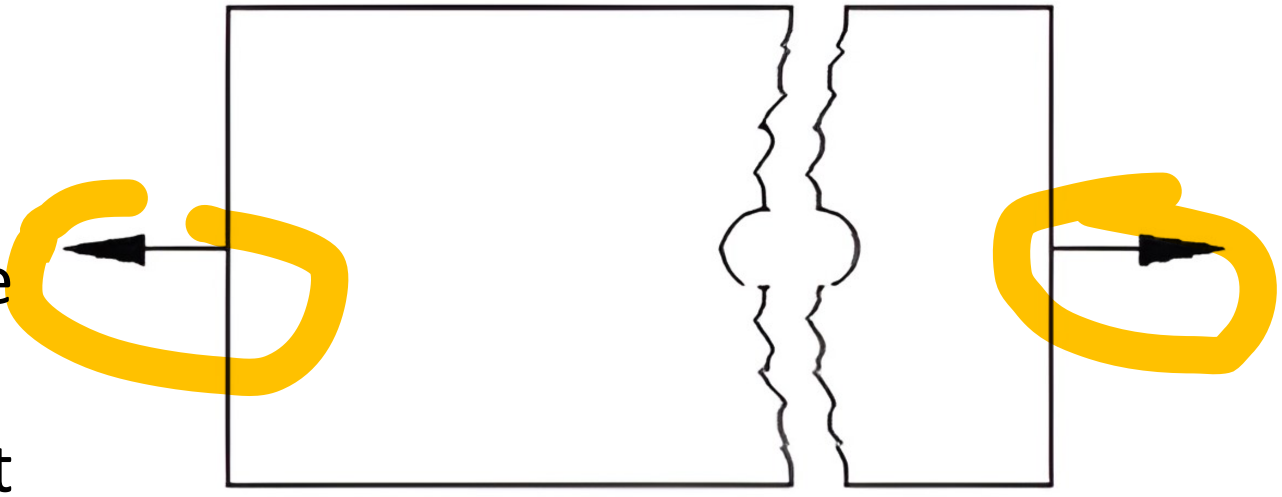
$$\sigma_{tu} = \frac{P_{tu}}{A_{net}}$$

A_{net} = $(W - nD)x\ thickness$

σ_{tu} = ultimate allowable tensile stress of plate

P_{tu} = tension load carried by net section

n = number of rivets



Net tension

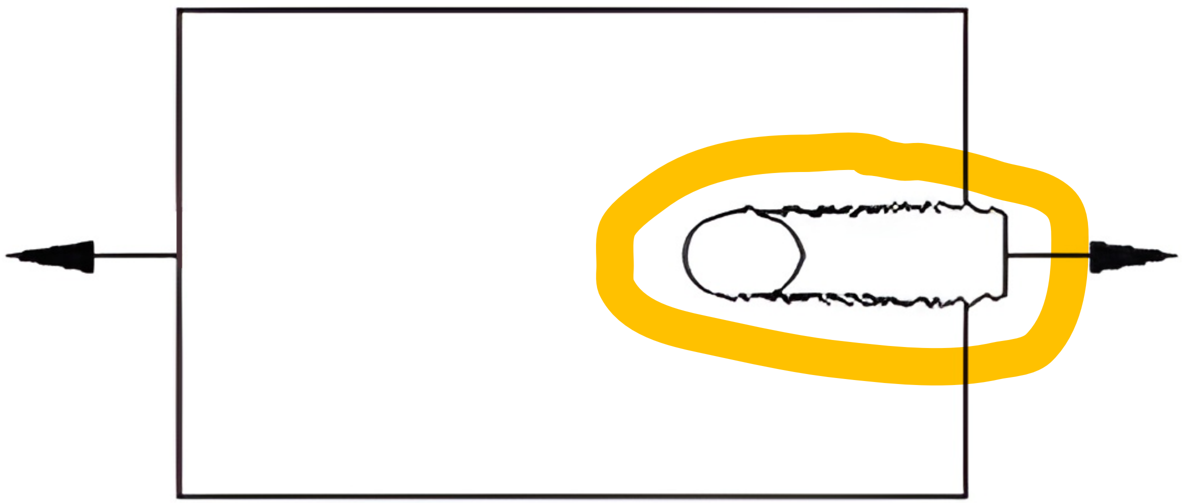
Primary Failure Modes

$$\tau_{su} = \frac{P_{su}}{2Lt}$$

τ_{su} = plate shear ultimate stress

L = edge margin minus radii

t = thickness



Shear-Out

Primary Failure Modes

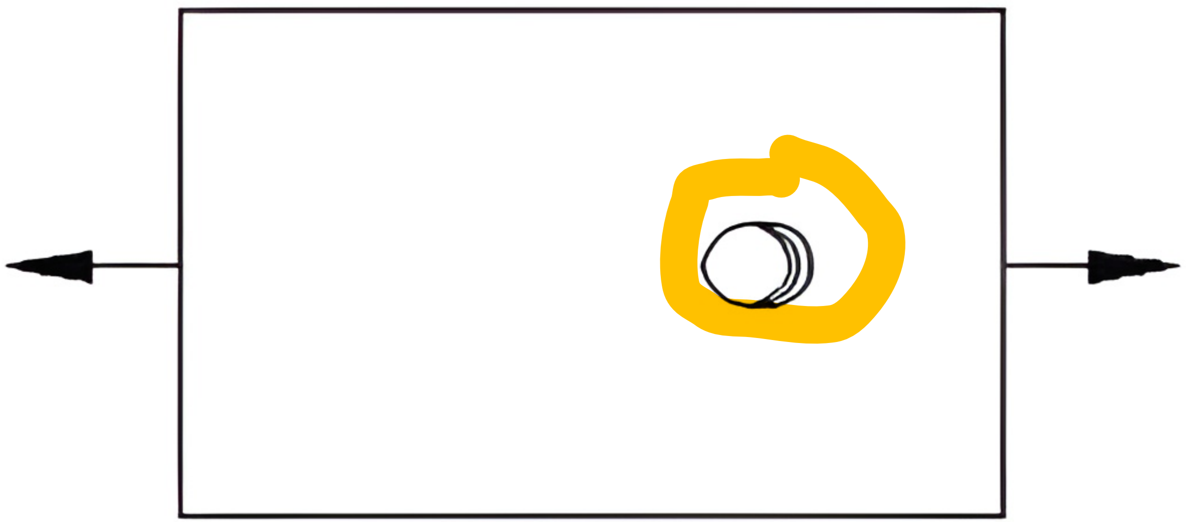
$$\sigma_{bru} = \frac{P_{bru}}{tnD}$$

t = thickness

D = hole diameter

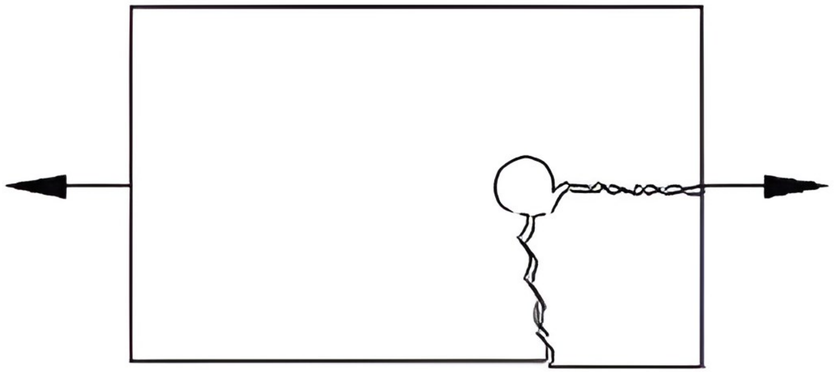
n = number of rivets

σ_{bru} = ultimate bearing stress of plate (compression)

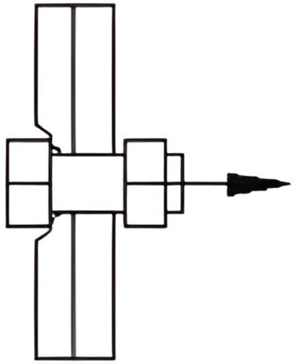


Bearing

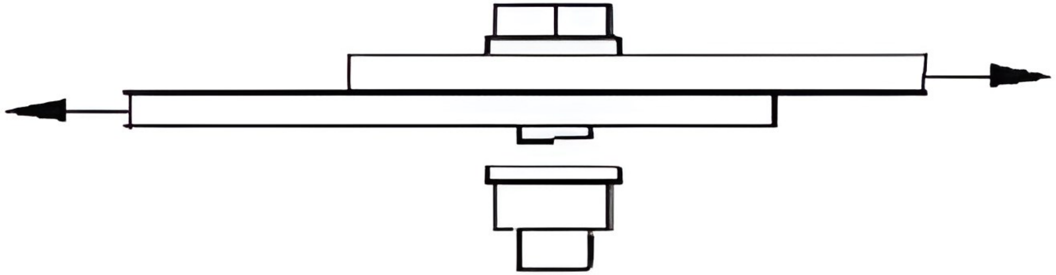
Another failure modes



Cleavage



Fastener Pull-Through



Fastener Failure

Structural Fasteners

Used to **join sheet metal structures**, they come in a variety of sizes and shapes

Many of them, **are specialized and specified to certain aircraft manufacturer**

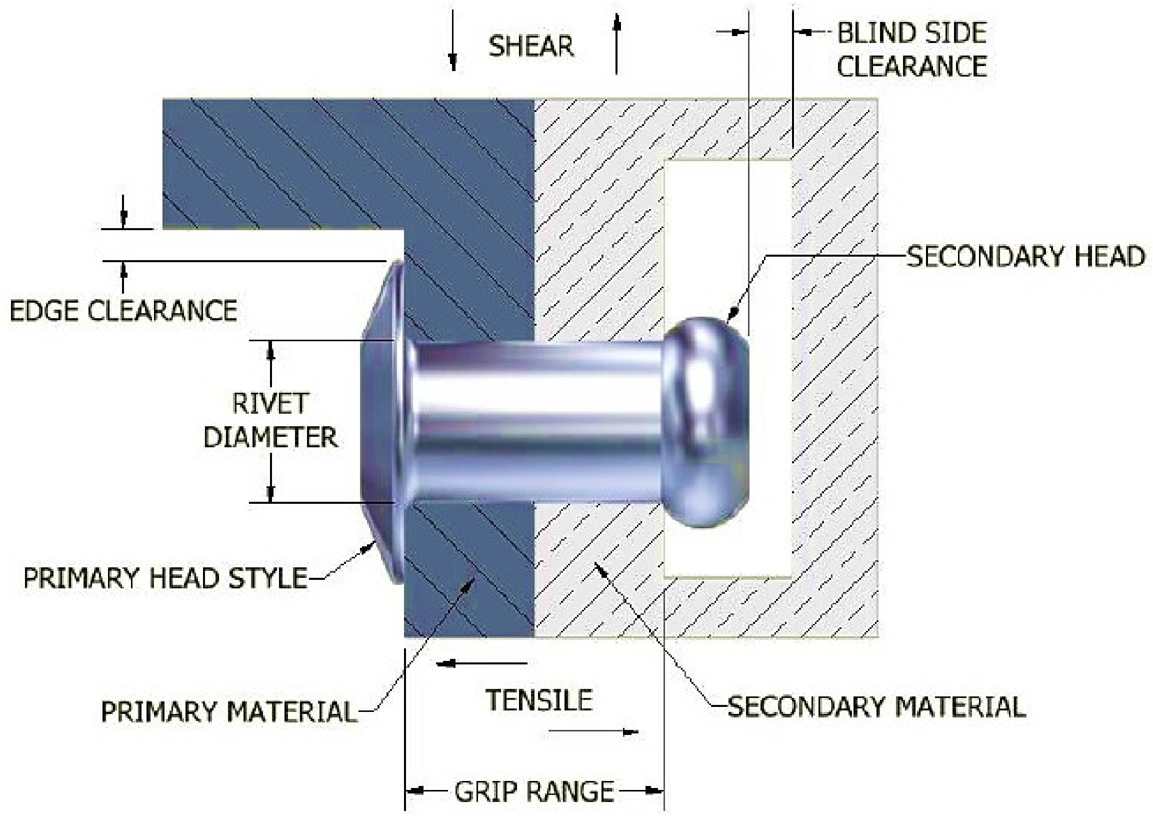
Fasteners are divided in two main groups: **Solid shank rivets** and **special purpose fasteners** that include blind rivets

Solid shank rivets

These are the most common type of rivet used in aircraft construction. Solid shank rivets are relatively low cost, permanently installed fasteners

They are faster to install than bolts and nuts

Rivets should not be used in thick materials or in tensile applications as their tensile strengths are quite low relative to shear their shear strength

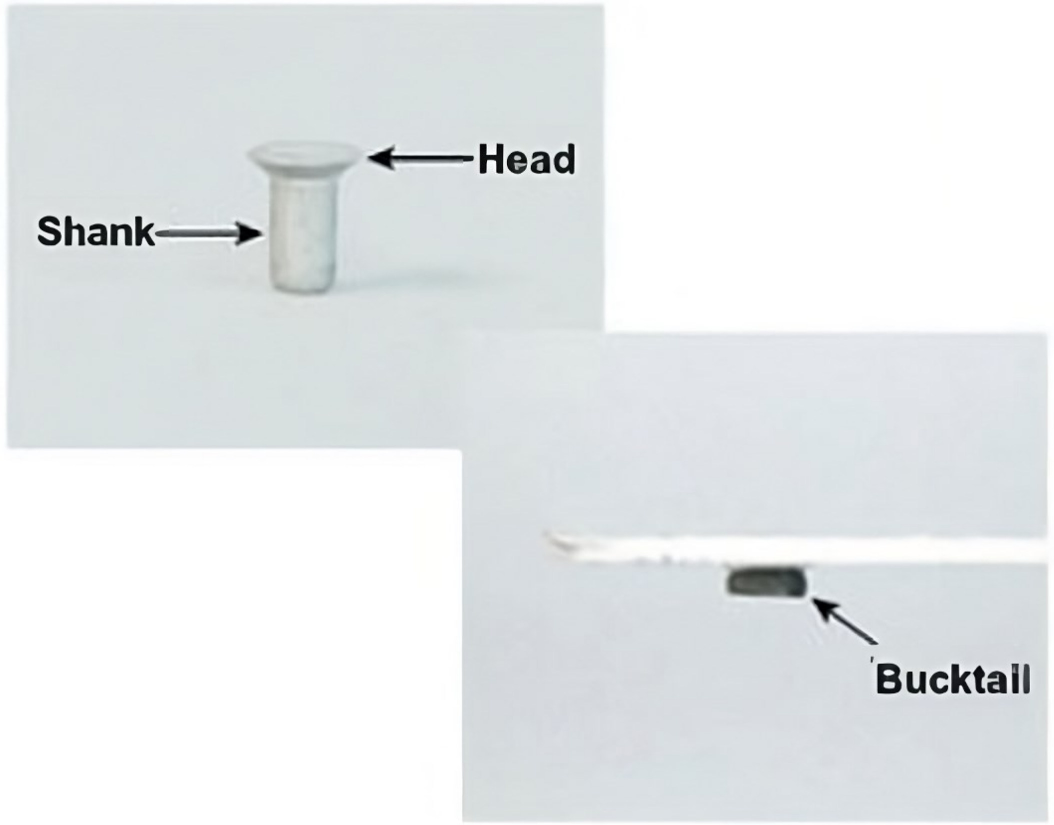


Solid shank rivets

The solid rivet consists of a **smooth cylindrical shaft** with a factory head on one end

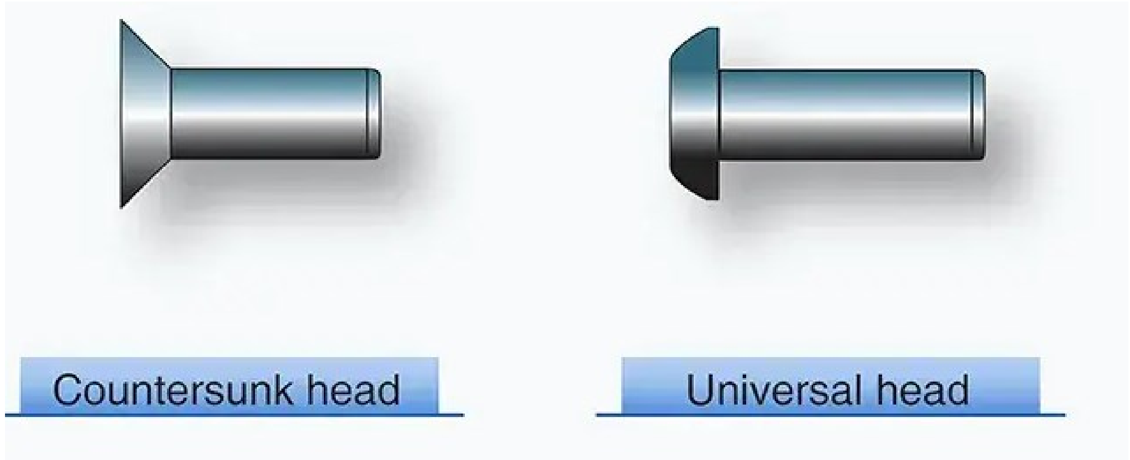
The opposite end is called the bucktail. To secure two sheet of metals together, the rivet is placed into a hole cut a bit larger in diameter than the rivet itself

Then, the bucktail is deformed mechanically with a pneumatic tool



Rivet head shape

The universal and the countersunk head are the most used in aircraft structures



Universal rivets

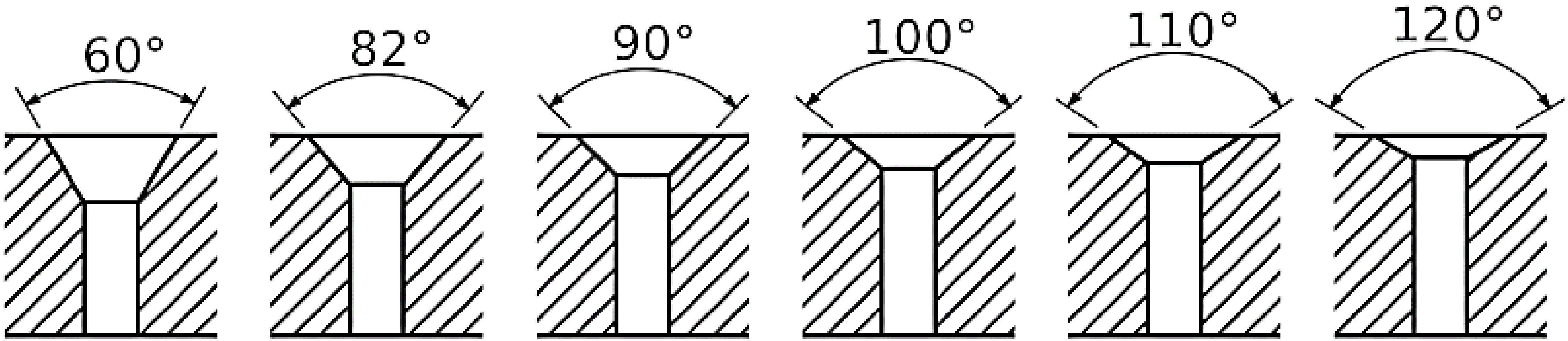
Universal rivets were developed specifically for the aircraft industry. These are used in non aerodynamic significant areas

The **head diameter** of the universal rivets is commonly **twice the shank diameter**

The head height is approximately 42% of the shank diameter

The countersunk rivet

The countersunk head angle can vary from 60° to 120° but the **100° has been adopted as standard**



The countersunk rivet

The 100° has the **best tension/shear** ratio and **flushness requirements**

This rivet is used **where flushes is required** because the rivet is flat-topped

The flat-topped form is made in order to allow the head to fit into a **countersunk or dimple hole**

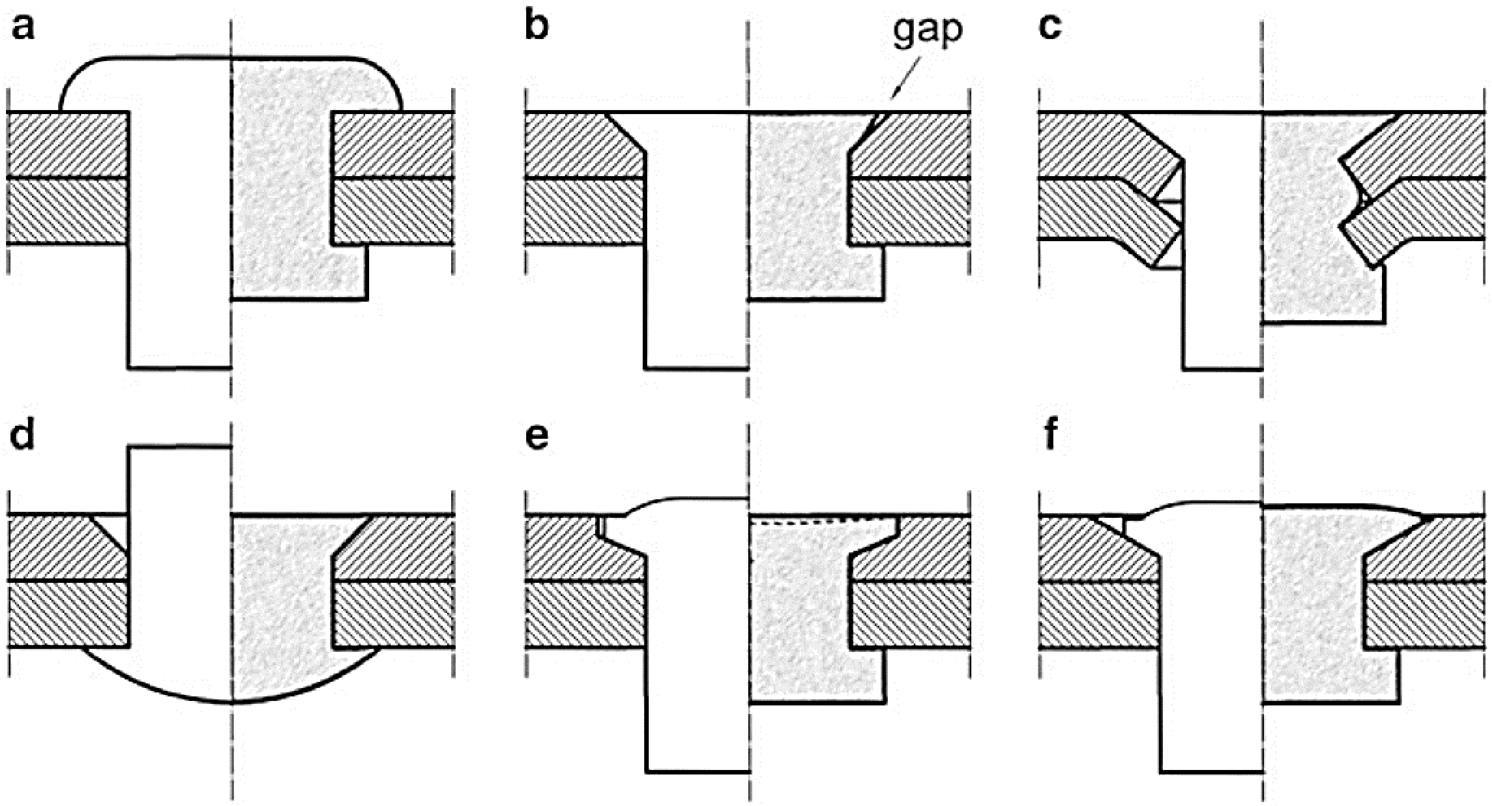
The countersunk rivet

One of the main goals of the countersunk rivets is the need of aerodynamic smoothness in critical sections

Riveting

Left side: before riveting

Right side: after riveting



Rivets

Typically rivets are fabricated from aluminum alloys such as:

- 2017 T-4
- 2024 T-7
- 2117 T-4
- 7075
- 5056

Others

- Titanium
- Nickel based alloys, such as Monel

It is important that an aircraft technician know the strength and different properties of several kinds of rivets and how to identify them

Standard categories

Military Standard MS (military standard preparation for and installation of rivets and screws, rocket, missile, and airframe structures, MIL STD 403 C), **MMPDS Metallic Materials Properties Development and Standardization, FAA, DOT**

- Manufacturer
- National Aerospace Standard NAS (Boeing)

The Boeing Company Drawing System for the plane model in the SRM uses a fastener symbol system as given in National Aerospace Standard NAS 523 and Boeing Detail Standard BACD 2074

Fastener categories

Solid Rivets — Solid rivets are defined as one piece fasteners installed by mechanically upsetting one end.

Blind Fasteners — Blind fasteners are usually multiple piece devices that can be installed in a joint which is accessible from one side only.

When a blind fastener is being installed, a self-contained mechanical, chemical, or other feature forms an upset on its inaccessible or blind side. **These fasteners must be destroyed to be removed**. This fastener category includes such fasteners as **blind rivets, blind bolts, etc**.

Fastener categories

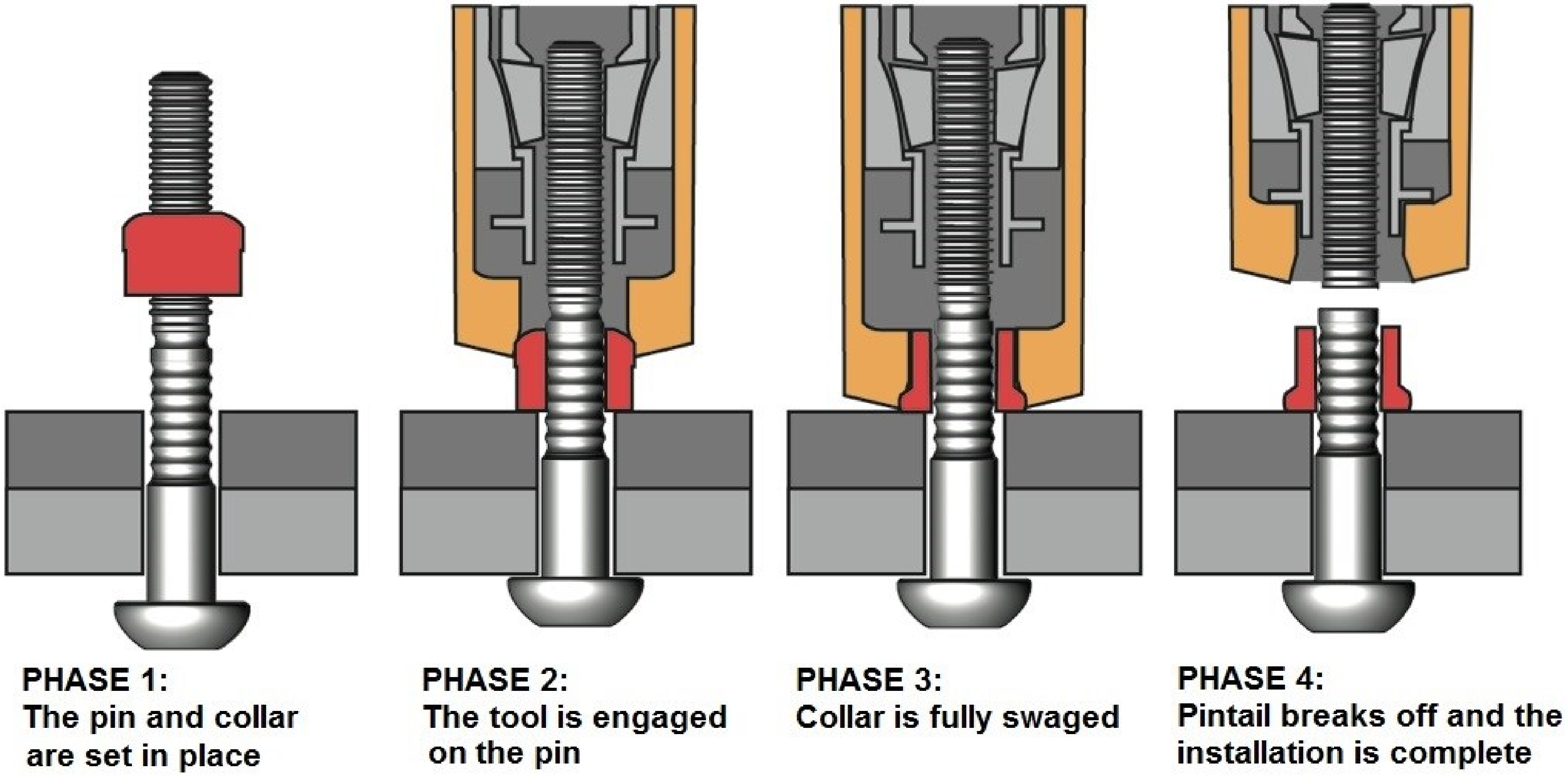
Fastener categories

Swaged Collar Fasteners — Swaged collar fasteners are multiple piece fasteners, usually consisting of a solid pin and a malleable collar which is swaged or formed onto the pin to clamp the joint.

This fastener usually is permanently installed. This fastener class includes such fasteners as “Hi-Shear” rivets, “Lockbolts”, and “Cherrybucks®”.

Hi-shear: https://www.youtube.com/watch?app=desktop&v=IAEAmcMbv5Q&ab_channel=WBuffington

Fastener categories



Fastener categories

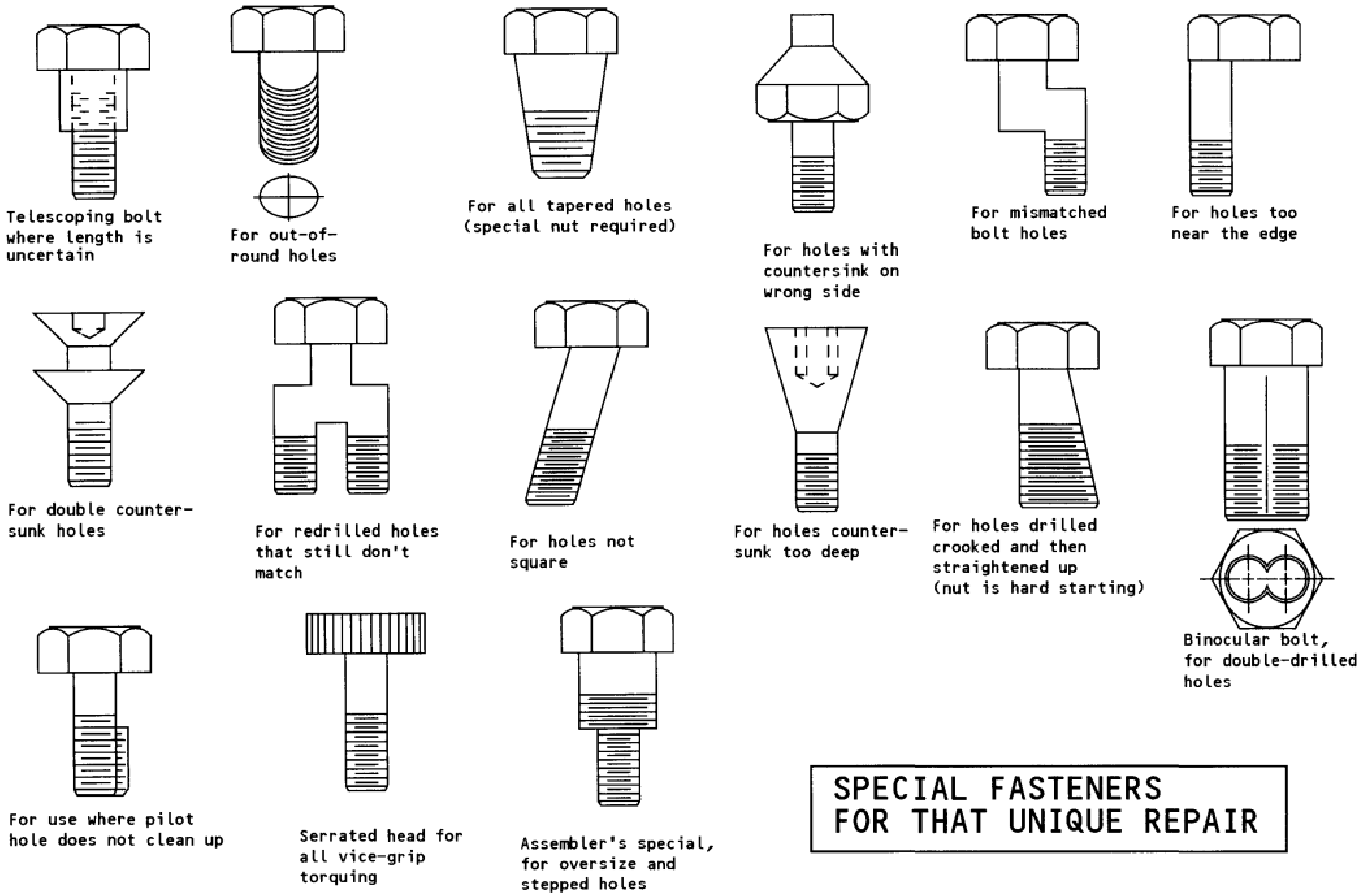
Threaded Fasteners — Fasteners in this category are considered to be any threaded part (or parts) that after assembly in a joint can be easily removed without damage to the fastener or to the material being joined.

This classification includes bolts, screws, and a wide assortment of proprietary fasteners

Fastener categories

Special Fasteners — As the name implies, this category of fastener is less commonly used in primary aircraft structure than the four categories listed above.

Examples of such fastening systems are sleeves, inserts, panel fasteners, etc.



FASTENERS—PERMANENT AND REMOVABLE

Fastener categories

Boeing 787 SRM

Table 1 Rivets

TYPE	ORIGINAL FASTENER	OVERSIZE FASTENER	
	PART NUMBER	PART NUMBER	NOMINAL OVERSIZE
SOLID SHANK UNIVERSAL HEAD	BACR15BB( )AD( )C MS20470AD	BACR15ET( )AD( )C OR BACR15BB( )AD( )C	1/32 (0.0312)
	BACR15BB( )B( )C MS20470B	BACR15ET( )B( )C	1/32 (0.0312)
	BACR15BB( )D( )C MS20470D	BACR15ET( )D( )C OR BACR15BB( )D( )C	1/32 (0.0312)
	BACR15BB( )DD( )C MS20470DD	BACR15ET( )DD OR BACR15BB( )DD	1/32 (0.0312)
	BACR15BB( )KE( )C MS20470E	BACR15BB( )KE( )C	1/32 (0.0312)
SOLID SHANK FLUSH HEAD	BACR15BA( )AD( )C MS20426AD	BACR15BA( )AD( )C	1/32 (0.0312)
	BACR15BA( )B( )C MS20426B	BACR15BA( )B( )C	1/32 (0.0312)
	BACR15BA( )D( )C MS20426D	BACR15BA( )D( )	1/32 (0.0312)
	BACR15BA( )DD( )C MS20426DD	BACR15BA( )DD	1/32 (0.0312)
	BACR15BA( )KE( )C MS20426E	BACR15BA( )KE( )C	1/32 (0.0312)
	BACR15CE( )D( )C	BACR15DS( )D( )C OR BACR15EA( )D( )C	1/32 (0.0312) 3/64 (0.0468)
	BACR15CE( )KE( )C	BACR15DS( )KE( )C	1/32 (0.0312)
	BACR15CE( )M	BACR15DS( )M	1/32 (0.0312)

Airbus A321 SRM

FASTENER IDENTIFICATION								
STANDARD PARTNUMBER	CALLUP AND DESIGN. 51-40-12 Fig. No.	TYPE	FORM	MAT./ PROT.	LUBRICATION	REMARKS	DIA	LEADER PARTNUMBER
2TCCC**	75	COLLAR Swaged	Cylin- drical/ Tension	AI 2024/ S.A.A.	Cetyl Alocohol		N	ABS0270-**
2TCCM**EC		COLLAR Swaged	Cylin- drical/ Tension	Monel None	Dry Film		N	ASNA2044-*
2TL300-*-*	112	TAPER-LOK	CSK Tension	ST/ Cadmium	Cetyl Alcohol	Old designation	N	TL300-*-* NSA5484-*-*N <4>
2TL300-*-*N	112	TAPER-LOK	CSK Tension	ST/ Cadmium	None	Old designation	N	TL300-*-* NSA5484-*-*N <4>
2TL310-*-*	112	TAPER-LOK	CSK Tension	ST/ Cadmium	Cetyl Alcohol	Old designation	1st O/S	TL310-*-*
2TL310-*-*N	112	TAPER-LOK	CSK Tension	ST/ Cadmium	None	Old designation	1st O/S	TL310-*-*
2TL400-*-*	113	TAPER-LOK	UNIV Tension High	ST/ Cadmium	Cetyl Alcohol	Old designation	N	TL400-*-* NSA5485-*-*N <4>
2TL400-*-*N	113	TAPER-LOK	UNIV Tension High	ST/ Cadmium	None	Old designation	N	TL400-*-* NSA5485-*-*N <4>
2TL410-*-*	113	TAPER-LOK	UNIV Tension High	ST/ Cadmium	Cetyl Alcohol	Old designation	1st O/S	TL410-*-*
2TL410-*-*N	113	TAPER-LOK	UNIV Tension High	ST/ Cadmium	None	Old designation	1st O/S	TL410-*-*
2TL945-*-*	112	TAPER-LOK	CSK Special Shear	ST/ Cadmium	Cetyl Alcohol	Old designation	N	ABS1418-*-*

Fasteners - Alphanumerical List

Table 3

Solid rivets, general preparation

The size of the selected rivet shank should correspond in general to the thickness of the material being riveted

If an **excessively large rivet** is used in a thin material, the force necessary to drive the rivet properly causes an **undesirable bulging around the rivet head**

If an **excessively small rivet** diameter is selected for thick material, the **shear strength of the rivet is not great enough** to carry the load of the joint

Solid rivets, general

Whenever possible, **select rivets of the same alloy number as the material being riveted**

For example, use 1100 and 3003 rivets on parts fabricated from 1100 and 3003 alloys, and 2117-1 and 2017-T rivets on parts fabricated from 2017 and 2024 alloys

Installation of rivets (Repair layout)

Repair layout involves:

- Determining **the number of rivets** required

- The **proper size and style of rivets** to be used, their **material**, **temper** condition and **strength**, the **size of the holes**

- The distances between the holes, and the distance between the holes and the edges of the patch (edge margin)

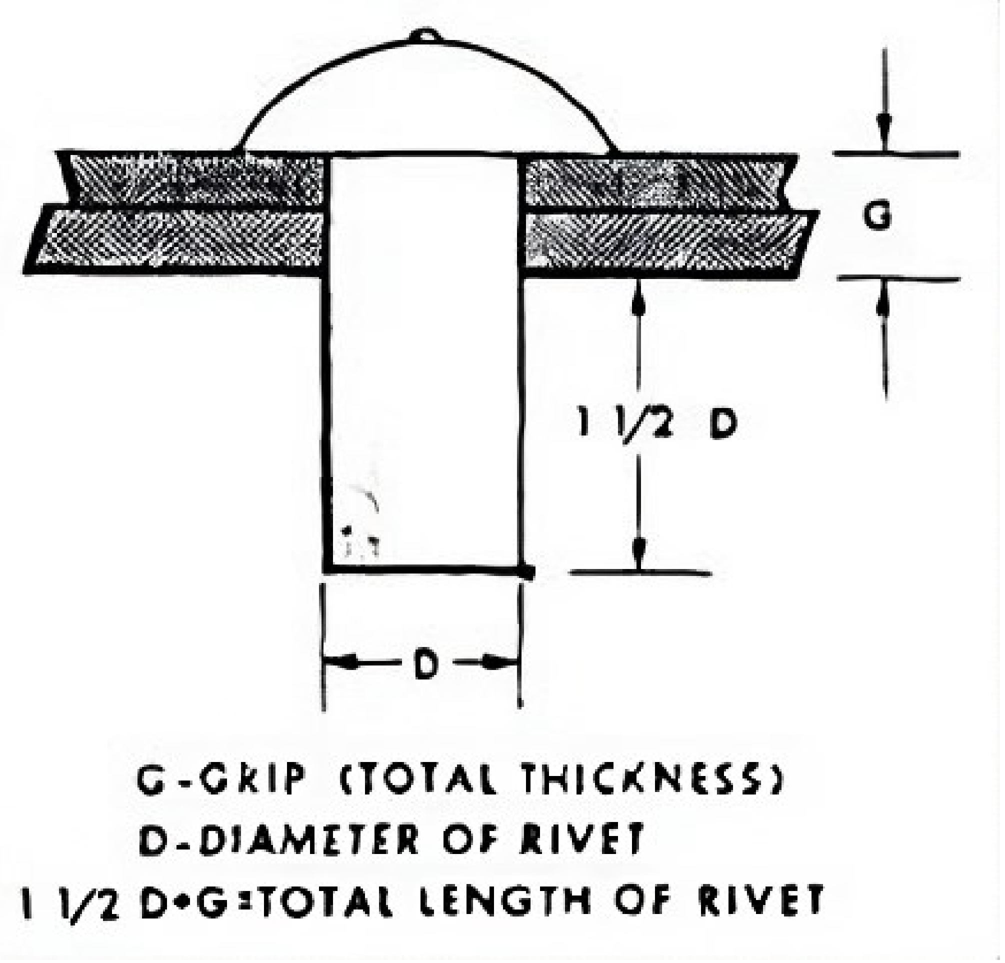
¡Distances are measured in terms of rivet diameter!

Rivet length

To determine the total length A of a rivet:

The combined thickness of the materials to be joined must first be known. This measurement is known as the grip length G

The amount of rivet shank needed to form a proper **shop head** D, usually $1\,{}^{1}/_{2}$ times the diameter of the rivet shank



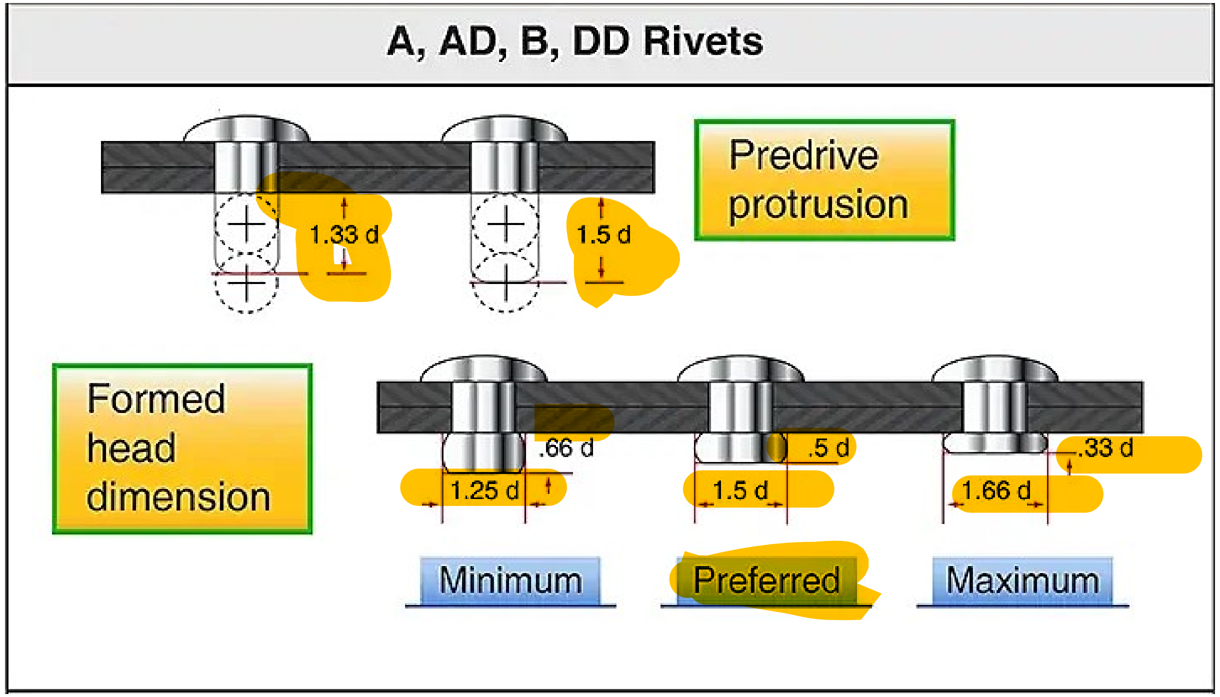
Rivet strength

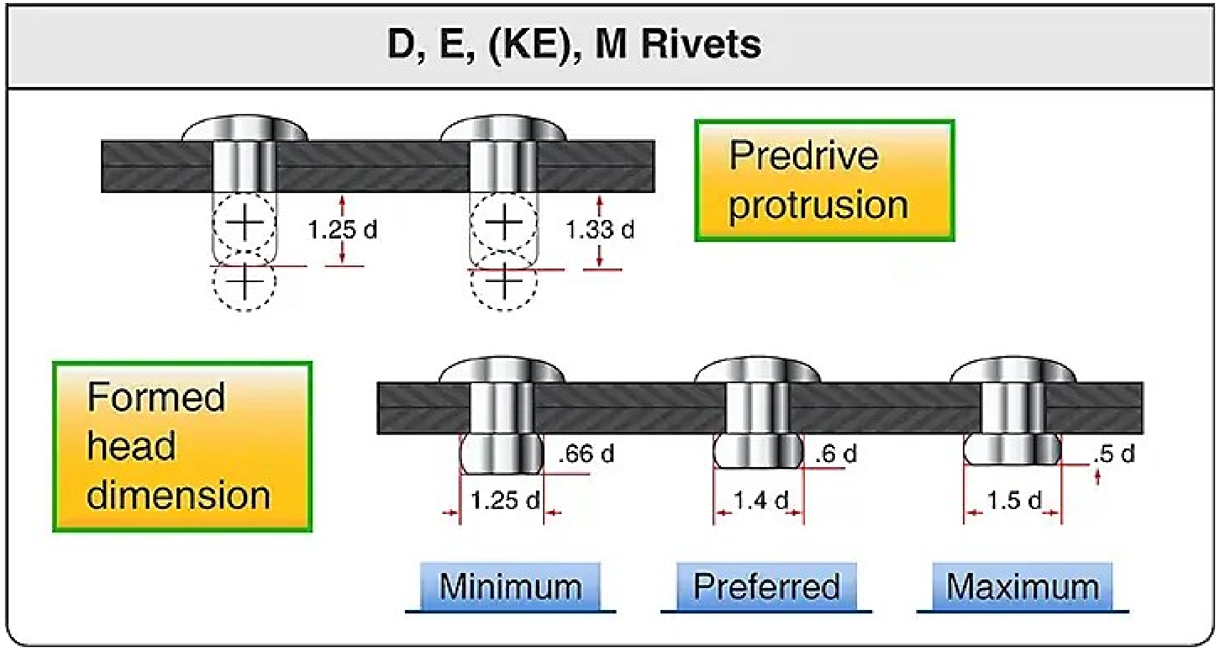
Rivets made of material that is lower in strength should not be used as replacements unless the drawback is balanced with a higher diameter **(this is not recommended in aircraft applications)**

The 2117 T rivet is commonly used for general repair work (Corrosion resistant, high shear strength, relatively soft)

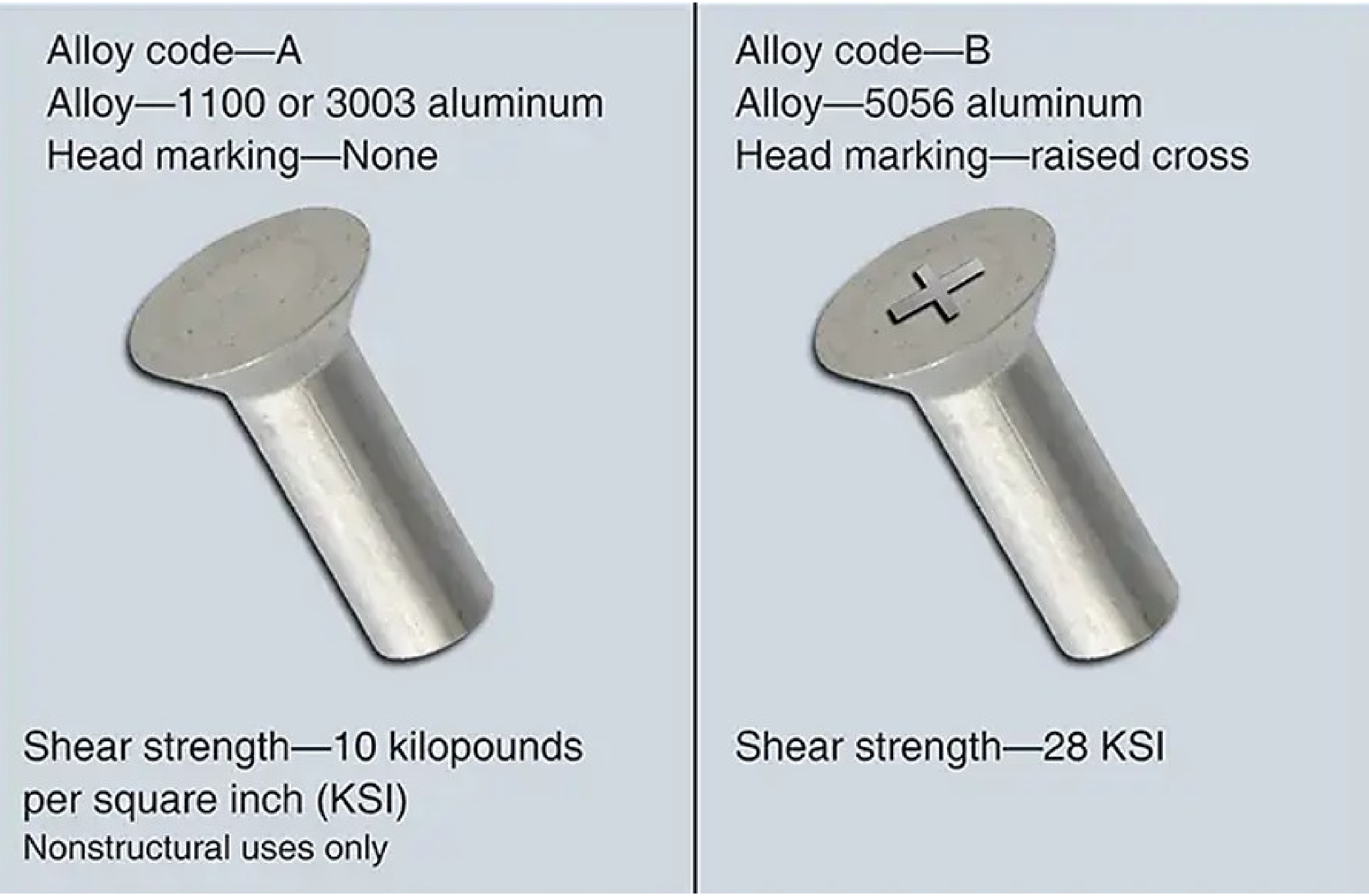
Always consult the SRM for correct rivet type, allowable zones, and materials

Driven rivet standards

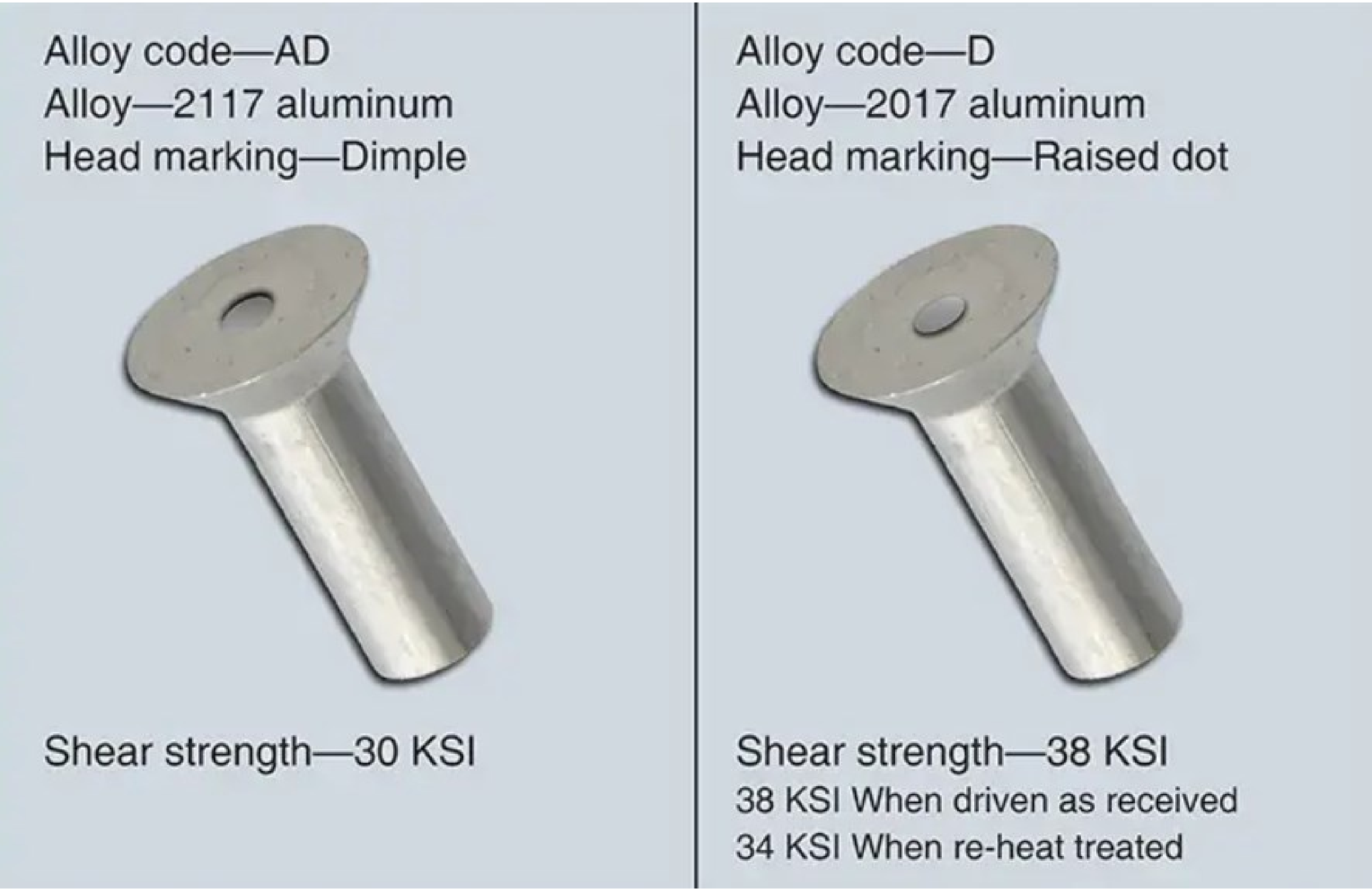




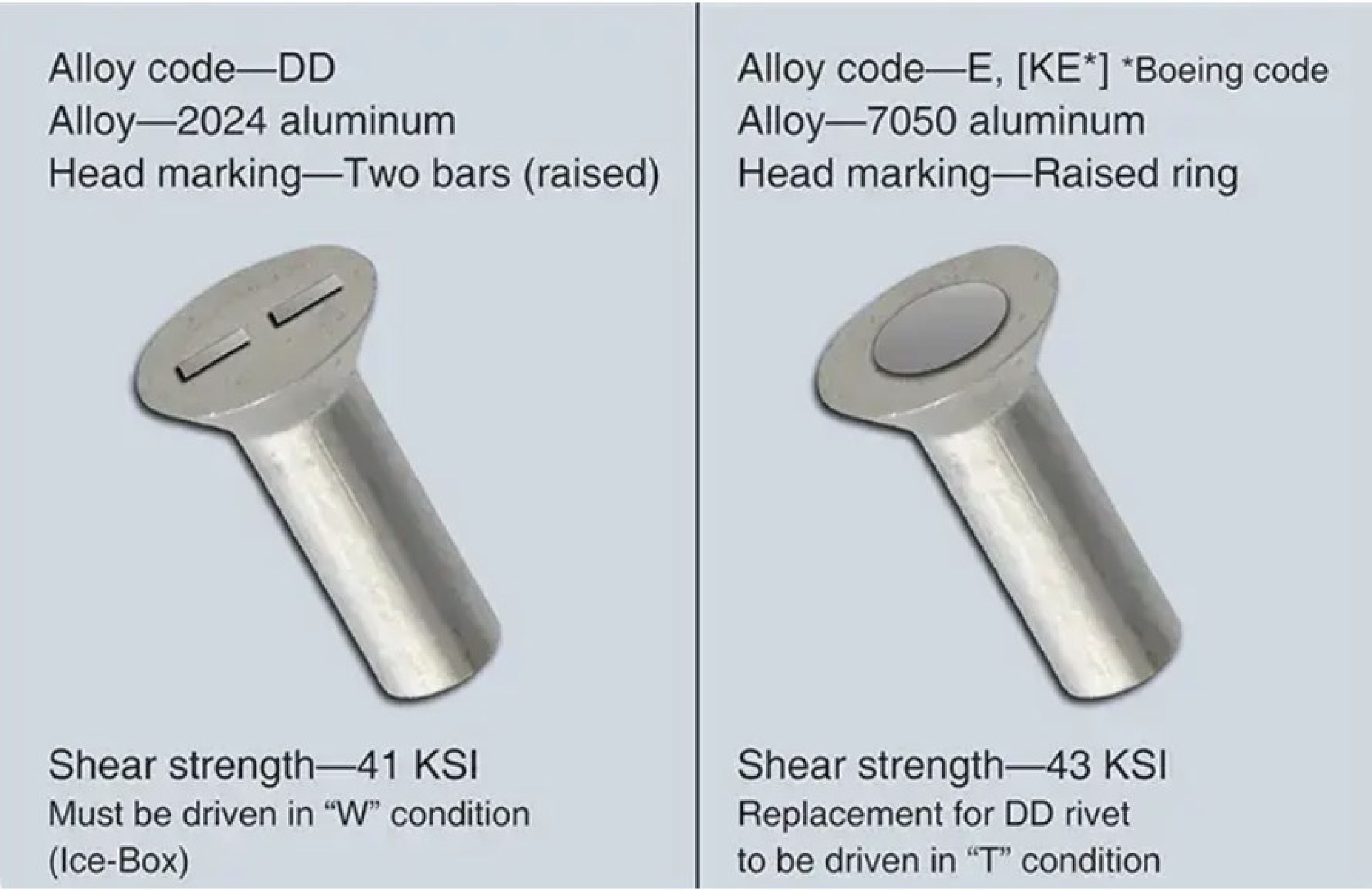
Standard rivet alloy code markings



Standard rivet alloy code markings

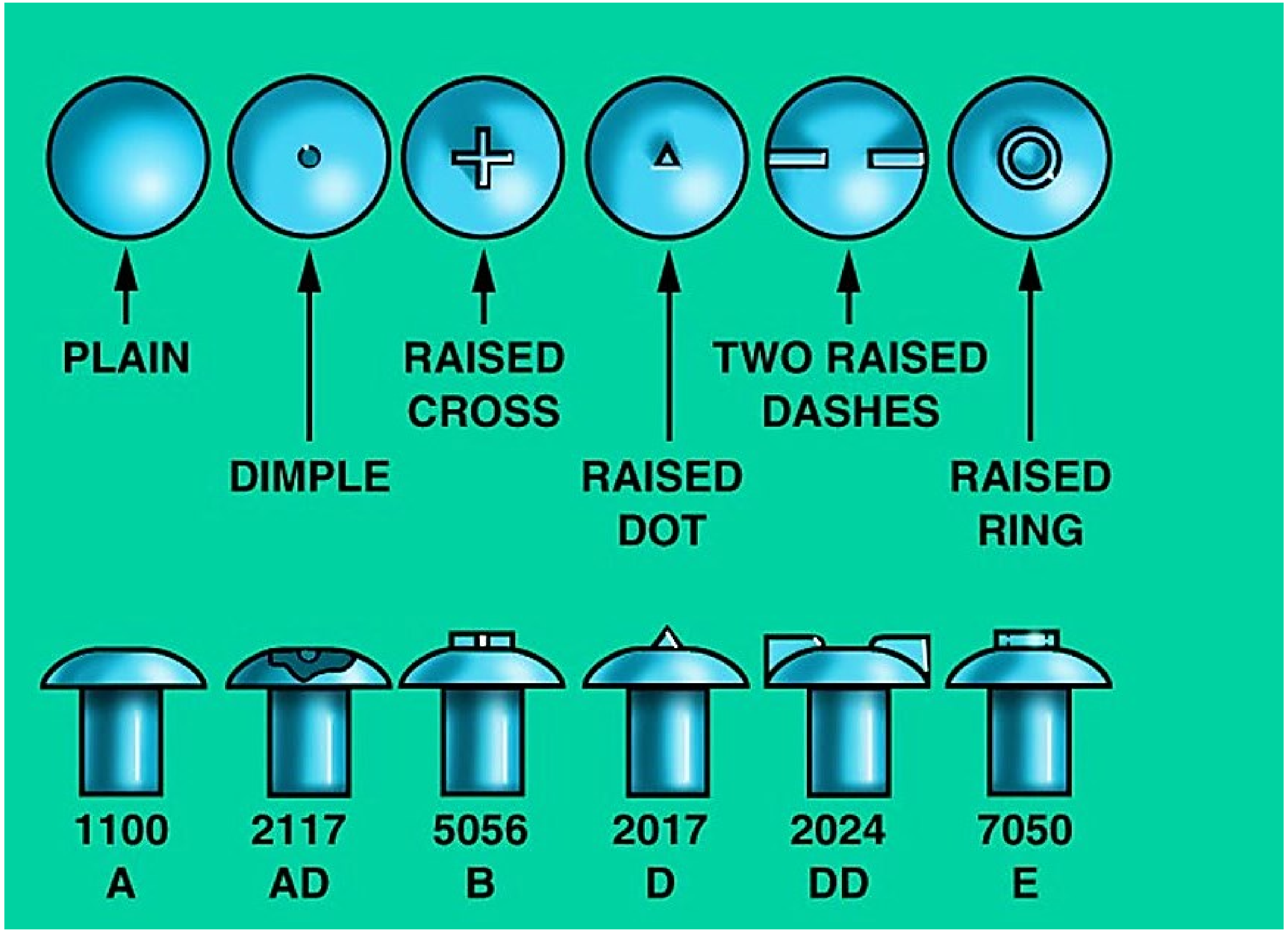


Standard rivet alloy code markings

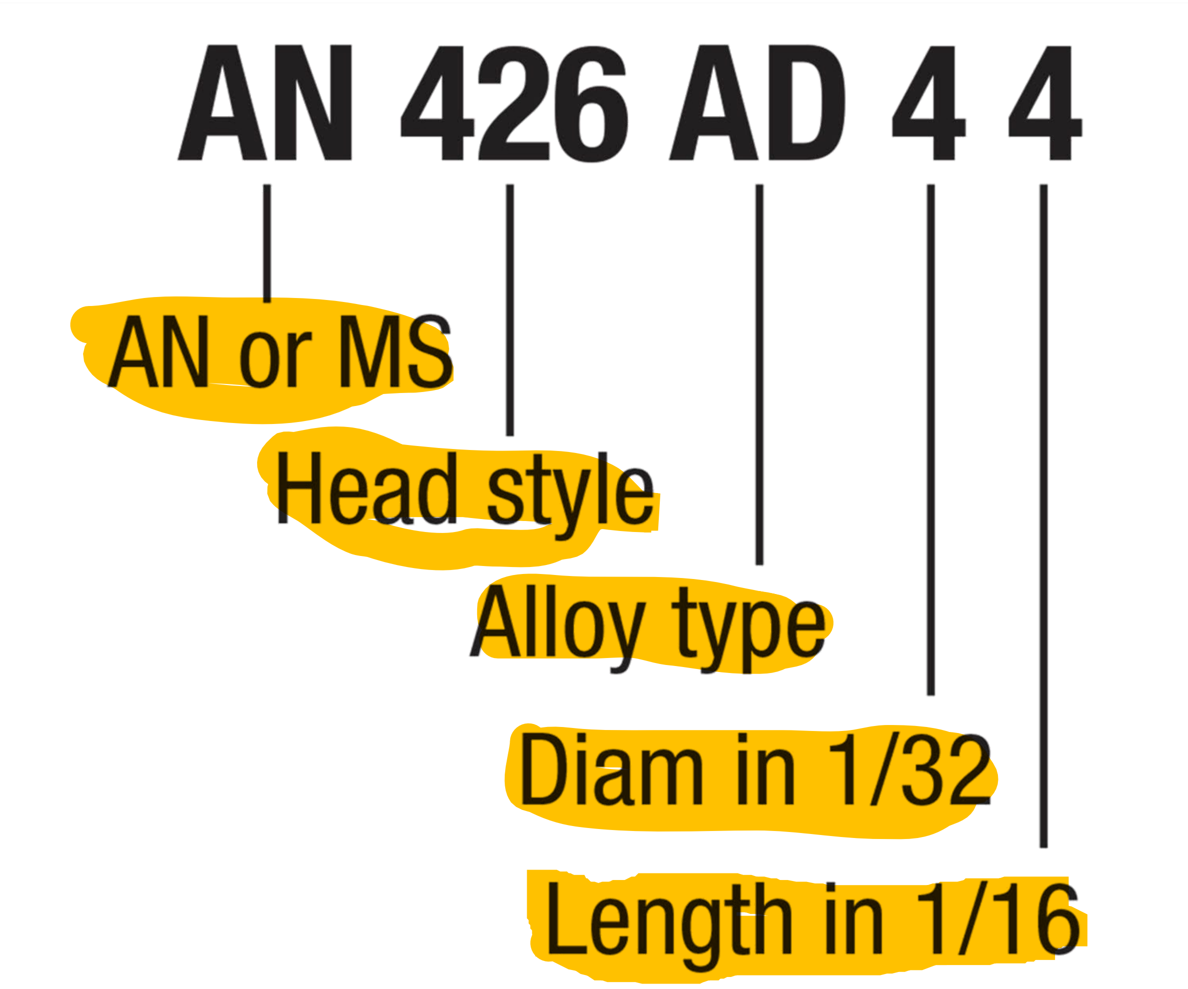


Rivet head markings

Markings on the heads of rivets are used to classify their characteristics



Rivet identification MS General



AN: Air force - Navy standards

MS: Military standards

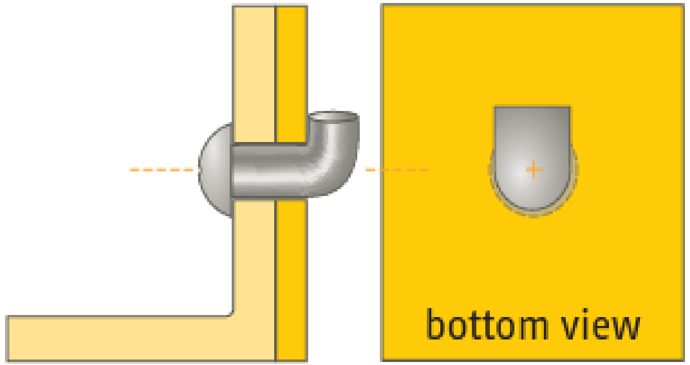
426: flush head rivet

470: universal head rivet

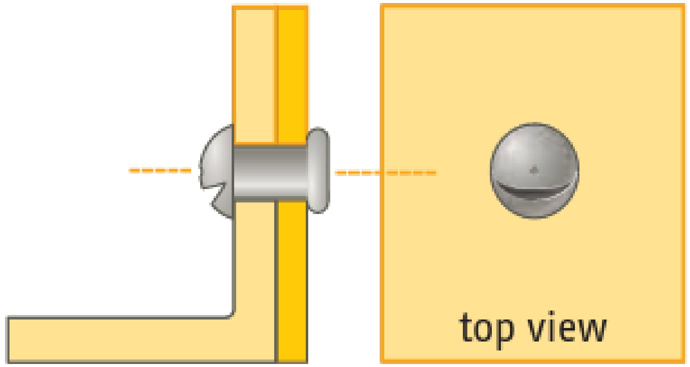
Rivet gauges

DEFECTIVE RIVETS

"DUMPED" RIVET

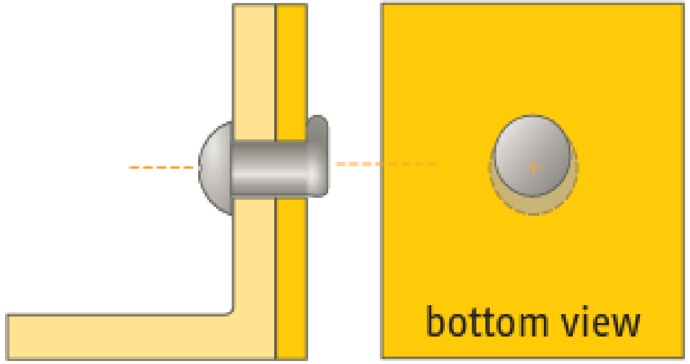


"SMILEY" RIVET



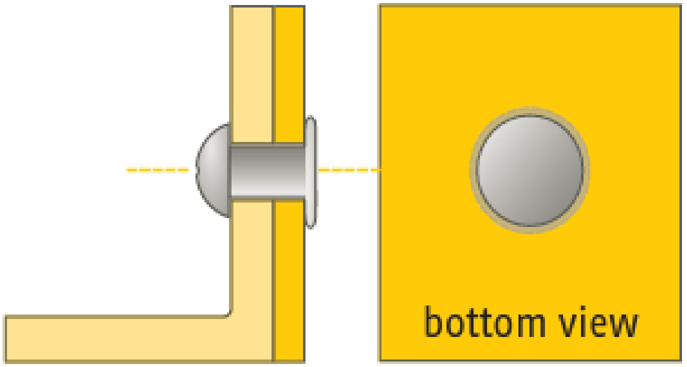
Although this rivet has been driven to the correct dimensions, the rivet gun was allowed to come off the rivet head during setting with the result of the smiley. The degrading of the factory head is sufficient to necessitate this rivet be replaced.

NON-CONCENTRIC SETTING

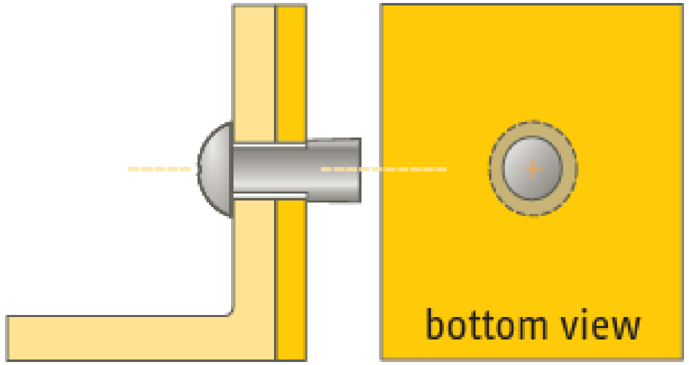


Rivet shop head has been driven non-concentric

OVER-DRIVEN RIVET



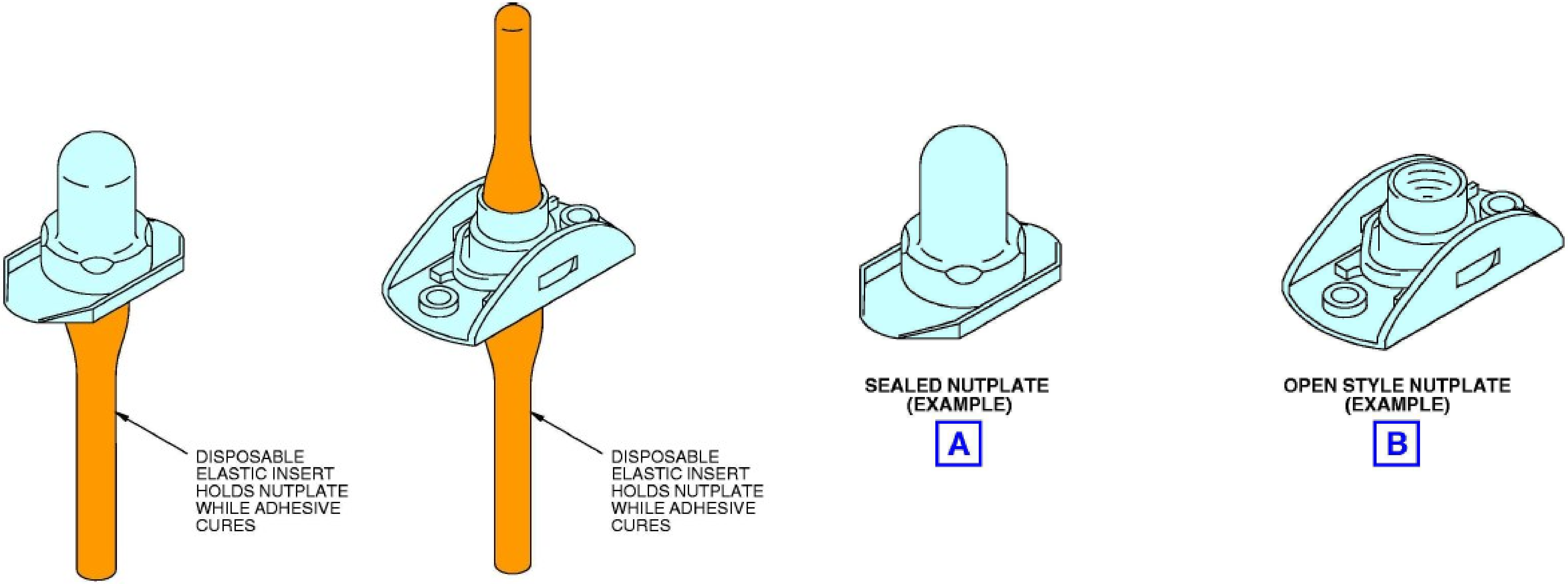
UNDER-DRIVEN RIVET



Boeing Fastener identification

- BAC**R**15 Rivet
- BAC**B**30 Bolt, Lockbolt or hexdrive bolt
- BAC**C**30 Collar
- BAC**W**30 Washer
- BAC**F** Filler
- BAC**N**10 Nut or nutplate
- BAC**S** Shim or screw

Nutplate


DISPOSABLE
ELASTIC INSERT
HOLDS NUTPLATE
WHILE ADHESIVE
CURES
DISPOSABLE
ELASTIC INSERT
HOLDS NUTPLATE
WHILE ADHESIVE
CURES
SEALED NUTPLATE
(EXAMPLE)
A
OPEN STYLE NUTPLATE
(EXAMPLE)
B

Boeing standard rivets

RIVET IDENTIFICATION		UNIVERSAL	MODIFIED UNIVERSAL	100° CSK	100° SHEAR HEAD	82° CSK	120° CSK/CB
MATERIAL	MARKS	STANDARD RIVET NO.					
		BACR15BB	BACR15FT	BACR15BA	BACR15CE	BACR15FH	BACR15FV
2117(AD)	DIMPLED						
2017(D)	RAISED DOT EXCEPT [*]				* NO MARKING		
2024(DD)	RAISED DOUBLE DASH						
5056(B)	RAISED CROSS						
1100(A)	PLAIN						
7050(KE)	RAISED CIRCLE EXCEPT [*]						* INDENTED CIRCLE
MONEL(M) NICKEL-COPPER	PLAIN						

Full part number for rivets and bolts

Rivets	Bolts
BAC15__*_**	BAC30__*_**_
__ = head style	__ = head style and material
* = Diameter (1/32'')	* = Diameter (1/32'')
_ = Material (letter code)	_ = Finish (letter code)
** = Grip length (1/16'')	** = Grip length (1/16")
	_ = Oversize (X=1/64'', Y=1/32'')

FASTENER	PART NUMBER	FASTENER TYPE	MATERIAL	SURFACE FINISH	F_{SU} (KSI)	NOTES
		HEX DRIVES				
YJA	BACB30NW*K	100^0 FLUSH SHEAR HEAD	TI 6AL-4V	ALUMINUM COAT	95	CETYL LUBE
YLR	BACB30NY*K	100^0 FLUSH TENSION HEAD	TI 6AL-4V	ALUMINUM COAT	95	CETYL LUBE
YHY	BACB30MY*K	PROTRUDING SHEAR HEAD	TI 6AL-4V	ALUMINUM COAT	95	CETYL LUBE
YLK	BACB30NX*K	PROTRUDING TENSION HEAD	TI 6AL-4V	ALUMINUM COAT	95	CETYL LUBE
XDA	BACB30FN	100^0 FLUSH SHEAR HEAD	4340 STEEL	CADMIUM PLATE	95	CETYL LUBE
XNB	BACB30JC	100^0 FLUSH TENSION HEAD	4340 STEEL	CADMIUM PLATE	95	CETYL LUBE
XCZ	BACB30FM	PROTRUDING SHEAR HEAD	4340 STEEL	CADMIUM PLATE	95	CETYL LUBE
XMX	BACB30MB	PROTRUDING TENSION HEAD	4340 STEEL	CADMIUM PLATE	95	CETYL LUBE
		LOCKBOLTS				
XFV	BACB30GY	100^0 FLUSH SHEAR HEAD	4340 STEEL	CADMIUM PLATE	95	CETYL LUBE
XFR	BACB30GW	PROTRUDING SHEAR HEAD	4340 STEEL	CADMIUM PLATE	95	CETYL LUBE
XFL	BACB30GX	100^0 FLUSH TENSION HEAD	4340 STEEL	CADMIUM PLATE	95	CETYL LUBE
		RIVETS				
XZK	BACR15BB*D	PROTRUDING UNIVERSAL HEAD	2017	ANODIZED	38	
XF	BACR15CE*D	100^0 FLUSH SHEAR HEAD	2017	ANODIZED	38	
XZG	BACR15BA*D	100^0 FLUSH HEAD	2017	ANODIZED	38	
YNE	BACR15FV*KE	120^0 MODIFIED SHEAR HEAD	7050-T73		41	BRILES RIVET
BF	MS20427M	100^0 FLUSH HEAD	MONEL	ANODIZED	49	HIGH TEMP, CORR RESISTANT
XD	BACR15BB*DD	PROTRUDING UNIVERSAL HEAD	2024	ANODIZED	41	ICE BOX RIVET
XB	BACR15BA*DD	100^0 FLUSH HEAD	2024	ANODIZED	41	
BM	MS20470D	PROTRUDING UNIVERSAL HEAD	2017	ANODIZED	38	

FASTENER - CODES AND PART NUMBERS

1. The fastener strength values given in these pages take into consideration the bearing strength of the material in which the fasteners are installed. This means that where the material will fail in bearing before fastener failure, the lower figure will be shown as the strength of the fastener.
2. The fastener strength values assume that the correct hole sizes have been used per the SRM, 51-40-05, and that edge margin requirements have been meet per the SRM, 51-40-06.
3. Refer to the following tables for the location of fastener strengths.

FASTENER		MATERIAL	LOCATION	
TYPE	PART NUMBER		FIG	TABLE
UNIVERSAL HEAD AL RIVETS	XZK-BACR15BB*D XD-BACR15BB*DD BM-MS20470D	2024-T3	1	I
		2024-T4, 2024-T42	1	II
		7075-T6	1	III
		7075-T6, -T6510, -T6511 EXT	1	III
FLUSH HEAD AL RIVETS	XZG-BACR15BA*D XB-BACR15BA*DD XF-BACR15CE*D YNE-BACR15FV*KE	2024-T3, 2024-T42	1	IV
		7075-T6	1	IV
FLUSH HEAD MONEL RIVET	BF-MS20427M	301-1/4 HARD CRES	1	V
		301-1/2 HARD CRES	1	V
		301-FULL HARD	1	V
		302-ANNEALED	1	V
PROTRUDING TENSION HEAD LOCKBOLTS AND HEX-DRIVES	XMX-BACB30MB YLK-BACB30NX	2024-T3	3	I
		2024-T4, 2024-T42	3	II
		7075-T6	3	III
		7075-T6, -T6510, -T6511 EXT	3	III
FLUSH TENSION HEAD LOCKBOLTS AND HEX-DRIVES	XNB-BACB30JC YLR-BACB30NY XFL-BACB30GX	2024-T3	4	II
		7075-T6	4	IV
FLUSH & PROTRUDING SHEAR HEAD LOCKBOLTS AND HEX-DRIVES	XCZ-BACB30FM XDA-BACB30FN XFR-BACB30GW XFV-BACB30GY YHY-BACB30MY YJA-BACB30NW	2024-T3	5	I
		7075-T6	5	III

FASTENER JOINT ALLOWABLES - INDEX

Example

BACR15 FV 6 KE 8

FV 120° modified shear head

Diameter: $6 = \frac{6}{32} = \frac{3}{16}\ in$

Material: Al 7050

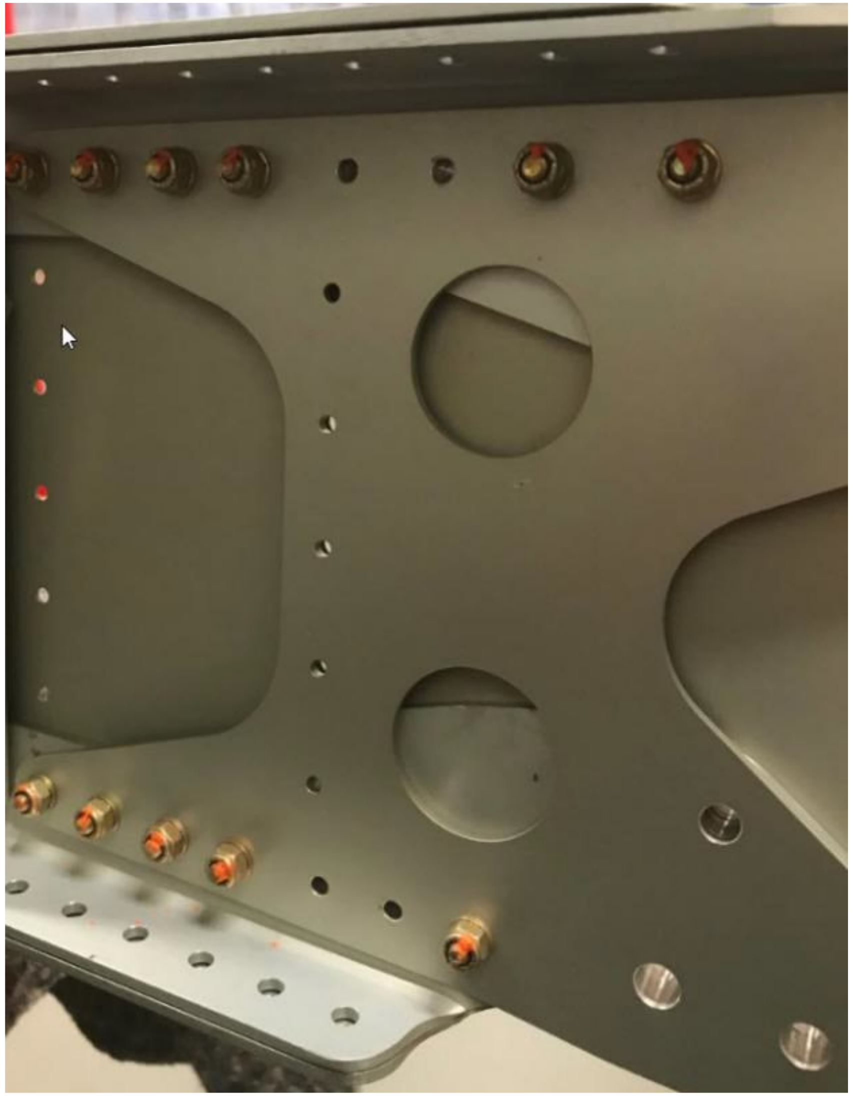
Length: $8 = \frac{8}{16} = \frac{1}{2}\ in$

Lockbolts

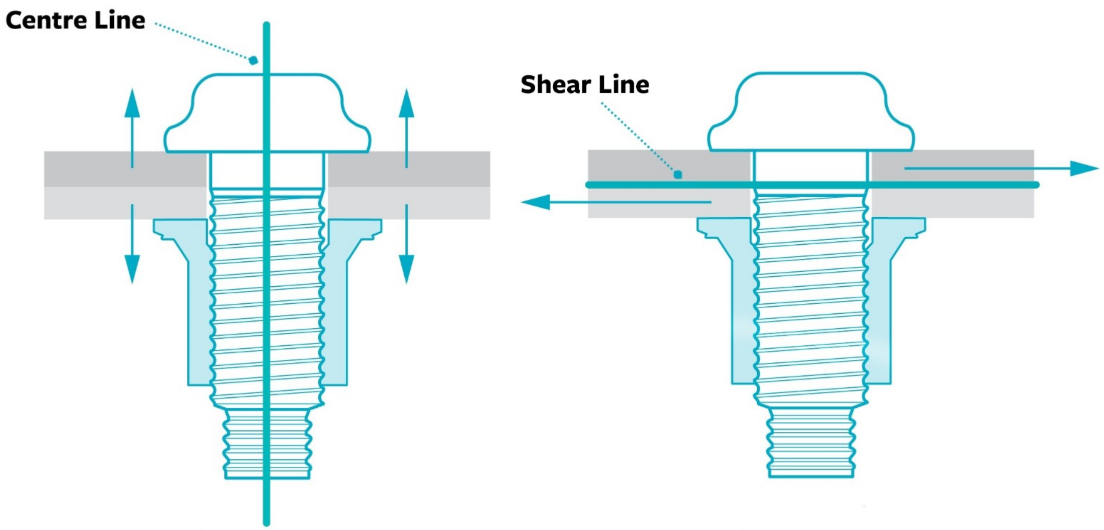
- Lockbolts are **permanent fasteners** that have a collar that is swaged onto the serrated end of the bolt
- Usually, lockbolts have a **higher shear strength** and a **higher clamp up force** than solid rivets
- The lockbolt pin has grooves cut or rolled onto the shaft
- The collar has no grooves, but is swaged onto the pin grooves by force
- A portion of the pin breaks off during the assembly, controlling the installation force (torque)

https://www.hfsindustrial.com/how-lockbolts-work

Lockbolts



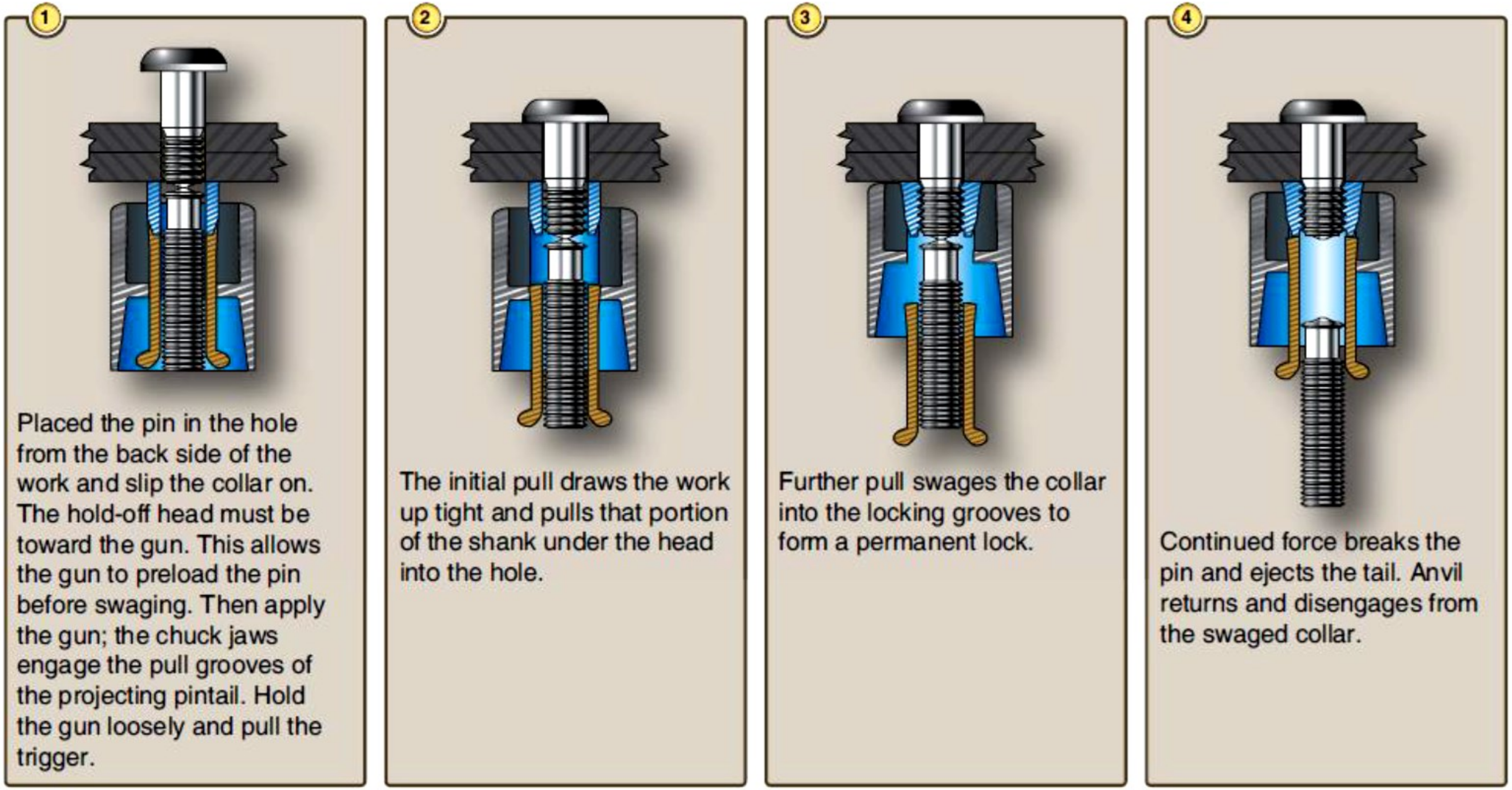
Tensile **Shear**



Pintail-less LockBolt after installation

LockBolt after installation

Lockbolts



1. Placed the pin in the hole from the back side of the work and slip the collar on. The hold-off head must be toward the gun. This allows the gun to preload the pin before swaging. Then apply the gun; the chuck jaws engage the pull grooves of the projecting pintail. Hold the gun loosely and pull the trigger.

2. The initial pull draws the work up tight and pulls that portion of the shank under the head into the hole.

3. Further pull swages the collar into the locking grooves to form a permanent lock.

4. Continued force breaks the pin and ejects the tail. Anvil returns and disengages from the swaged collar.

Hex-drive bolts

Hex-drive bolts (Hi locks) are almost the same as lockbolts but use a **threaded shank together with a threaded collar or nut**

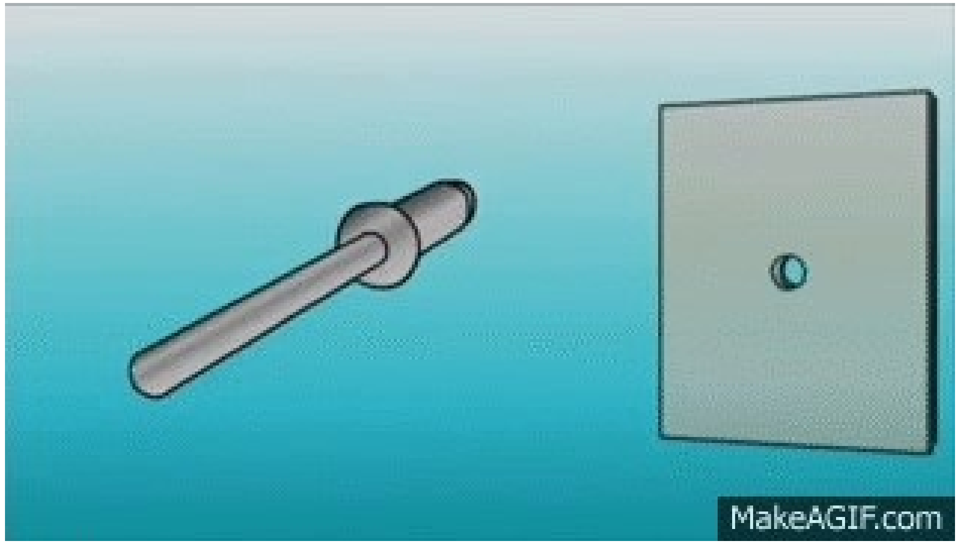
The installation force is controlled by a groove in the collar, which shears off during installation The collar deforms during the installation, providing the bolt locking mechanism

Blind Fasteners

You can use **blind fasteners** when there is **access to only side of the structure**

In some locations, you can **use blind fasteners where access is not available to make the upset head of a head solid rivet**

Inspection and remotion may be difficult



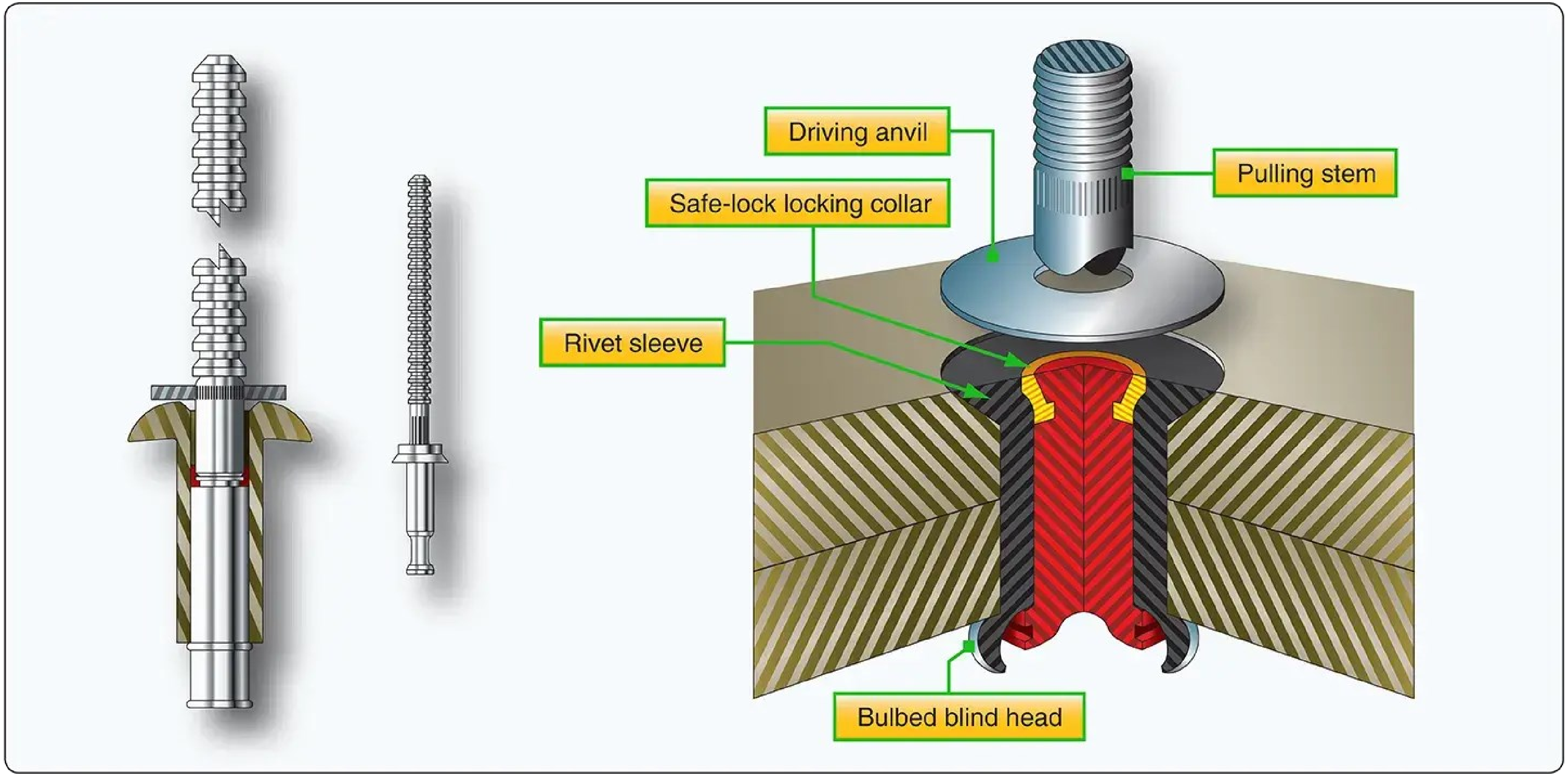
https://i.makeagif.com/media/12-15-2015/bLE_j1.gif

Blind bolts

Have larger manufactured heads and higher tension and shear strengths than the usual blind rivets:

- Threaded
- Pull

Blind rivet (Cherry Max)



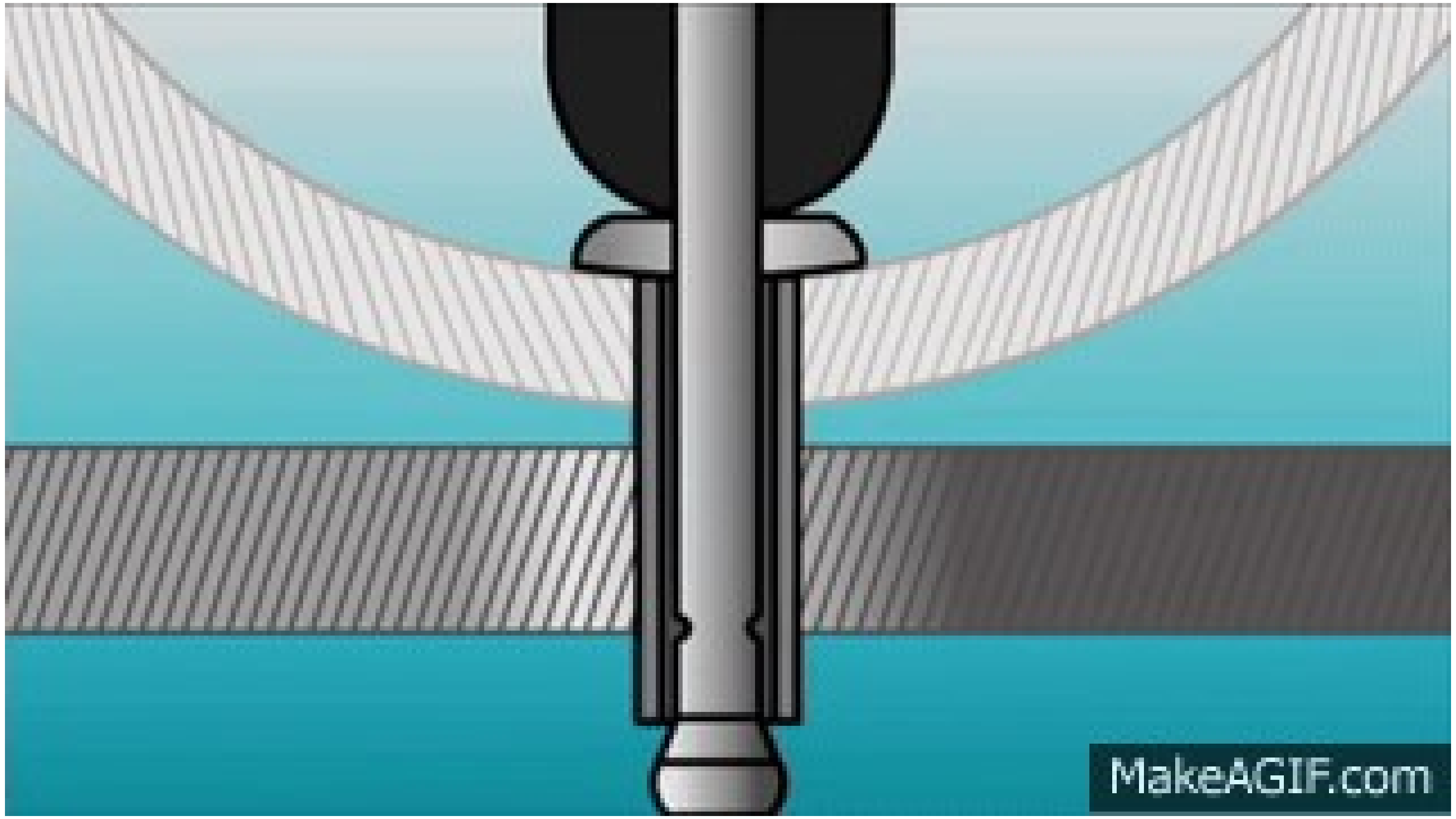
Blind rivets

Blind rivets are not the same as blind bolts. Blind rivets are lower in strength and **cannot be substituted for blind bolts**

They should **never be used in areas of higher tension loading** (highly stressed areas) or where head is subjected to prying (interference)

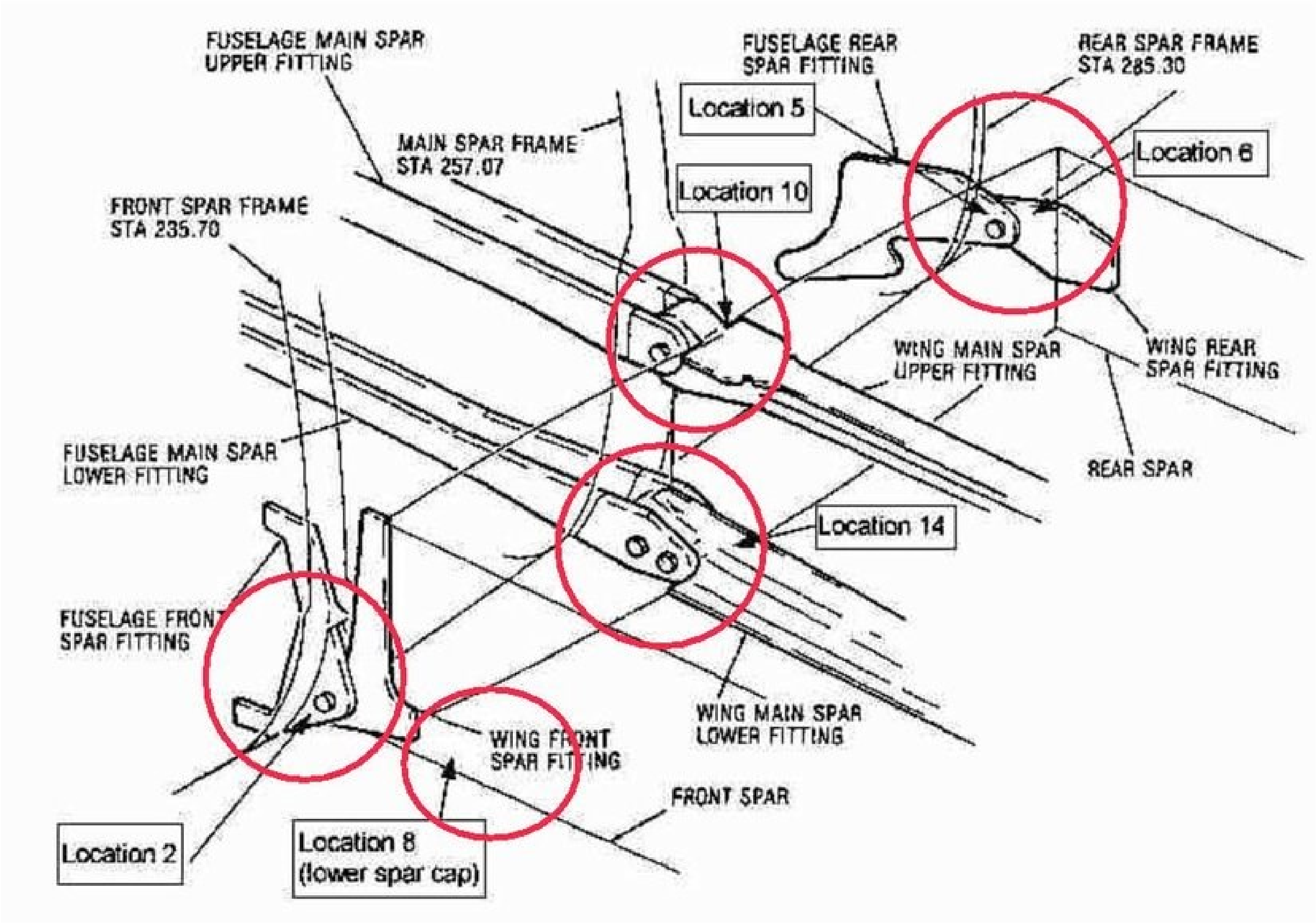
If blind rivets are used in a repair, **the repair is considered time limited** and should be inspected at frequent intervals for looseness.

Blind rivets

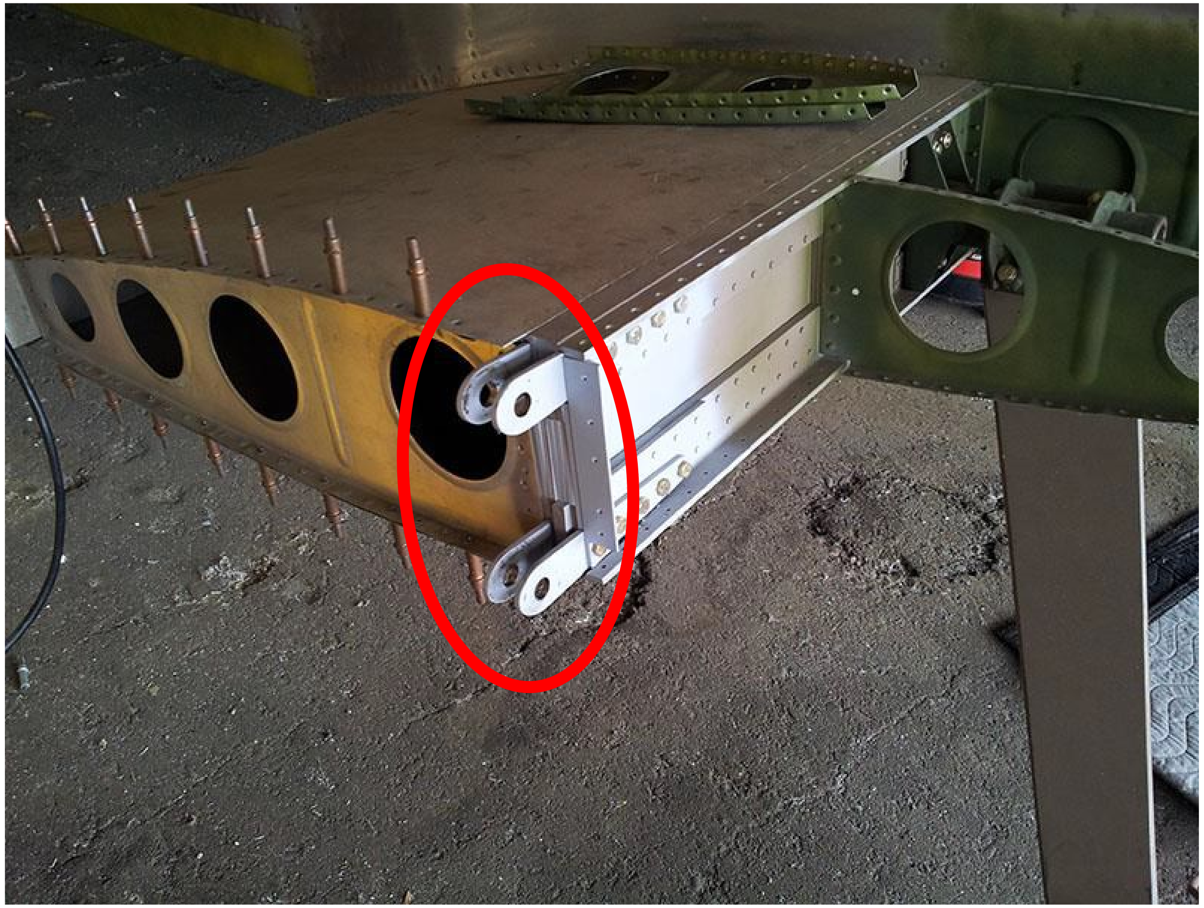


https://i.makeagif.com/media/10-25-2017/kQlgjx.gif

Fittings



FUSELAGE MAIN SPAR UPPER FITTING
FUSELAGE REAR SPAR FITTING
REAR SPAR FRAME STA 285.30
Location 5
Location 6
MAIN SPAR FRAME STA 257.07
Location 10
FRONT SPAR FRAME STA 235.70
WING MAIN SPAR UPPER FITTING
WING REAR SPAR FITTING
REAR SPAR
FUSELAGE MAIN SPAR LOWER FITTING
Location 14
FUSELAGE FRONT SPAR FITTING
WING FRONT SPAR FITTING
WING MAIN SPAR LOWER FITTING
FRONT SPAR
Location 2
Location 8 (lower spar cap)

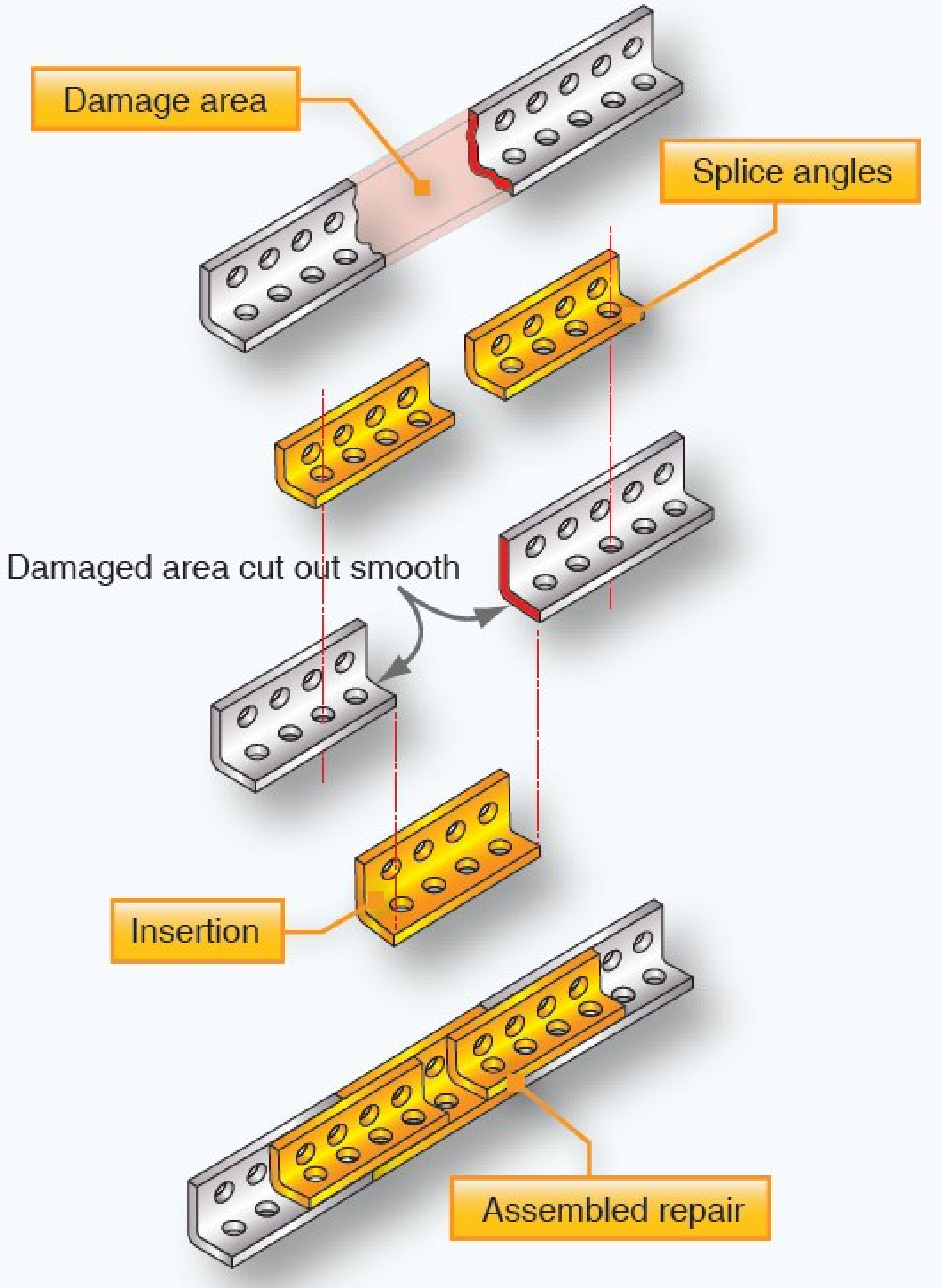


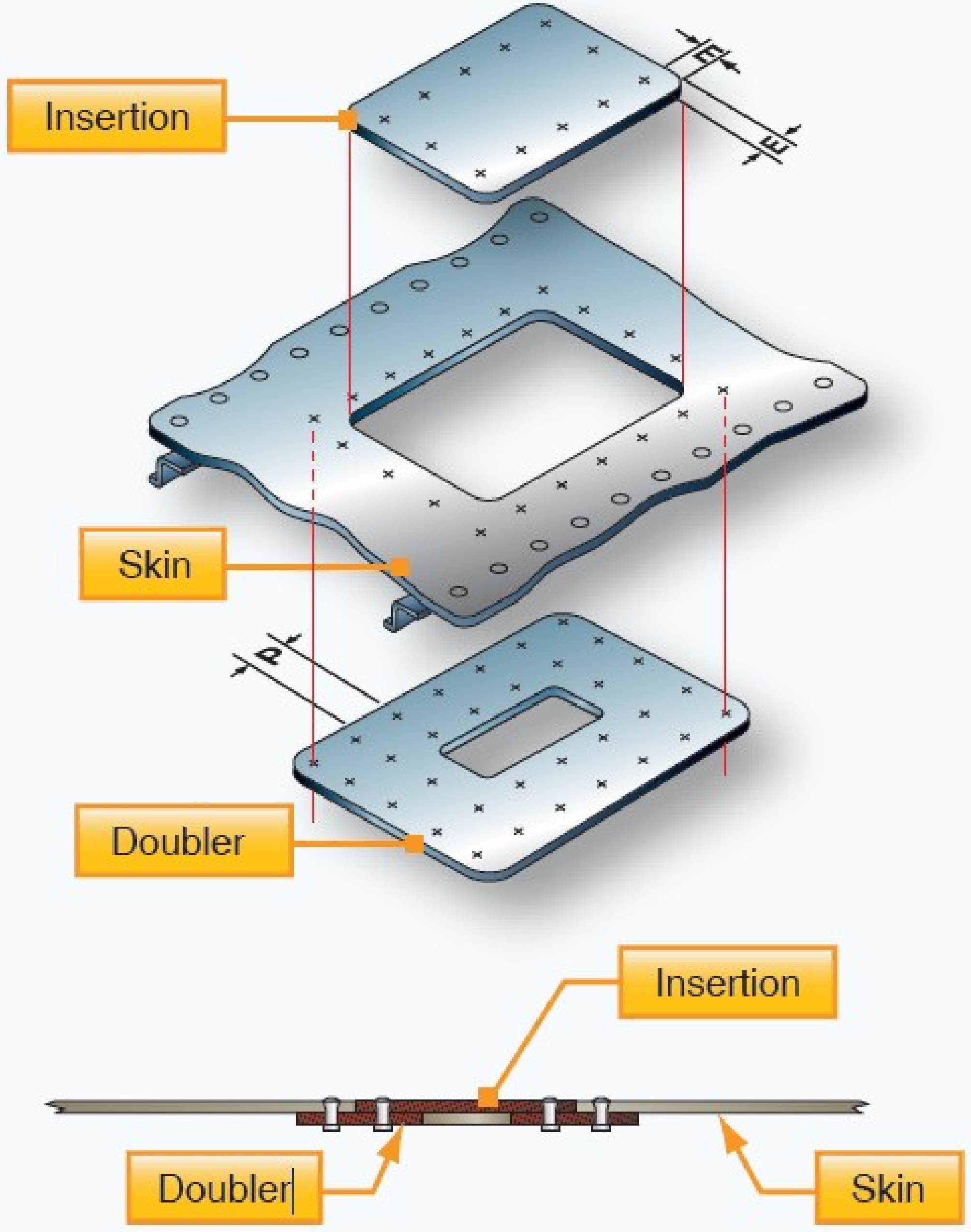
Splice and doublers

The splice function is to **transfer a given load**. It is kept as short as possible to accomplish this

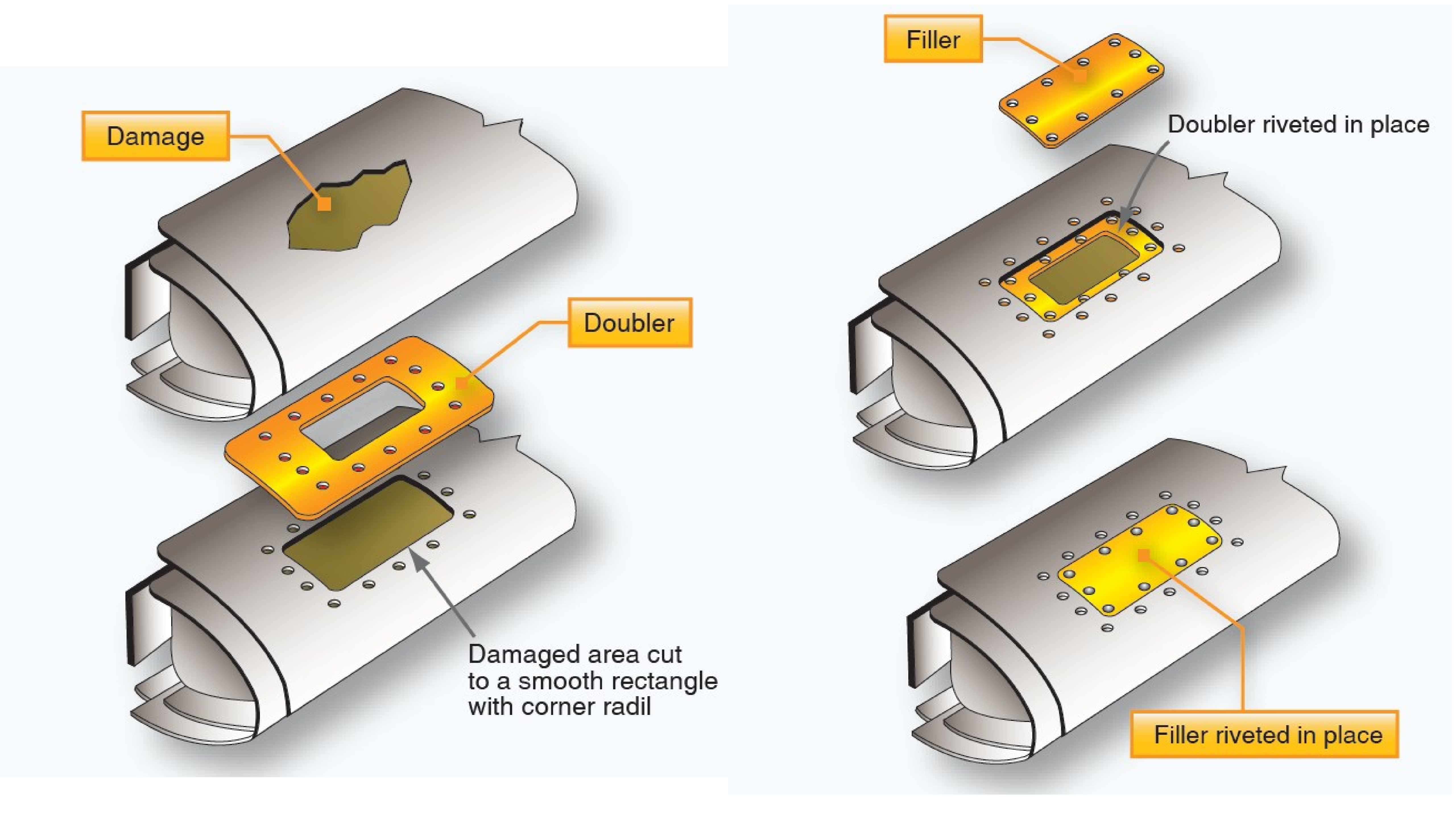
A doubler function is to **pick up the load and relieve another member**. It must have some considerable length

Doublers are more robust than splices



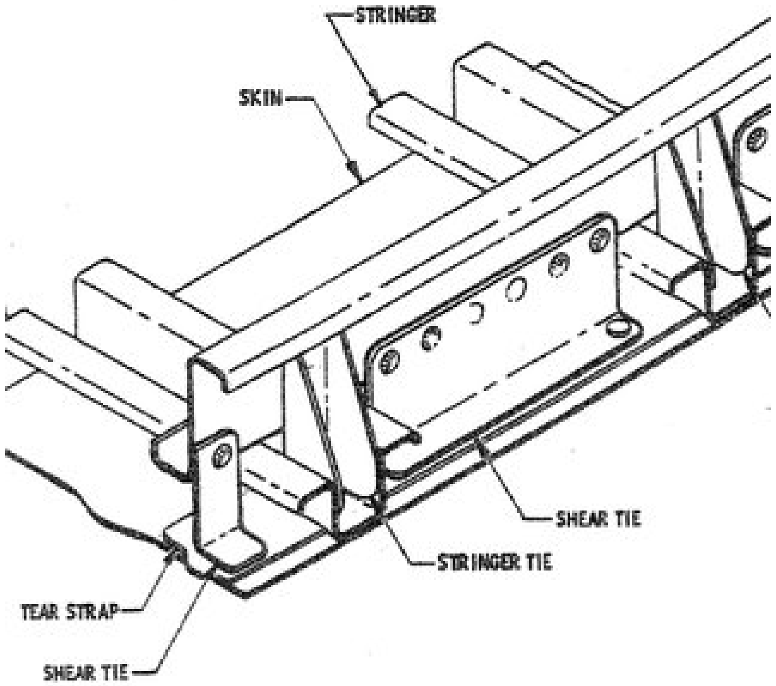


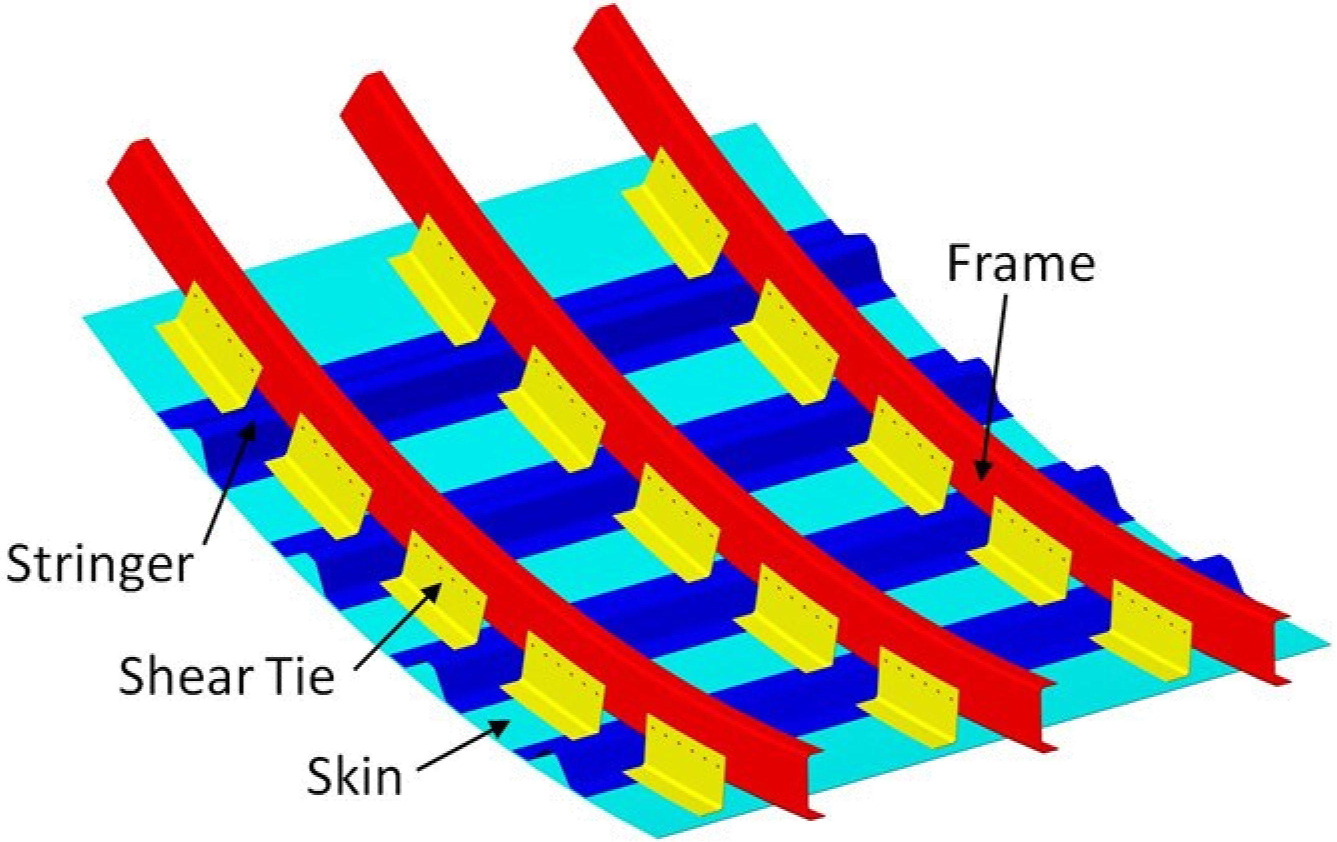
Insertion patch method


Damage
Doubler
Damaged area cut to a smooth rectangle with corner radii
Filler
Doubler riveted in place
Filler riveted in place

Shear tie

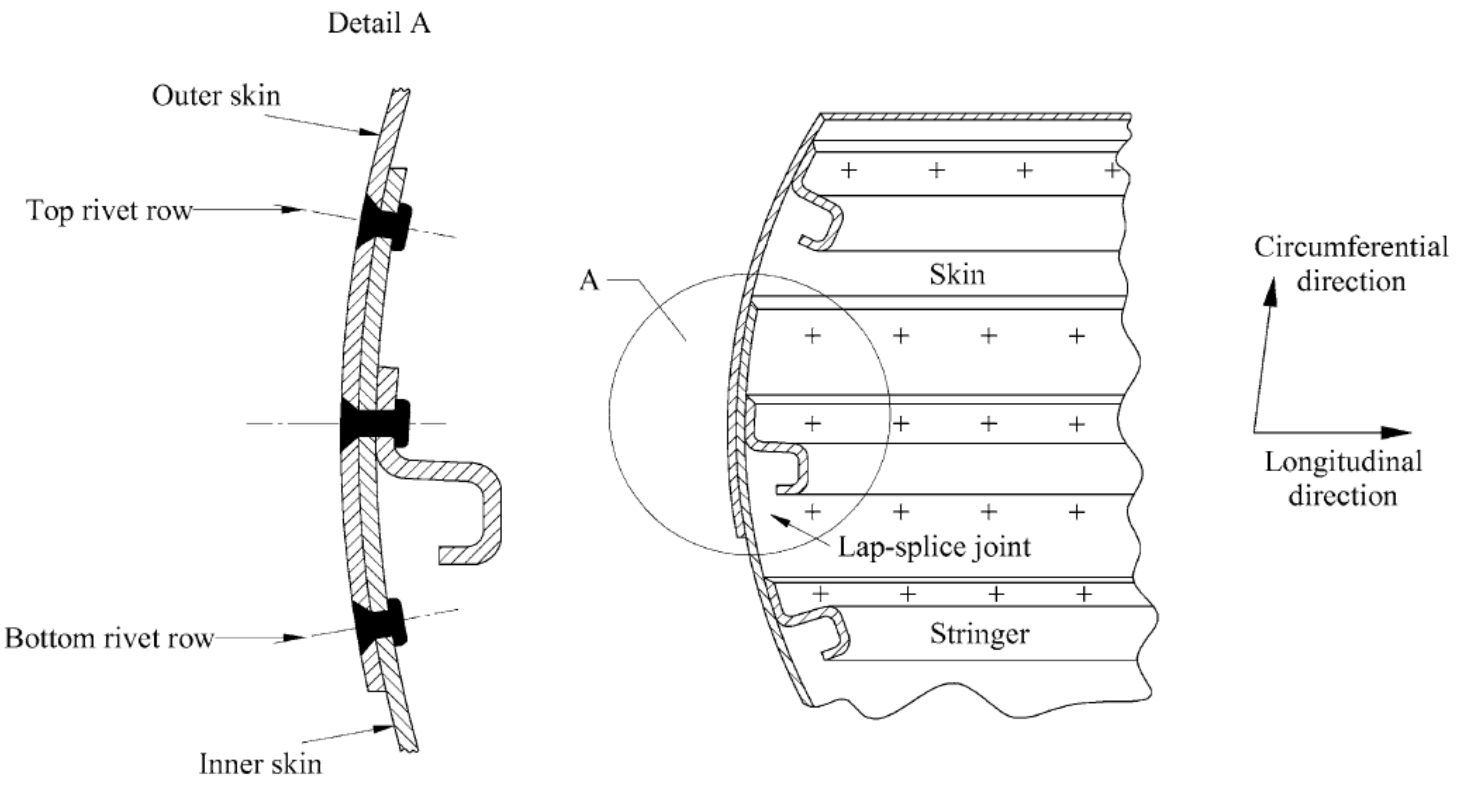
A structural member used to **transfer shear loads** from one piece to other.

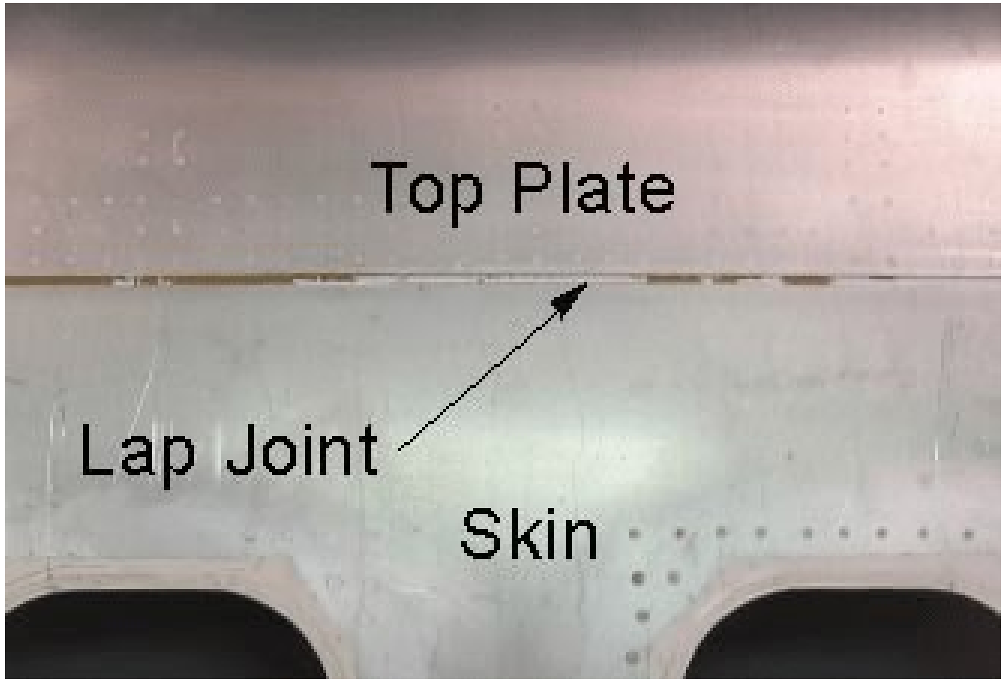




Lap joint

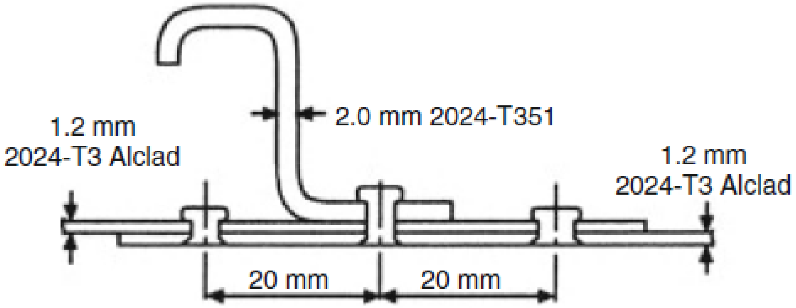
Two overlapping structural sheets joined by adhesive, welding or fasteners





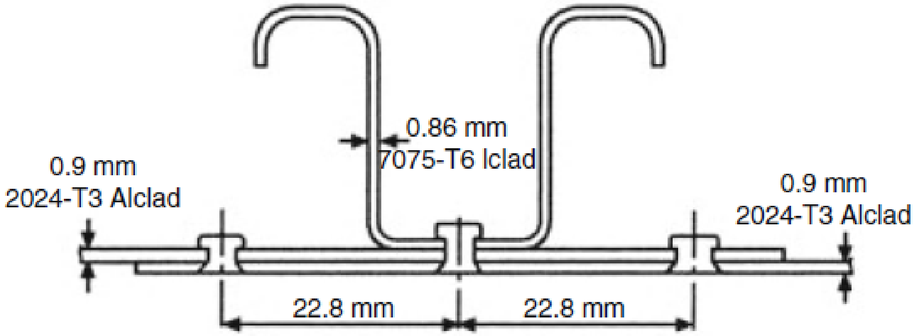
F100

- rivet pitch 20 mm
- rivet diameter 3.2 mm
- sheets chromic acid anodised,
- primed and cold bonded



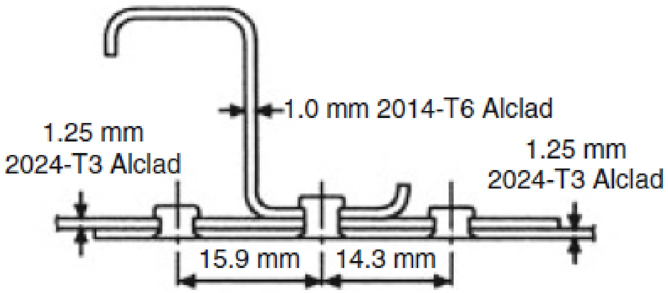
B737-200

- rivet pitch 25 mm
- rivet diameter 3.97 mm
- sheet cold bonded
- knife edges at outer sheet faying surface



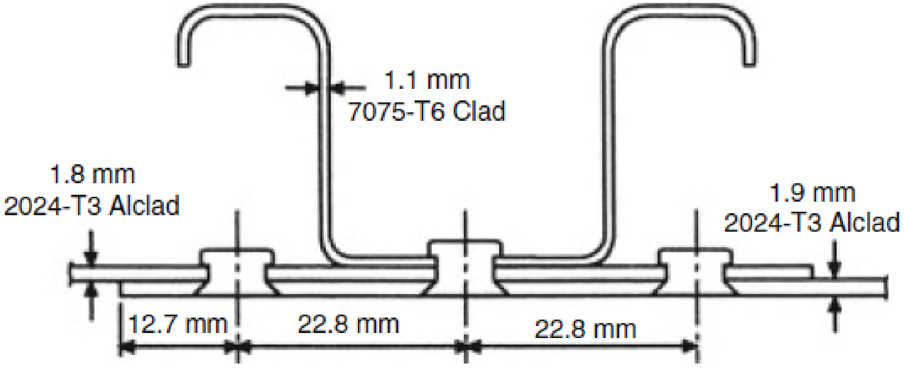
BAC 1-11

- stiffener rivet pitch 12.7 mm
- sheet rivet pitch 25.4 mm
- rivet diameter 3.2 mm
- sheet chromic acid anodised and primed
- Interfay sealant



BAC 727-100

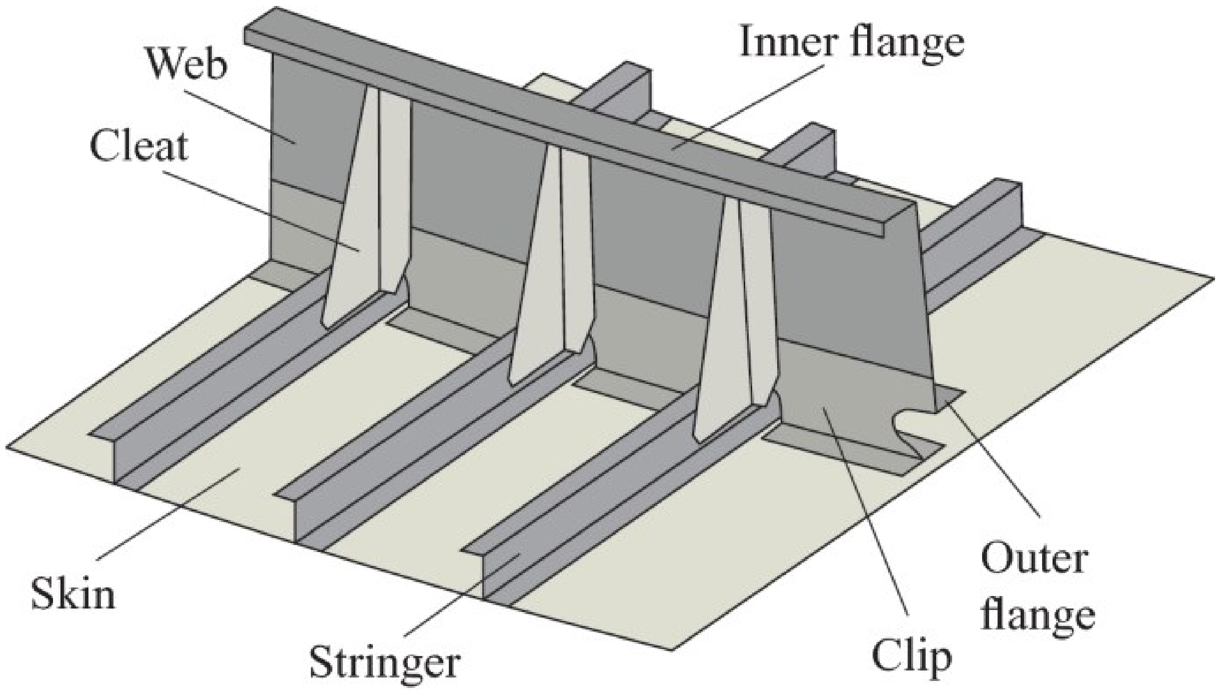
- rivet pitch 28-30 mm
- rivet diameter 4.9-5.1 mm
- sheet and stiffener primed
- Interfay sealant



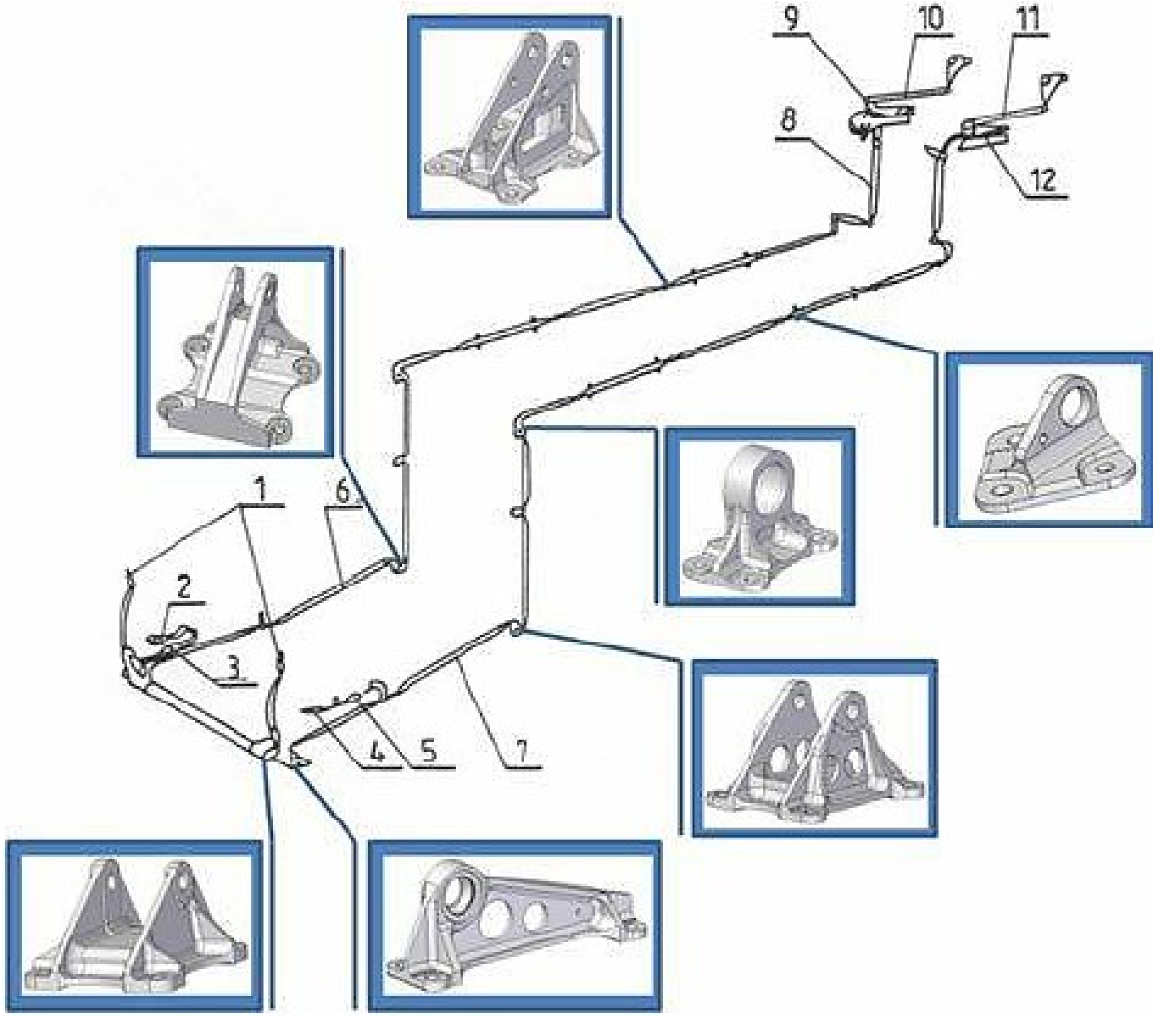
(Sub-assemblies)
Clips, cleats, brackets

Clips and cleats: small angles or simple sheet metal parts for (shear) connection of various parts.

Bracket: small fitting or support to attach system parts



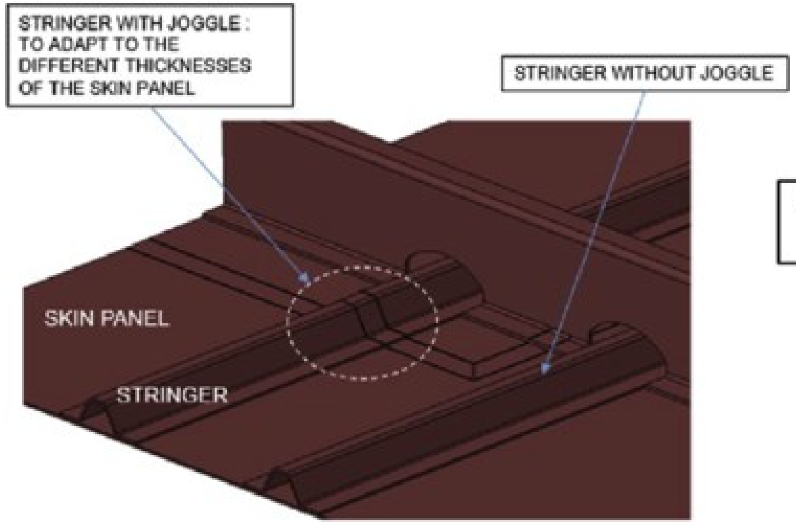
(Sub-assemblies)
Clips, cleats, brackets

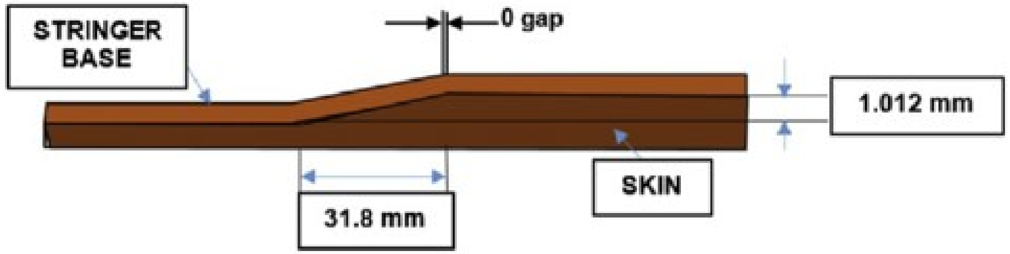


Stringer Joggling

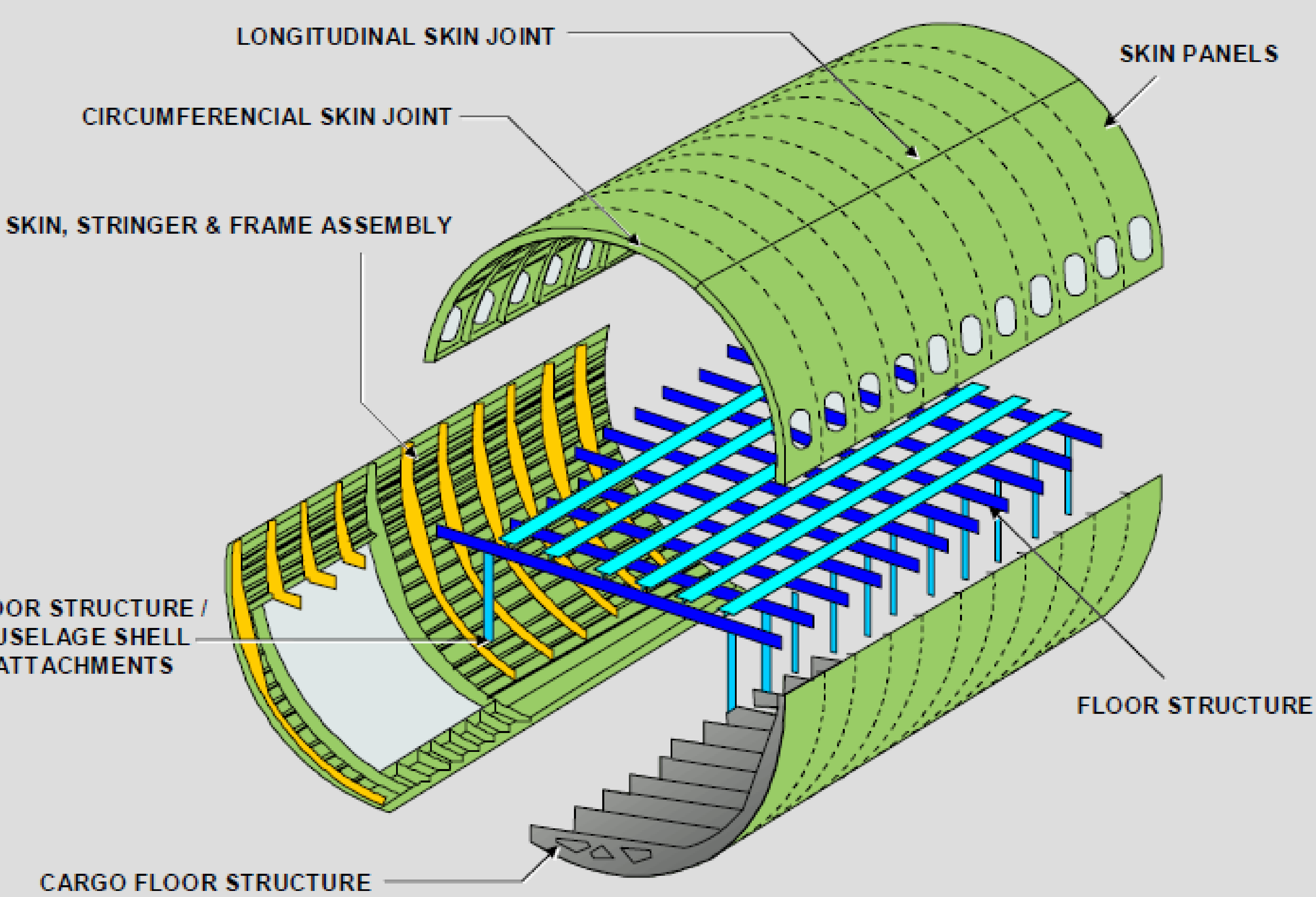
Because the loads are not constant throughout the fuselage structure, the required thickness of fuselage skin panels will vary

The outer surface of the fuselage must be undisturbed for aerodynamic reasons, which implies that thickness steps in the fuselage skin are provided at the inner side of the panel

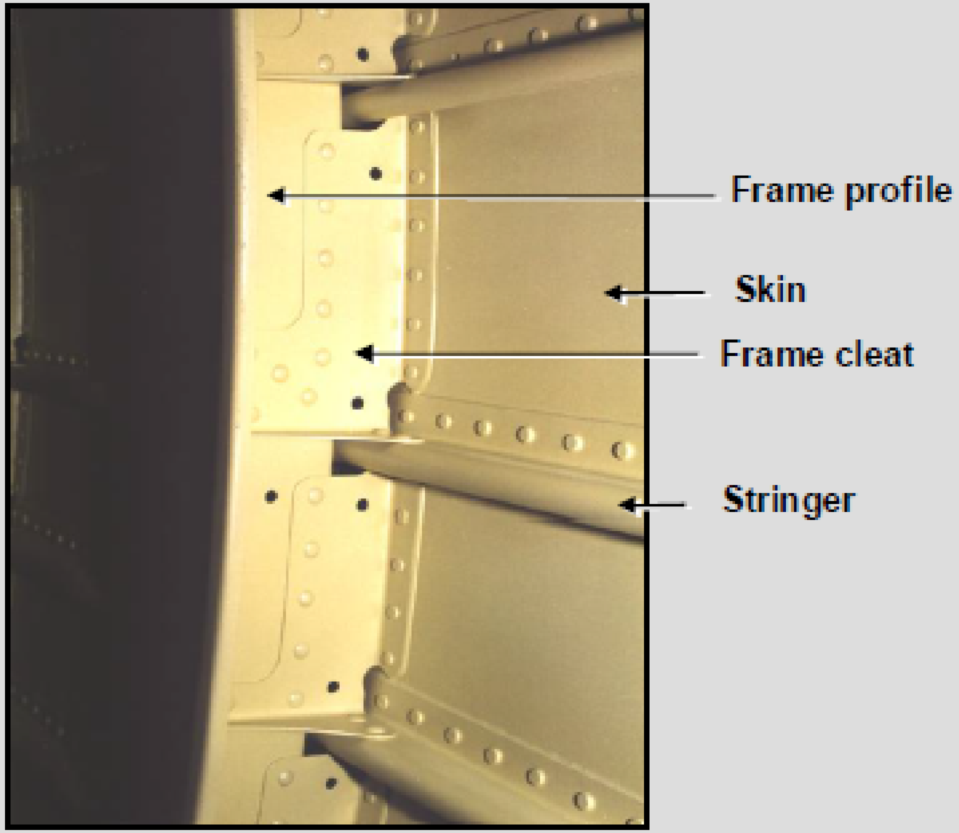


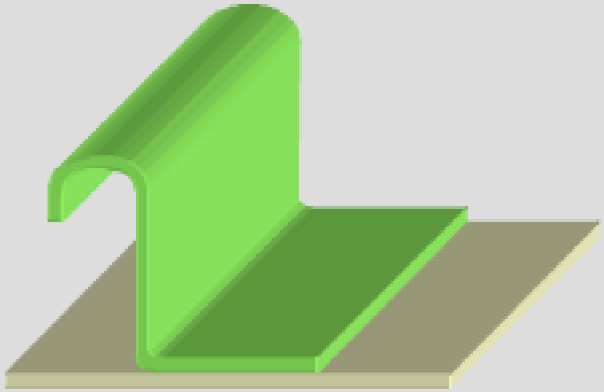


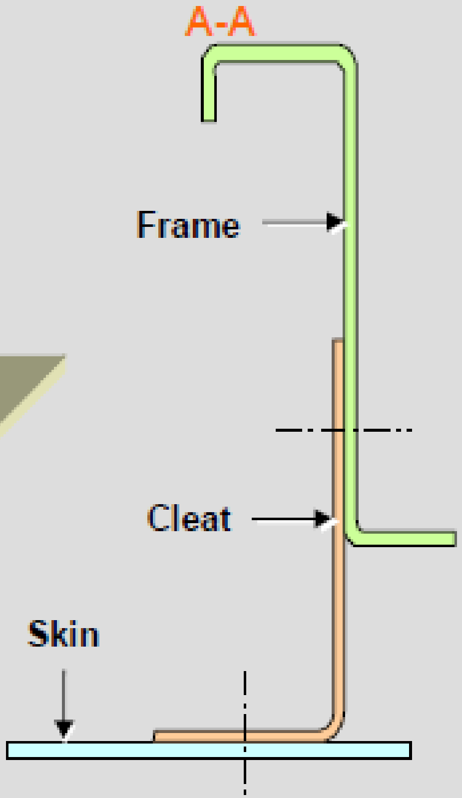
TYPICAL SECTION STRUCTURE ARRANGEMENT

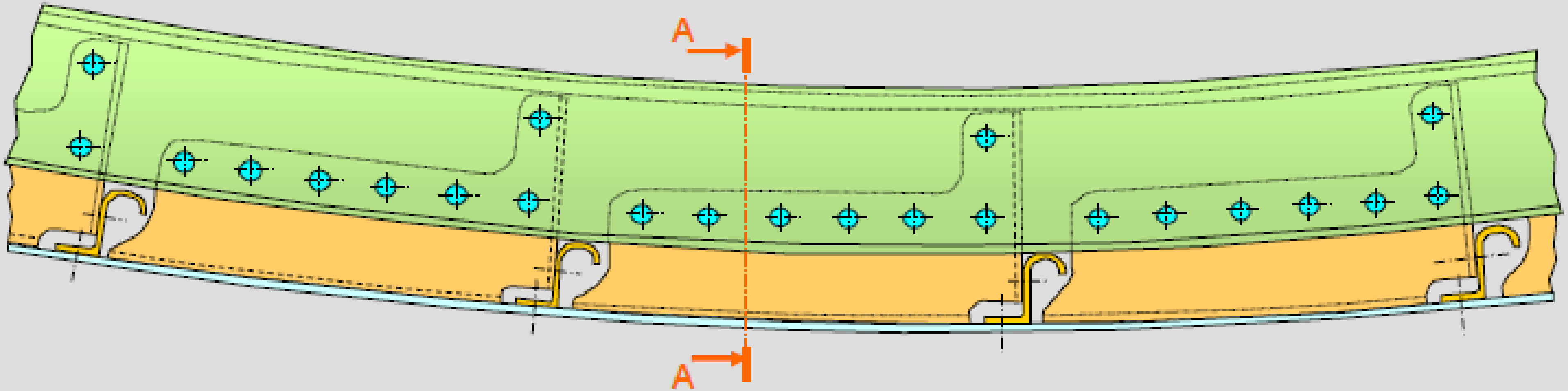


SKIN/FRAME/STRINGER ATTACHMENTS

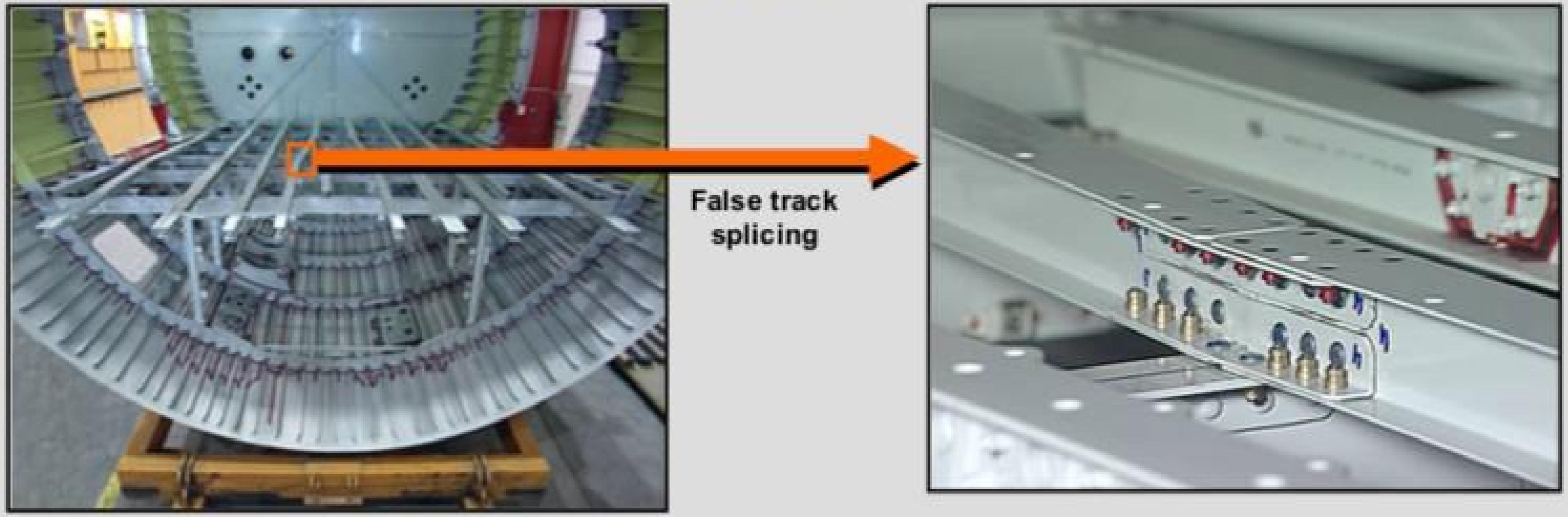


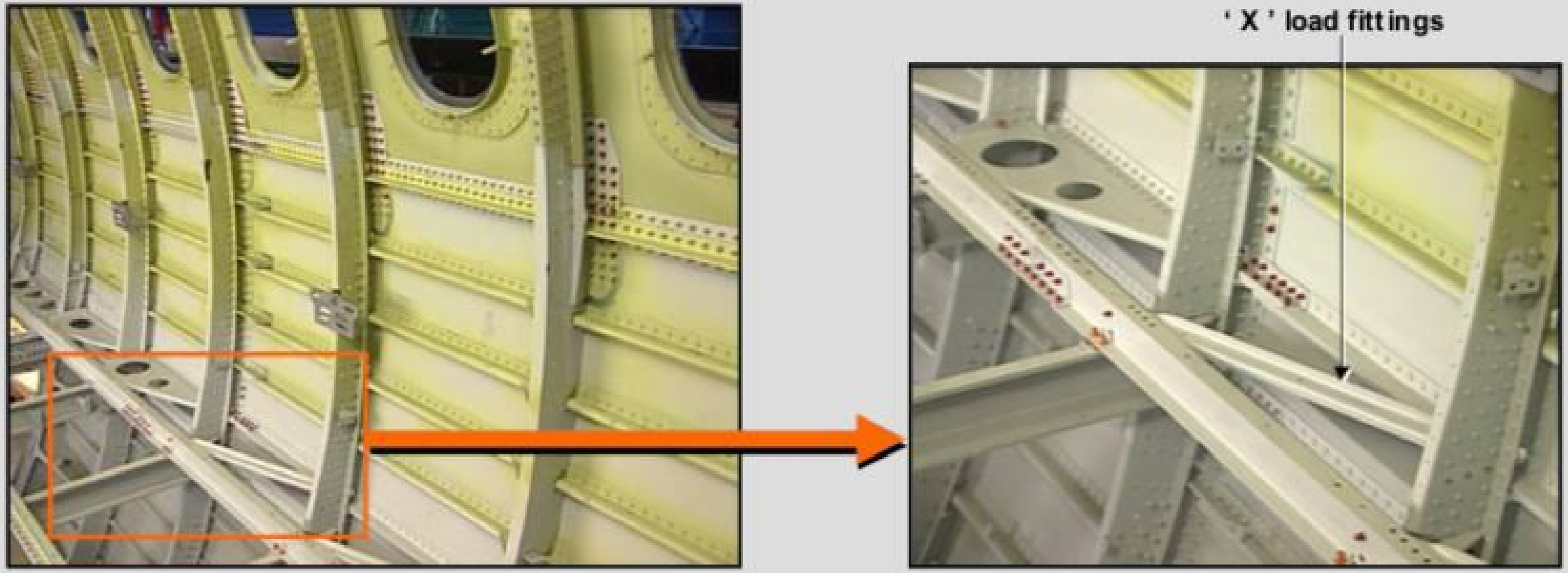






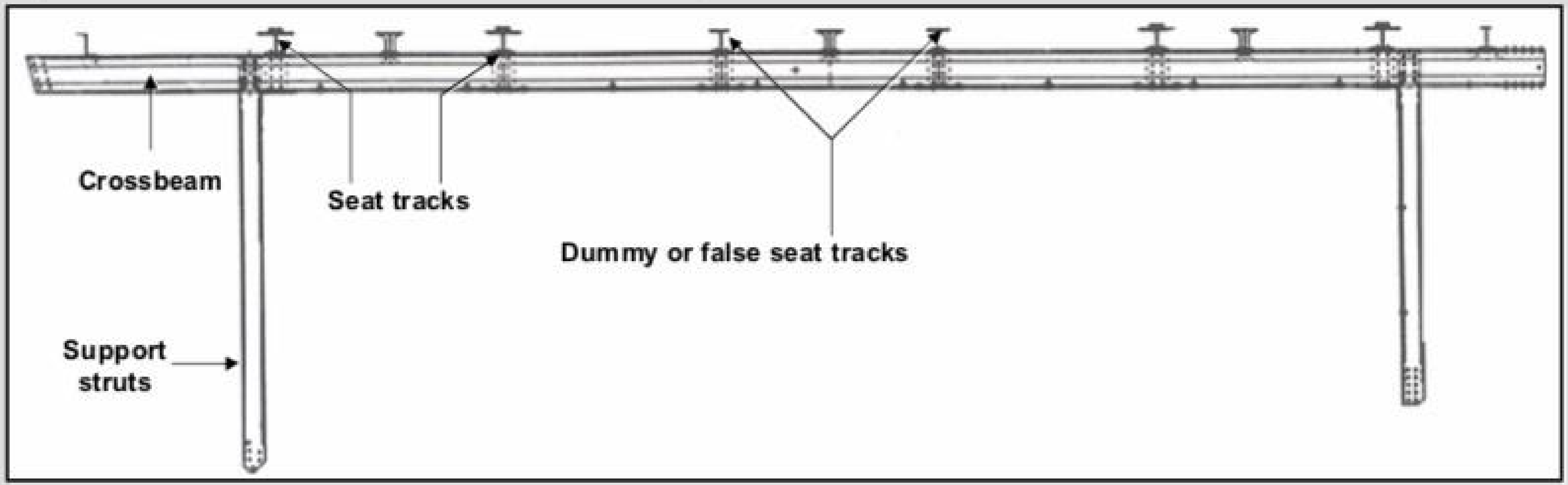
PASSENGER CABIN FLOOR STRUCTURE (CONT'D)





PASSENGER CABIN FLOOR STRUCTURE

Crossbeam-to-frame attachment

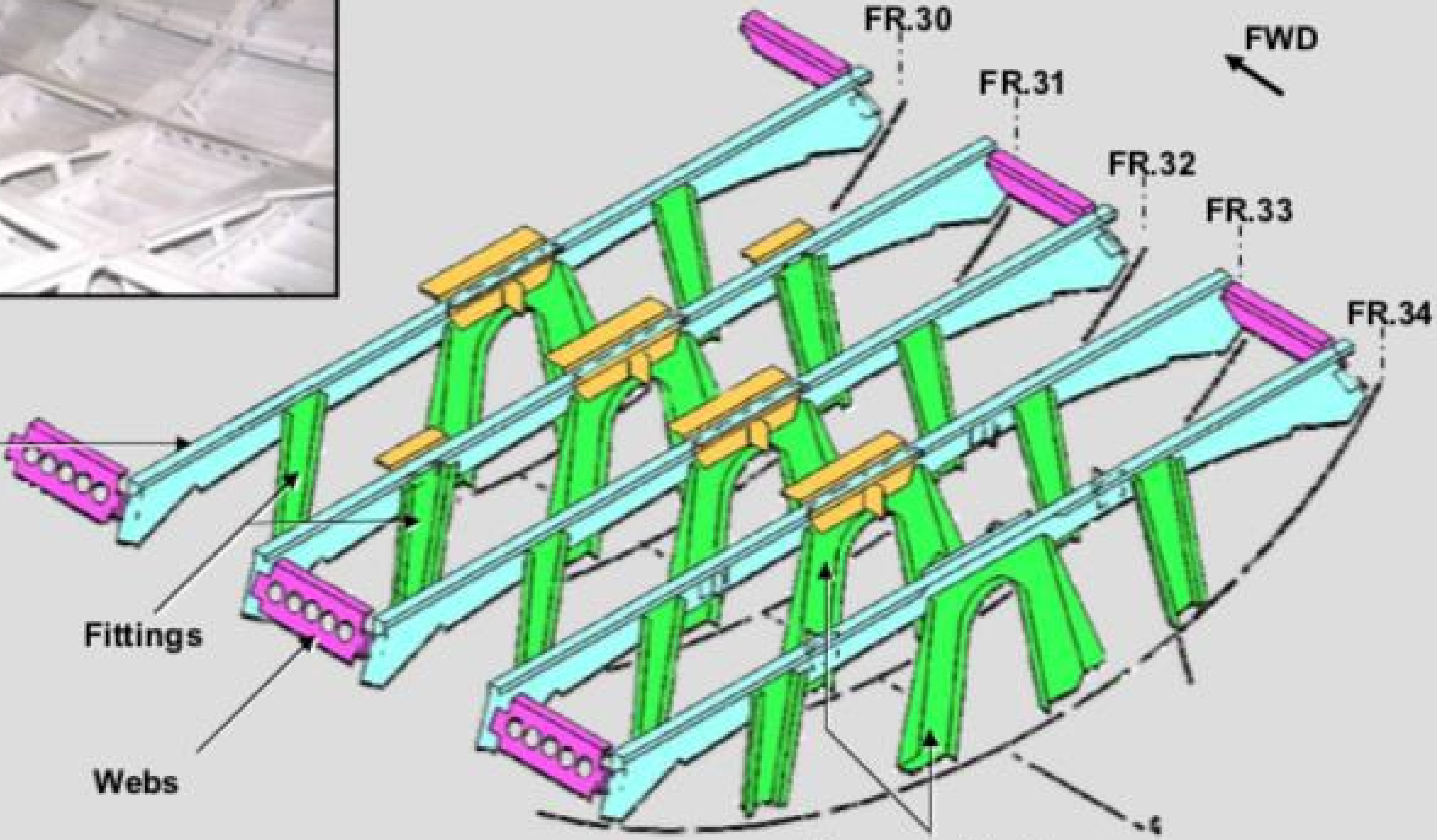


CARGO COMPARTMENTS

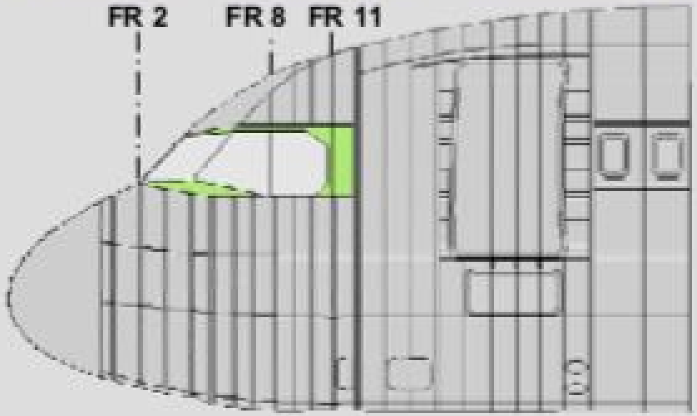
FLOOR STRUCTURE

E.g. Rear Fuselage

E.g. FWD Fuselage



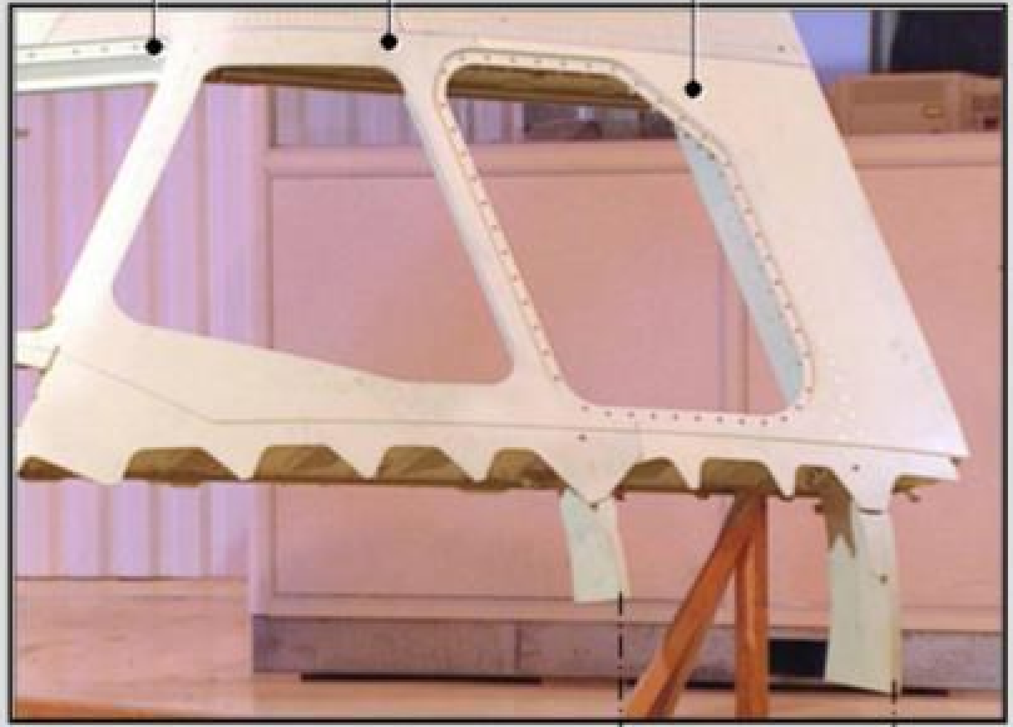
COCKPIT WINDOWS FRAMEWORK



Sliding window frame

Windshield frame

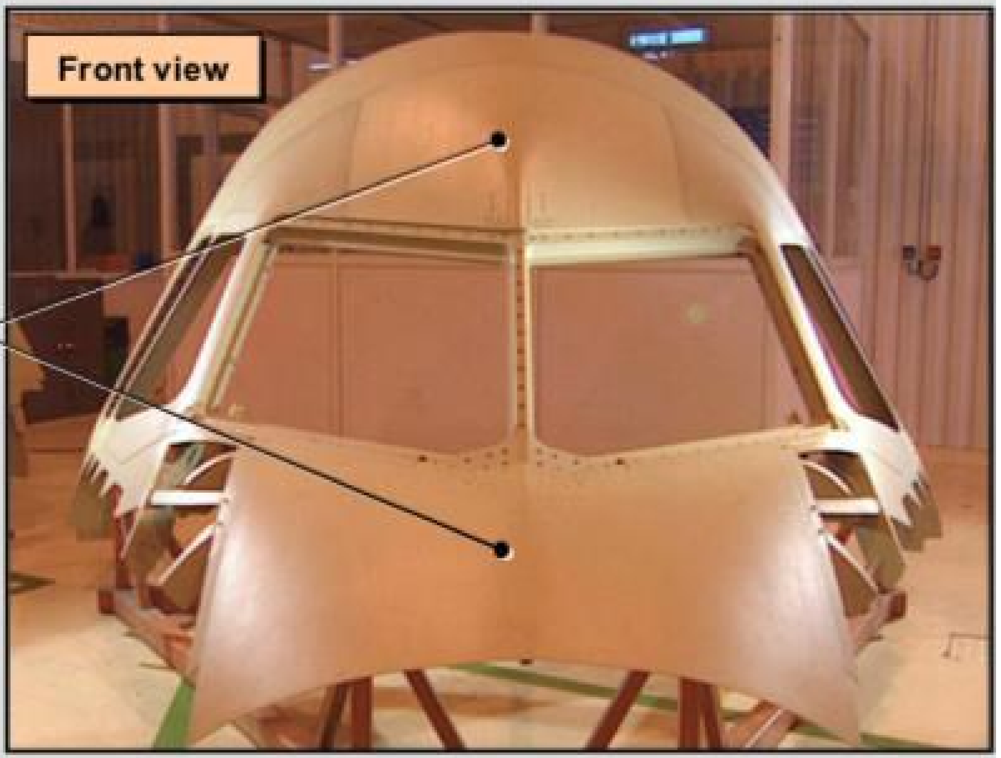
Side fixed window frame



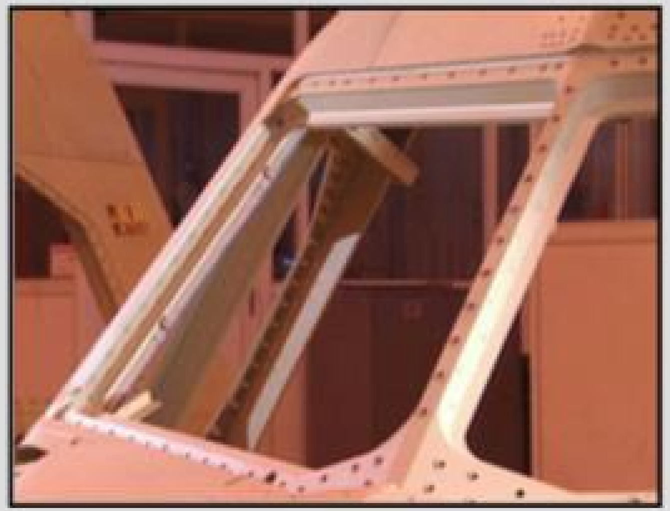
FR 8

FR 11

Skin panels
Ti alloy*



*For bird impact protection



APU access doors

Inner skin: Ti alloy
Outer skin: Al alloy on A318/A319/A321
Outer skin: Ti alloy on A320 up to MSN 261
Outer skin: Al alloy on A320 from MSN 262

APU exhaust nozzle
Ti alloy