Learn & Fly

Materials

Module #2

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2. Materials

2.1 Introduction

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Materials are the structural and/or functional support of all objects, structures and systems used in every activity of human life

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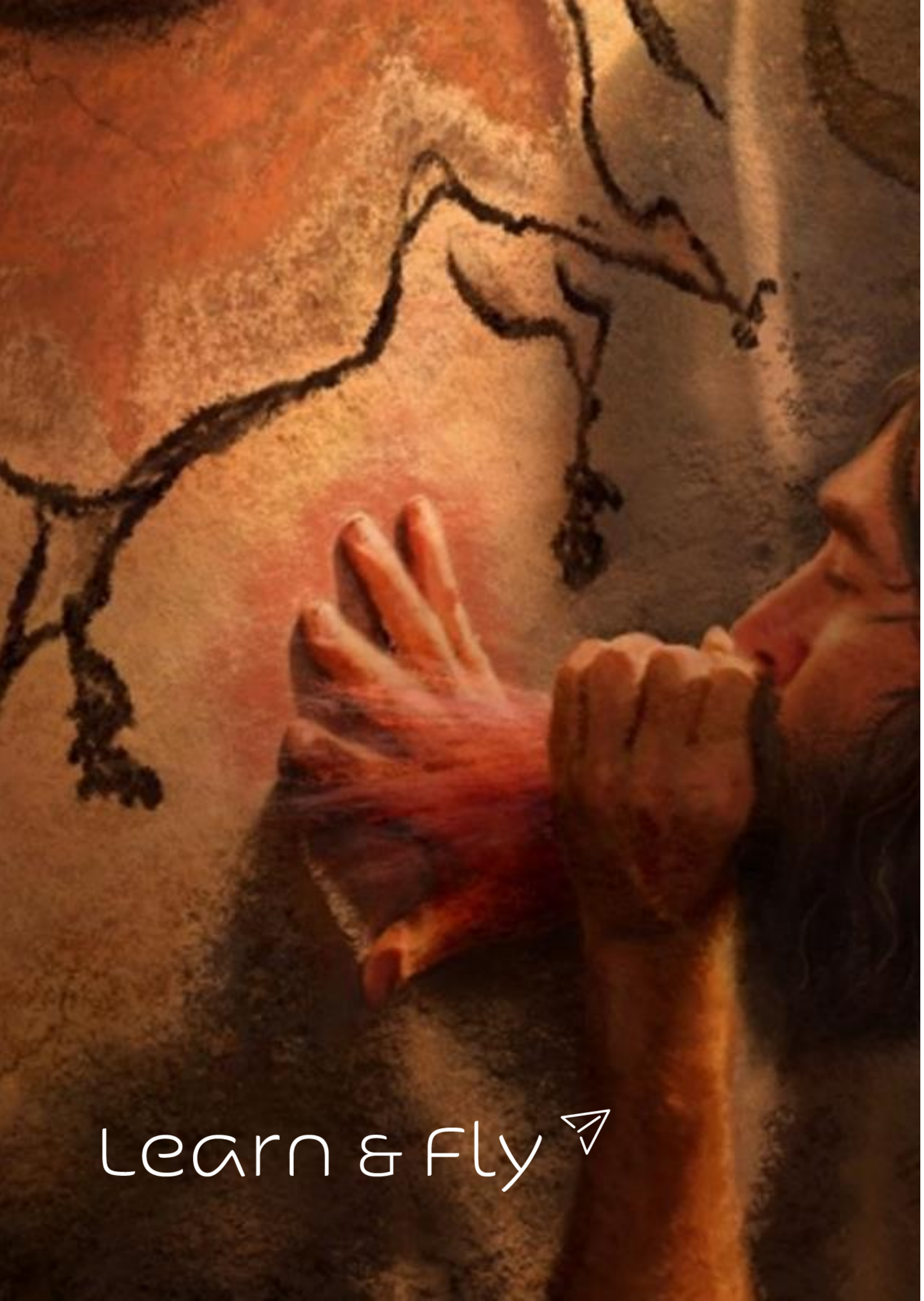
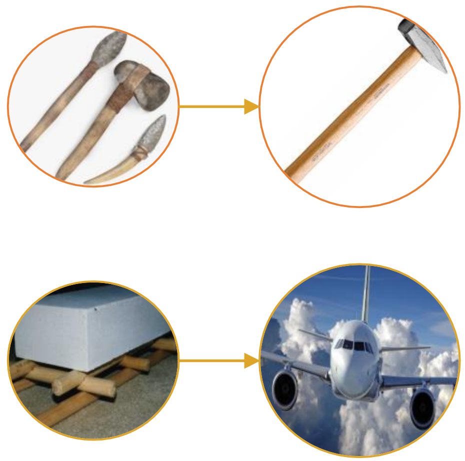


The history of materials is the history of humankind

Tools . Shelter . Weaponry . Clothes Self-expression . Transportation . Medicine



Natural Materials

Mineral:	Vegetal:	Animal:	Pure Metals (mostly gold and platinum)
			

Synthetic Materials

Man made - Transformation

PLASTICS + METALS + CERAMICS AND GLASSES = COMPOSITES

2. Materials

2.2 Materials requirements for aircraft

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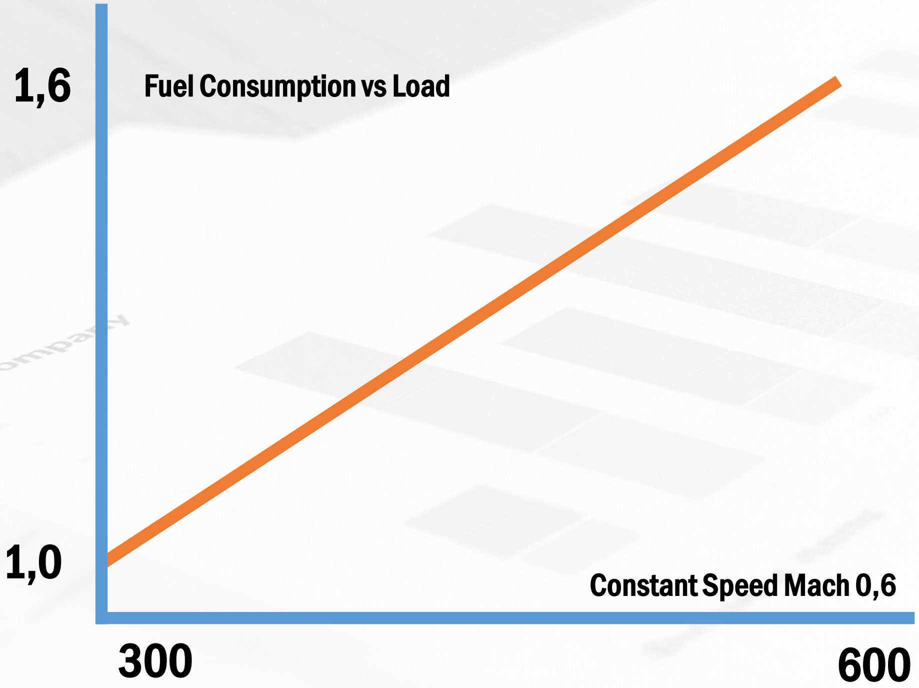
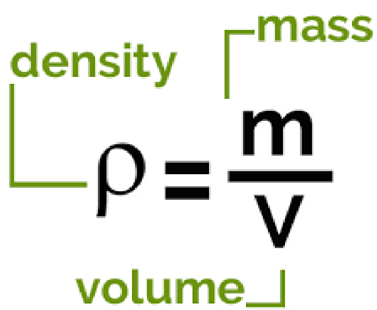


Low Density

- lower aircraft weight → lower fuel consumption
- fly farther
- fly faster
- higher passenger number or carrying capacity



Density

The density of a material varies with:

- **composition** (different alloys of the same metal, for example)
- **temperature**
- **pressure**

while density varies considerably with material composition, the effect of temperature and pressure is less pronounced

The density of a material doesn't depend on:

- **shape**
- **size**
- the value of a material property divided by the material density is a **specific property**
- this is a mean of using material data in a manner that is **independent of size or mass**

Structural Materials

- high mechanical properties
- provide physical support
- withstand applied load
- provide strength

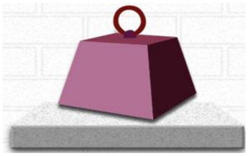
Functional Materials

other properties:

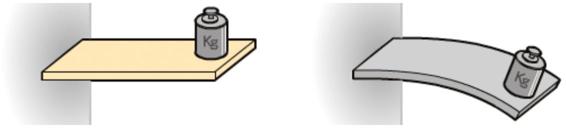
thermal   optical   magnetic   electric   chemical

High mechanical performance

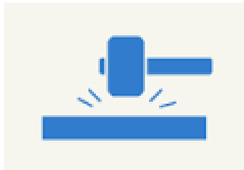
high strength



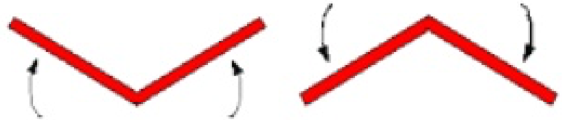
high rigidity



high toughness



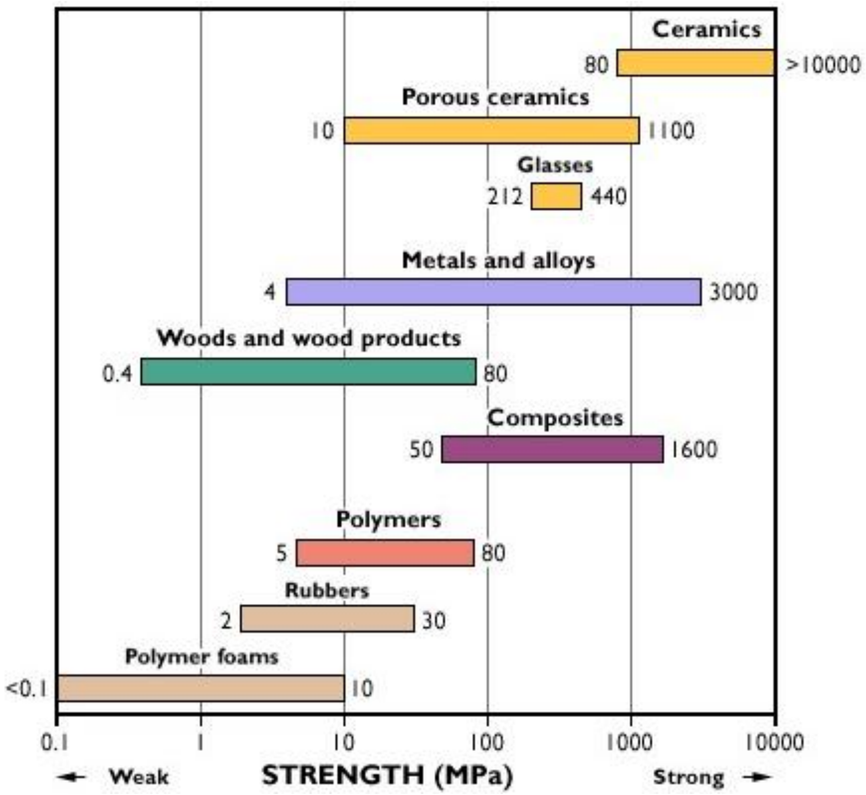
high resistance to fatigue

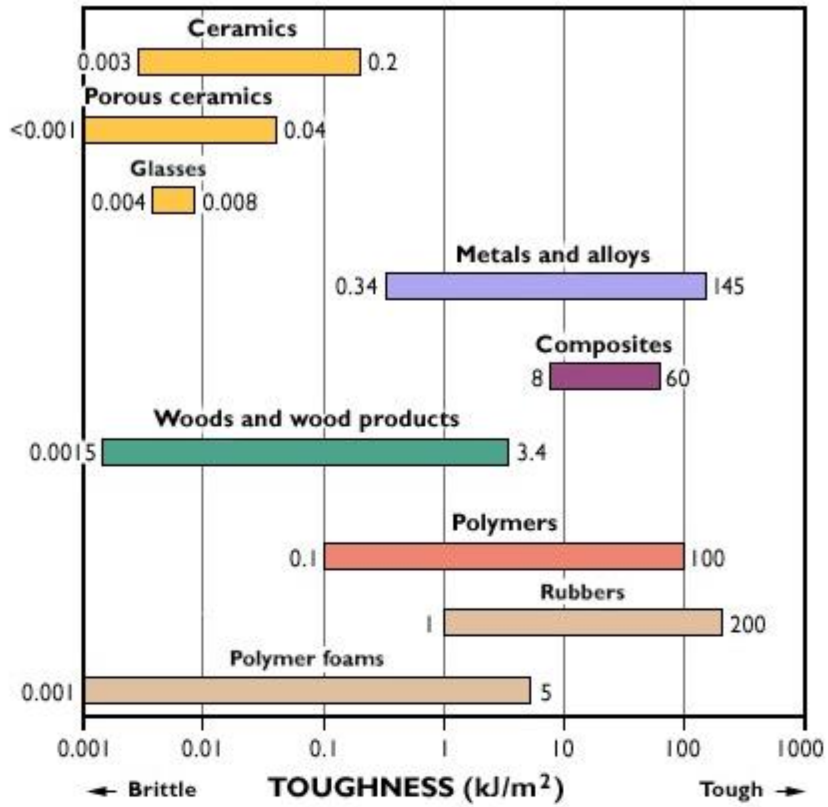


High resistance to corrosion

High resistance to temperature variation

High mechanical performance





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2.3 Materials for aircraft

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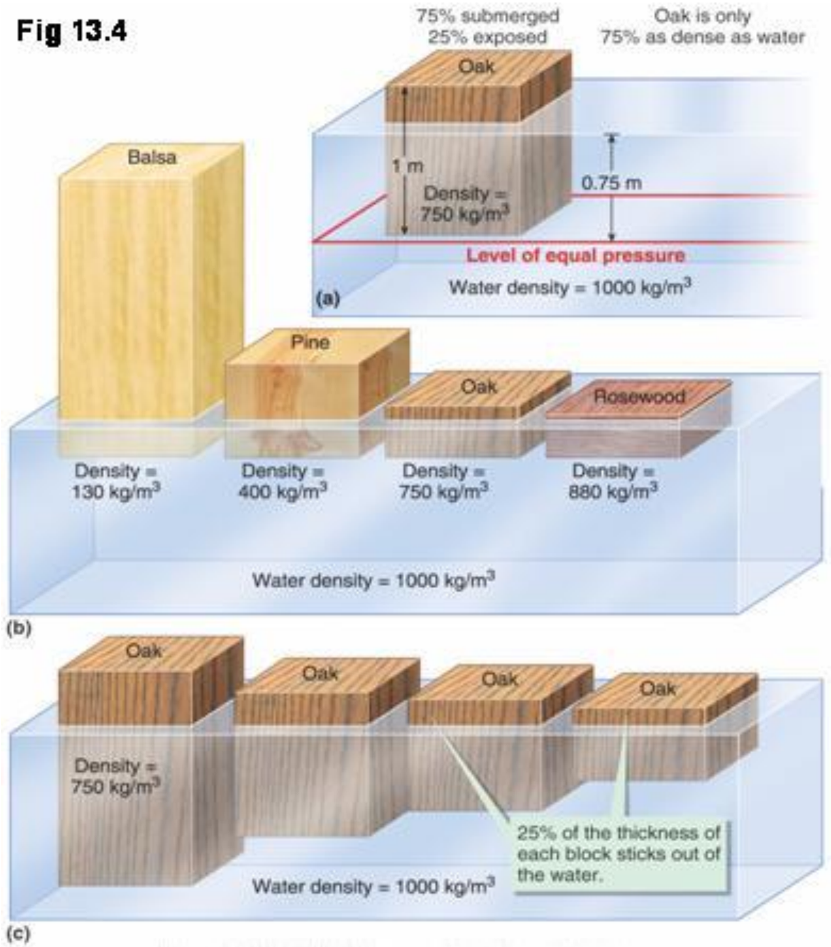
2.3 Materials for aircraft

2.3.1 WOOD

Fig 13.4



- natural composite
- celulose fibres in lenhine matrix
- typical properties:
- very low density
- strength is higher in the tree growing direction
- absorbes water
- combustible

Wright Flyer (1903)

Fuselage built on birch wood, covered with fabric

Aluminium engine block

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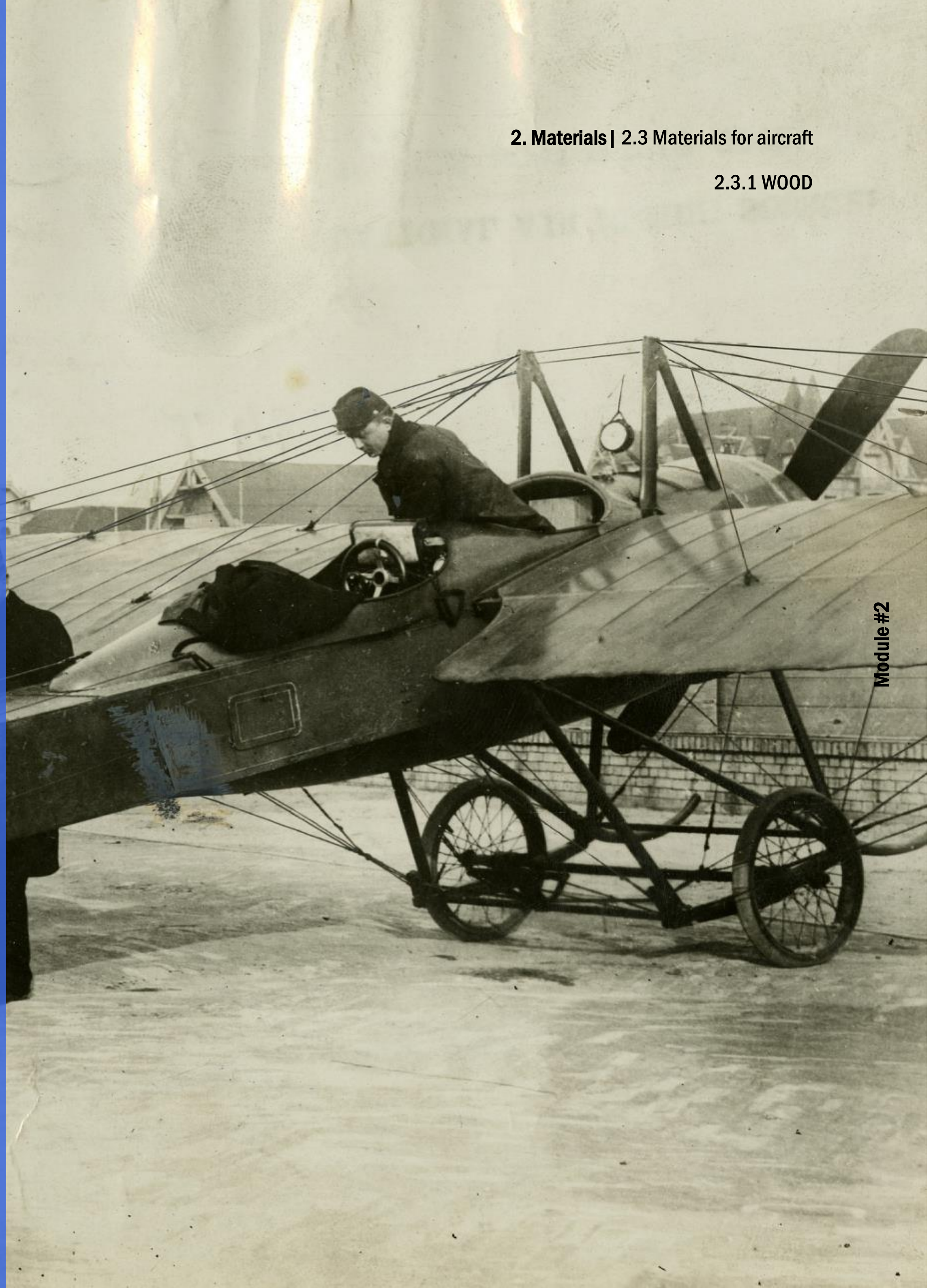
Deperdussin TT (1912)

Fuselage formed of three cross-grained layers of tulipwood, total thickness about 3 mm, covered with fabric inside and out

200 km/h



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Mosquito (1939)

Balsa wood sandwiched between layers of birch plywood, covered with fabric

Metal components only 127 kg

7700 units built until the 1940s

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Hughes Flying Boat, H-4 Hercules (1947)

Largest seaplane and largest wooden aircraft ever constructed (136 ton)

Airframe, surface structures, and flaps in laminated wood, fabric covered

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2.3 Materials for aircraft

2.3.1 WOOD - *main aircraft material up to the 1930s*

- inexpensive material
- low density material → low weight structures
- wood parts manufacturing and repairing is easy

wood success as aircraft material related to:

- slow development of lightweight high strength alloys
- slow development of structural alloys with high corrosion resistance

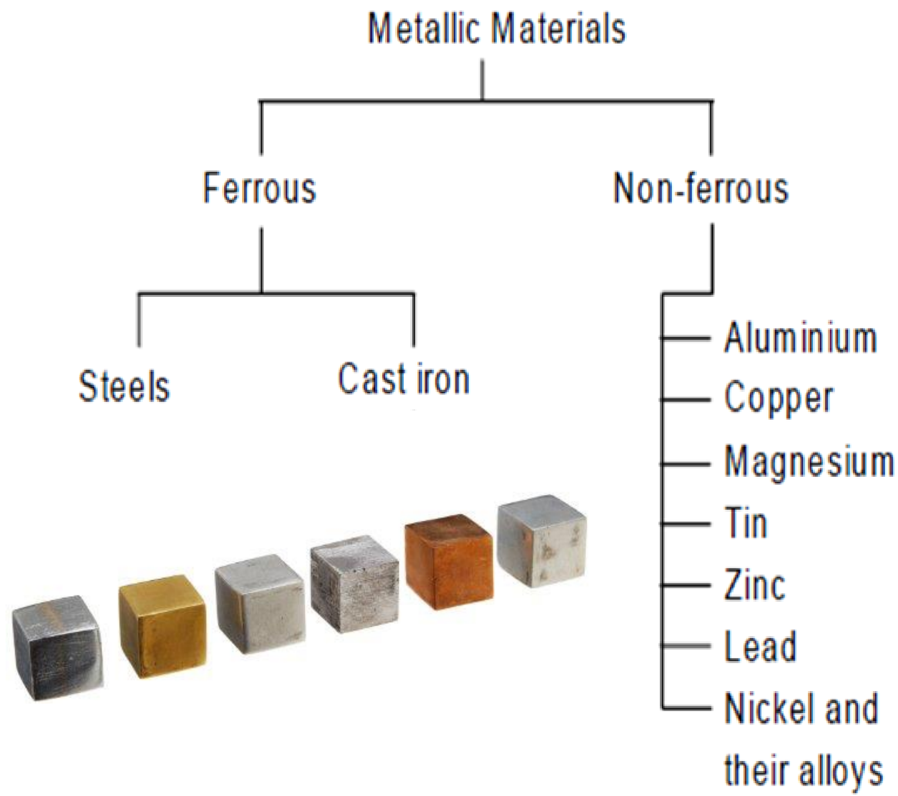
- Only a limited number of wood aircraft are produced nowadays, mostly by their owners and for education or recreation purposes
- Many wood aircrafts in which wood is the primary structural material still exist and operate, including some from the1930s. Proper maintenance and repair procedures allow them to be kept in airworthy condition

2.3 Materials for aircraft

2.3.2 ALUMINIUM

Metals - *typical properties:*

- high density
- high specific strength
- high rigidity
- low corrosion resistance
- high melting temperature



2.3 Materials for aircraft

2.3.2 ALUMINIUM

other metals in aircraft construction

Aluminium alloys

- low density ~ 2.7 g/cm³
- high specific strength
- high corrosion resistance
- low maximum service temperature

fuselage skin, stringers & frames wing skin, stringers & panels ribs & spars empennage (tail)

Titanium alloys

- intermediate density ~ 4.5 g/cm³
- high specific strength
- high corrosion resistance
- high temperature resistance
- significant creep resistance

skin panels
firewalls
fuel tank
engine blades & casing
noseconez

Steels

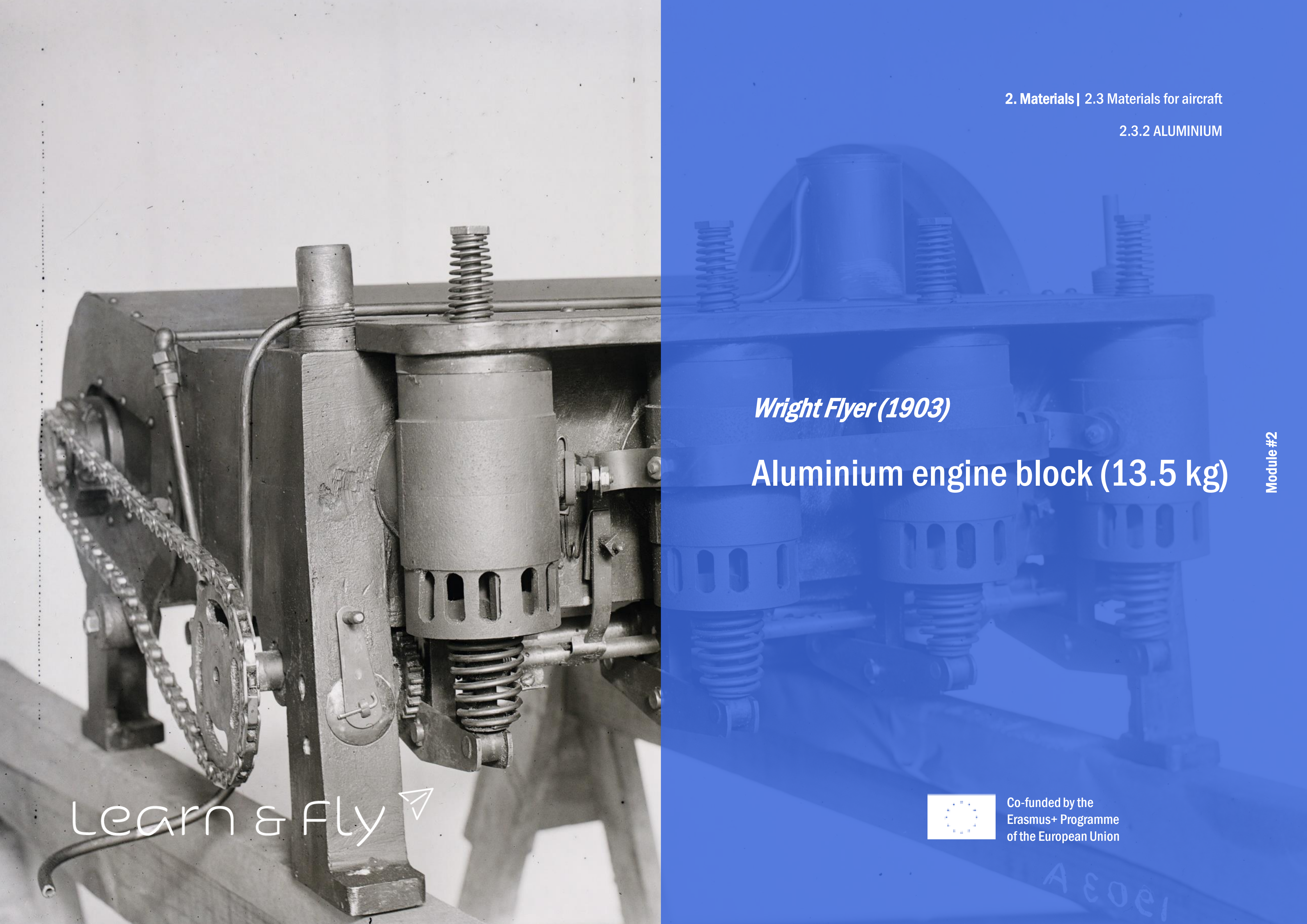
- high density ~ 7.8 g/cm³
- high specific strength
- low corrosion resistance
- low conductivity

slat tracks on wing leading edge
landing gear

Nickel alloys

- high density ~ 8.9 g/cm³
- high specific strength
- high corrosion resistance
- very expensive

engine blades



Wright Flyer (1903)

Aluminium engine block (13.5 kg)

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Alfred Wilm

DURALUMIN alloy (1906)

Al-3.5Cu-0.5Mg-0.5Mn

1st age-hardenable Al-alloy

strength increase

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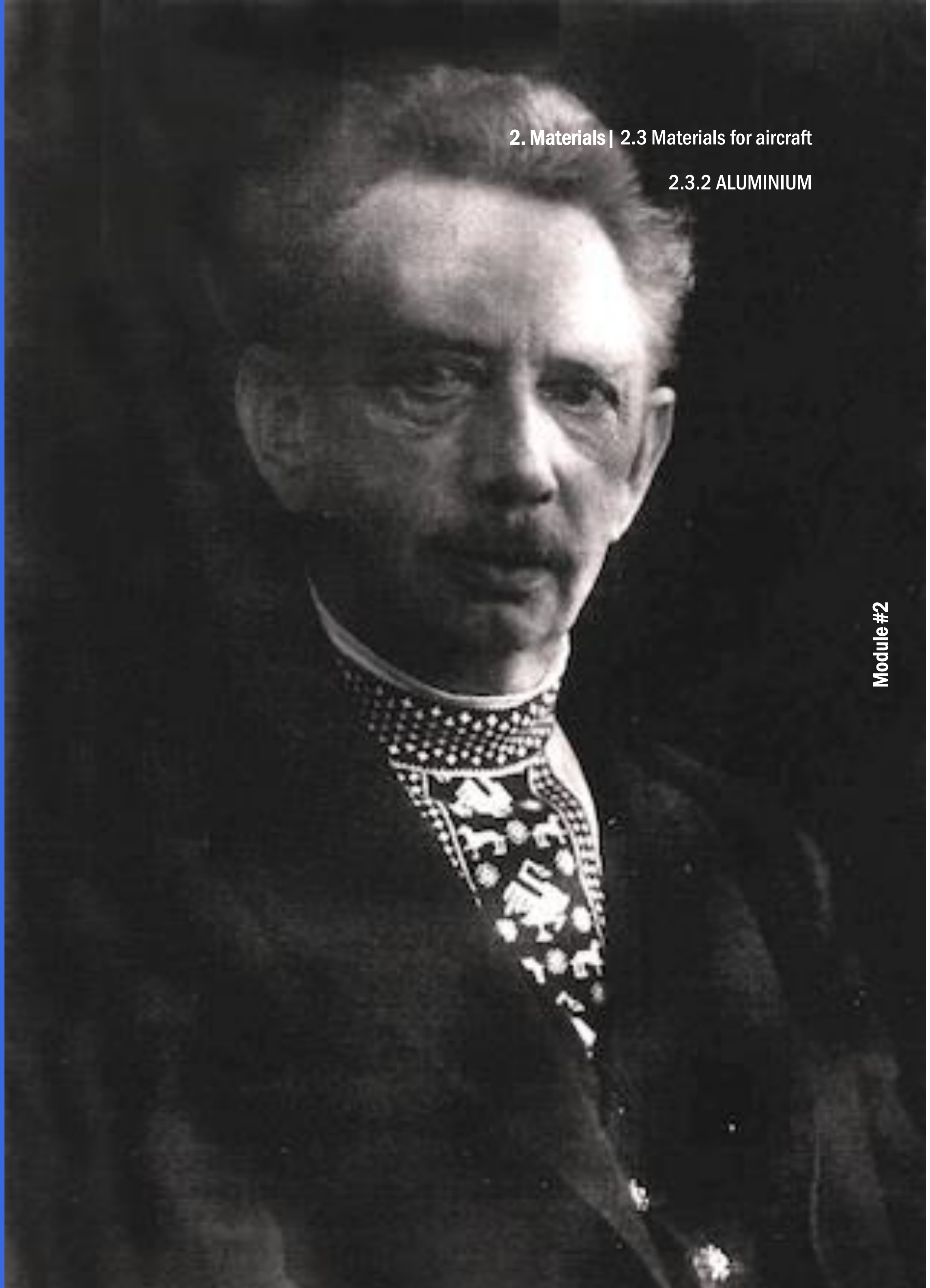


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Junkers J.I (1918)

German aviation on WWI first all-duralumin aircraft mass production

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U.S. Department of the Navy. Bureau of Aeronautics. Naval Aircraft Factory, National Archives and Records Administration. Public Domain,

Dirigible balloons (1920s-1930s

Passenger transportation

Duralumin aerostatic airframes

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2.3.2 ALUMINIUM - *state-of-the-art*

Concorde (1969-2003)

- possible cruise flight at 2x the speed of sound (Mach 2.04)
- development of new Al-alloy to bear aerodynamic heating
- HIDUMINIUM alloy (Al-2.5Cu-1.5Mg-1Fe-1.2Ni-0.2Si-0.1Ti

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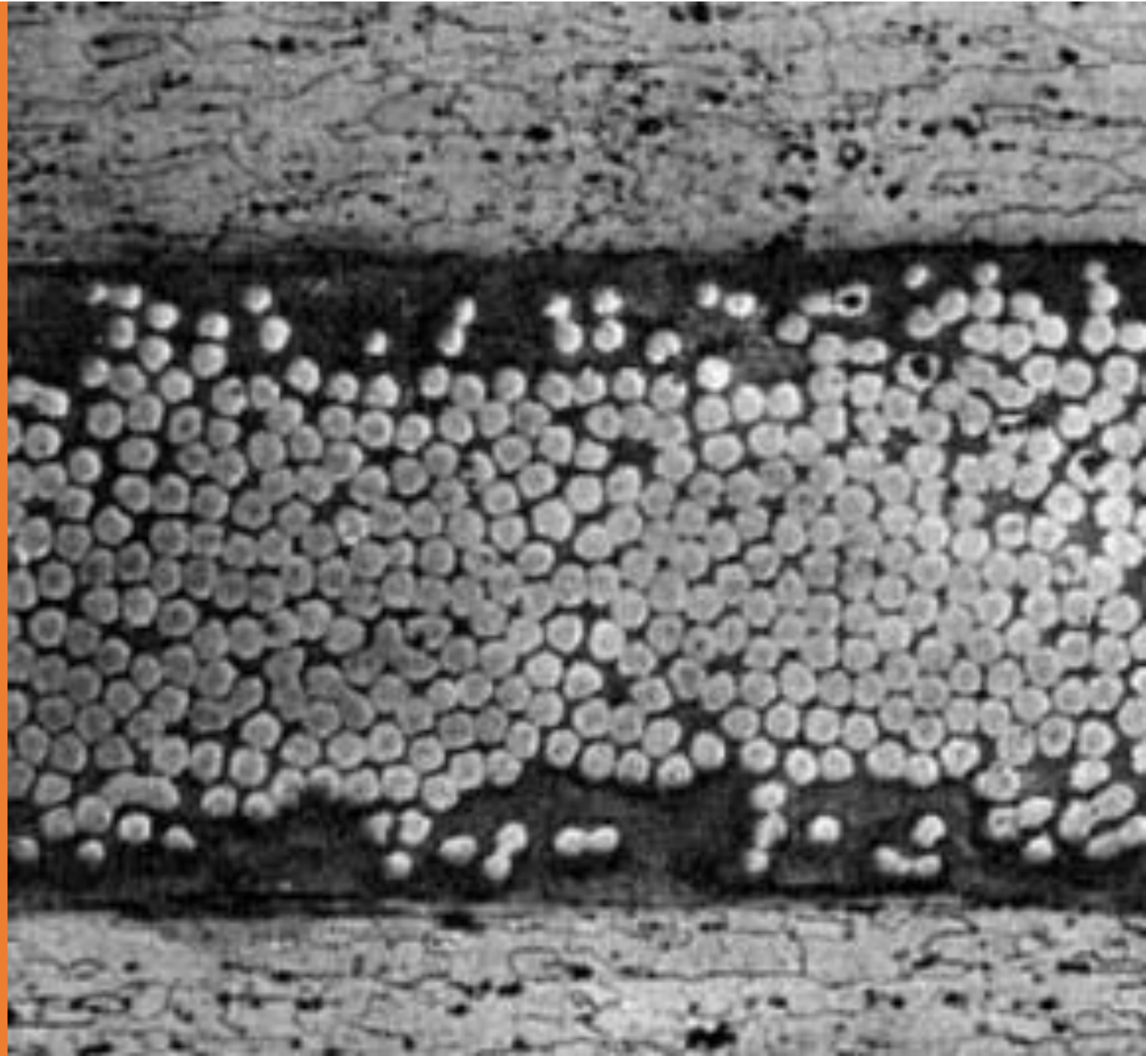
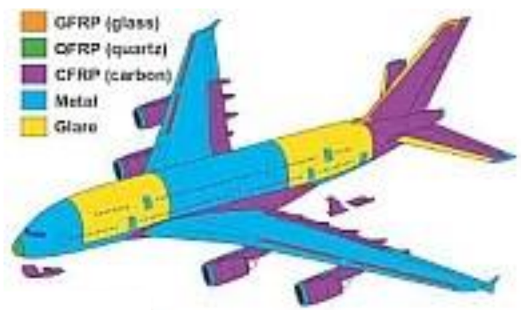
2.3 Materials for aircraft

2.3.2 ALUMINIUM - *state-of-the-art*

GLARE (1987)

- laminate of thin Al layers interspersed with glass-fiber layers, bonded with a resin
- better damage tolerance than Al
- lower density than Al





A380

2.3 Materials for aircraft

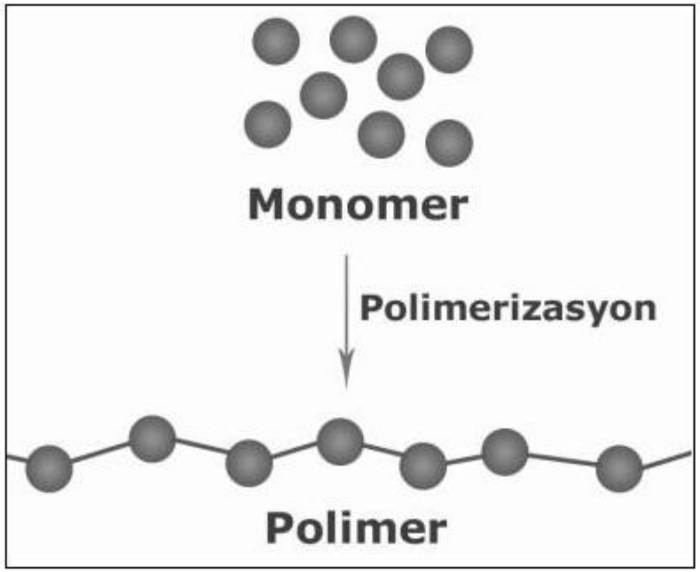
2.3.3. SYNTHETIC PLASTICS *(polymers)*

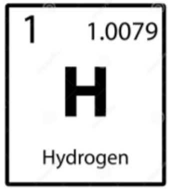
From the Greek, meaning πολύ poly (many) + μέρος mer (parts)

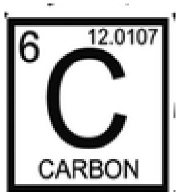
organic macromolecules

made mainly of

carbon and hydrogen







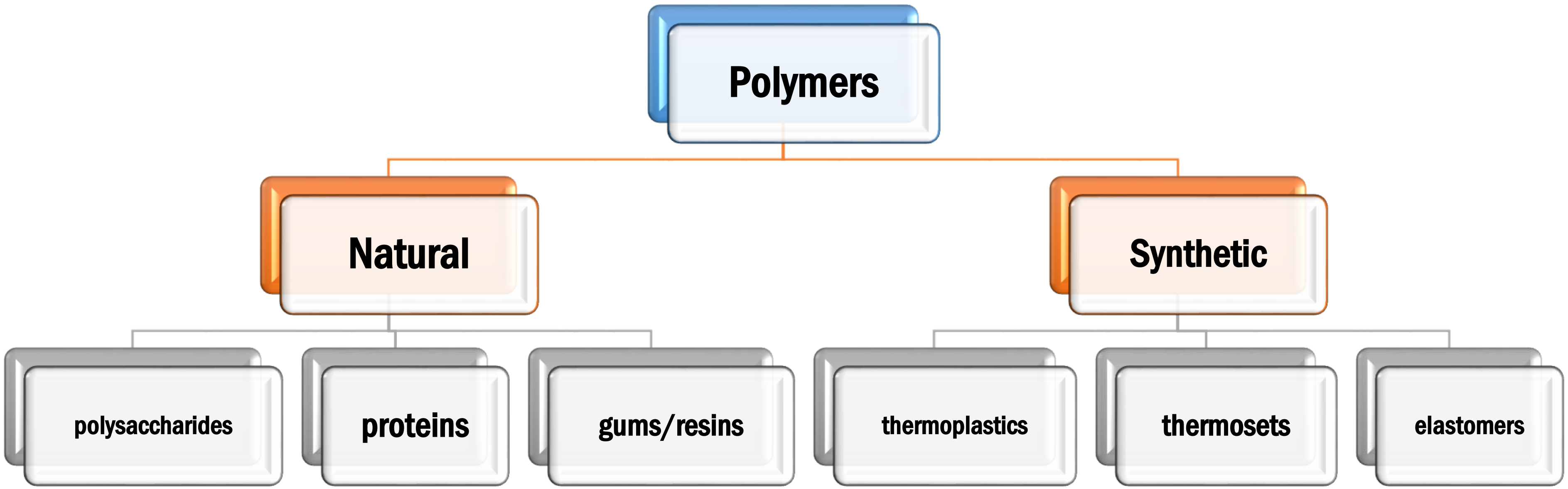
Plastics

- *typical properties:*

- very low density
- chemically inert
- thermal and electric insulators
- low melting temperature
- low rigidity
- easy to process
- inexpensive

2.3 Materials for aircraft

2.3.3. SYNTHETIC PLASTICS *(polymers)*



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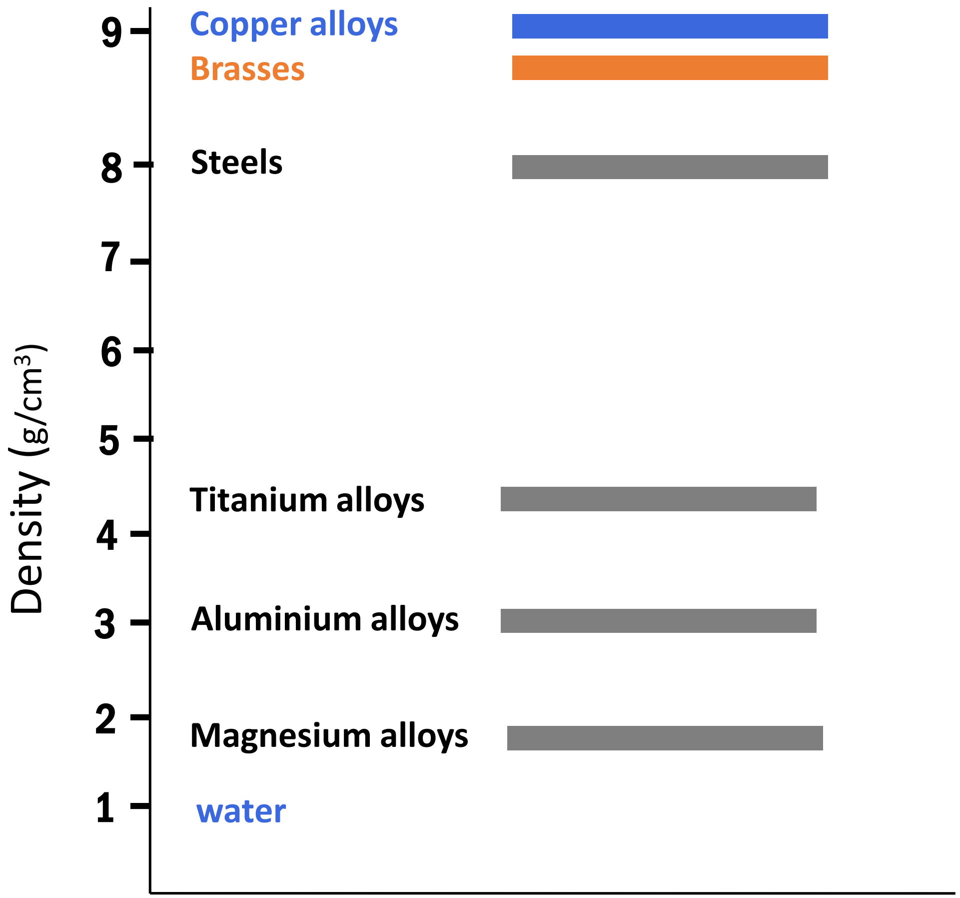
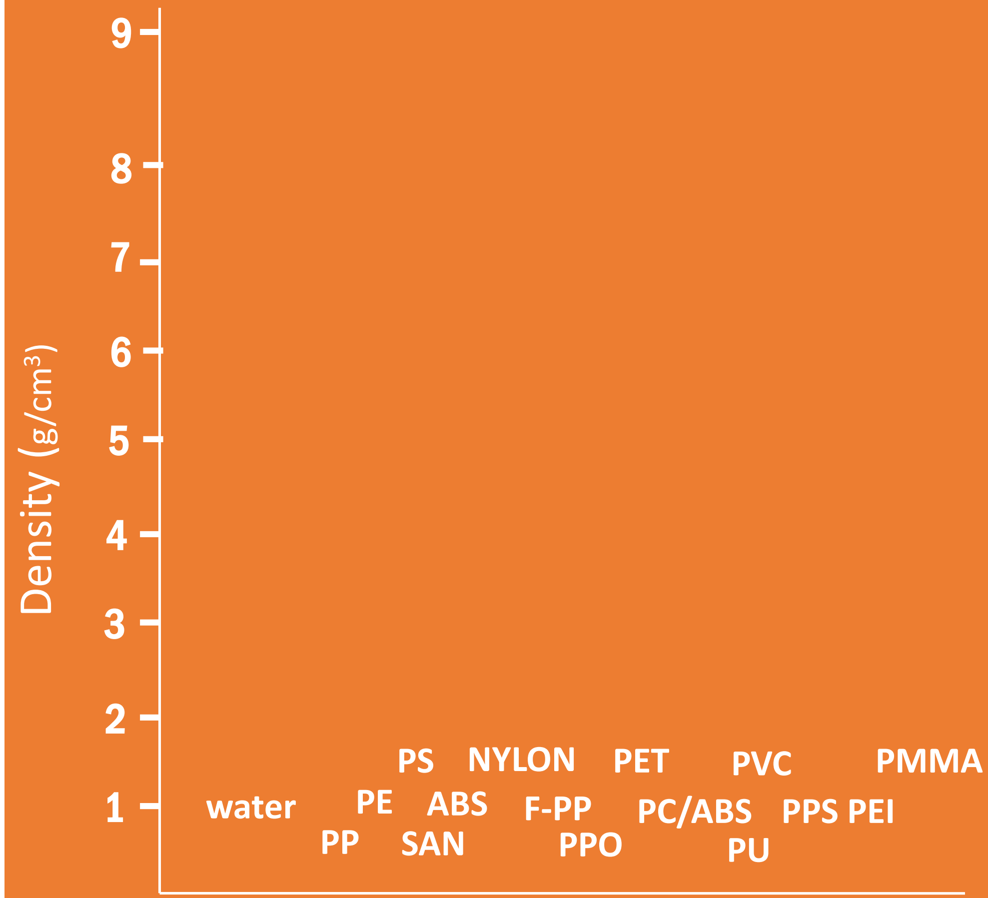
2.3.3. SYNTHETIC PLASTICS *density comparison*

Metals



Plastics



For the first time human manufacturing was not constrained by the limits of nature.
From then on, humans could create new materials.

Synthetic plastics *some history*

On the XIX century the growing popularity of billiards put a strain on the supply of natural ivory (obtained through the slaughter of wild elephants) to produce balls and cues

A New York firm offered $10,000 for anyone who could provide a substitute for ivory

John Wesley Hyatt took that challenge and invented the first synthetic polymer in 1869: **CELLULOID**

2.3 Materials for aircraft

2.3.3 Synthetic plastics *timeline*

- 1868 Cellulose Nitrate
- 1900 Viscose Rayon
- 1909 Phenol-Formaldehyde
- 1927 Cellulose Acetate
- 1933 Polyethylene
- 1933 Nylon
- 1941 Polyethylene Terephthalate
- 1942 Low Density Polyethylene
- 1942 Unsaturated Polyester
- 1957 Polypropylene
- 1964 Polyimide
- 1970 Thermoplastic Polyester
- 1978 Linear Low Density Polyethylene
- 1985 Liquid Crystal Polymers

2.3 Materials for aircraft

Synthetic plastics *identification codes*

Symbols	Description	Commonly found in
1 PETE	Polyethylene Terephthalate	Soda, water, and beer bottles; salad dressing containers
2 HDPE	High Density Polyethylene	Milk jugs; household cleaner containers; juice bottles; yogurt tubs
3 V	Vinyl	Shampoo bottles; cooking oil bottles; medical equipment; piping
4 LDPE	Low Density Polyethylene	Squeezable bottles; shopping bags; carpet; frozen food; food wraps
5 PP	Polypropylene	Yogurt containers; ketchup bottles; syrup bottles; medicine bottles
6 PS	Polystyrene	Meta trays; egg cartons; disposable plates and cups
7 OTHER	Miscellaneous	Sunglasses; iPod cases; computer cases; bullet-proof materials

plastics have contributed to life quality improvement in many ways

plastics production and discarded products have major impact on the environment

there are seven types of plastics labeled for recycling purposes

2.3 Materials for aircraft

Synthetic plastics *in aircraft construction*

low mechanical performance:

- low mechanical strength
- low rigidity
- only non-critical applications
- except for use as matrix material in composite materials

2.3 Materials for aircraft

2.3.4 Composites

synthetic materials resulting from the blending of two or more constituents, which differ in form and in chemical composition and are insoluble in each other, remaining separate and distinct in the finished structure

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2.3 Materials for aircraft

2.3.4 Composites - *some history*

the first known synthetic composites were found in Egypt: **adobe bricks** (mud or clay + straws)

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2.3 Materials for aircraft

2.3.4 Composites - *some vocabulary*

MATRIX phase

continuous phase

keeps the reinforcement in position

involves and protects the reinforcement

REINFORCEMENT phase

discontinuous phase dispersed within the matrix

generally with higher mechanical performance

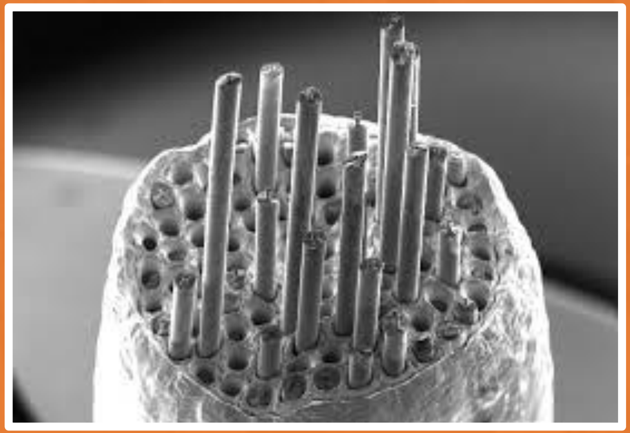
2.3 Materials for aircraft

2.3.4 Composites

Fibre-reinforced polymers are:

the main composites (by far) used in engineering applications

almost the only composites used in aircraft construction

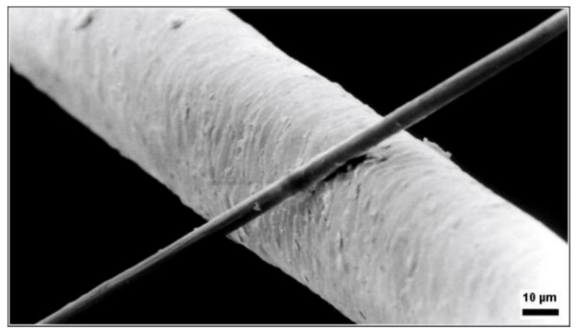


2.3 Materials for aircraft

2.3.4 Composites

epoxy resin reinforced with carbon fibers

is the most used composite material in aircraft construction



carbon fibre (6 µm) compared to a human hair (50 µm)

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2.3 Materials for aircraft

2.3.4 Composites advantages in aircraft construction

- overall weight reduction up to between 20 to 50 %
- higher strength at lower weight
- high impact resistance
- high thermal stability
- high damage tolerance enhances accident survivability
- resistant to fatigue
- resistant to corrosion
- structural components made of composite materials are easy to assemble

2.3 Materials for aircraft

2.3.4 Composites disadvantages in aircraft construction

- damages in the interior structure are difficult to detect
- repair is more difficult and costly than in metals
- the resin matrix weakens at temperatures as low as 150 ºC, limiting service temperature and demanding extra precautions to avoid fires
- fire involving composite materials can release toxic fumes and micro-particles into the air, causing health risks
- above 300 ºC matrix degradation can cause structural failure
- composite materials are expensive

F-14A (1970) horizontal stabilizers

F-14A (1970) horizontal stabilizers

2.3 Materials for aircraft

2.3.4 Composites - *some history*

originally used in military aircraft...

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F-15 e **F16** (1972 e 1974)
horizontal and vertical stabilizers

AV-8B (1981)
wing, stabilizers, part of outer fuselage

2.3 Materials for aircraft

2.3.4 Composites - *some history*

originally used in military aircraft...

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2.3 Materials for aircraft

2.3.4 Composites - *some history*

... and in very small amounts in commercial aircraft

Boeing 707 passenger jet (1957)
fiberglass-reinforced resin (2 %)

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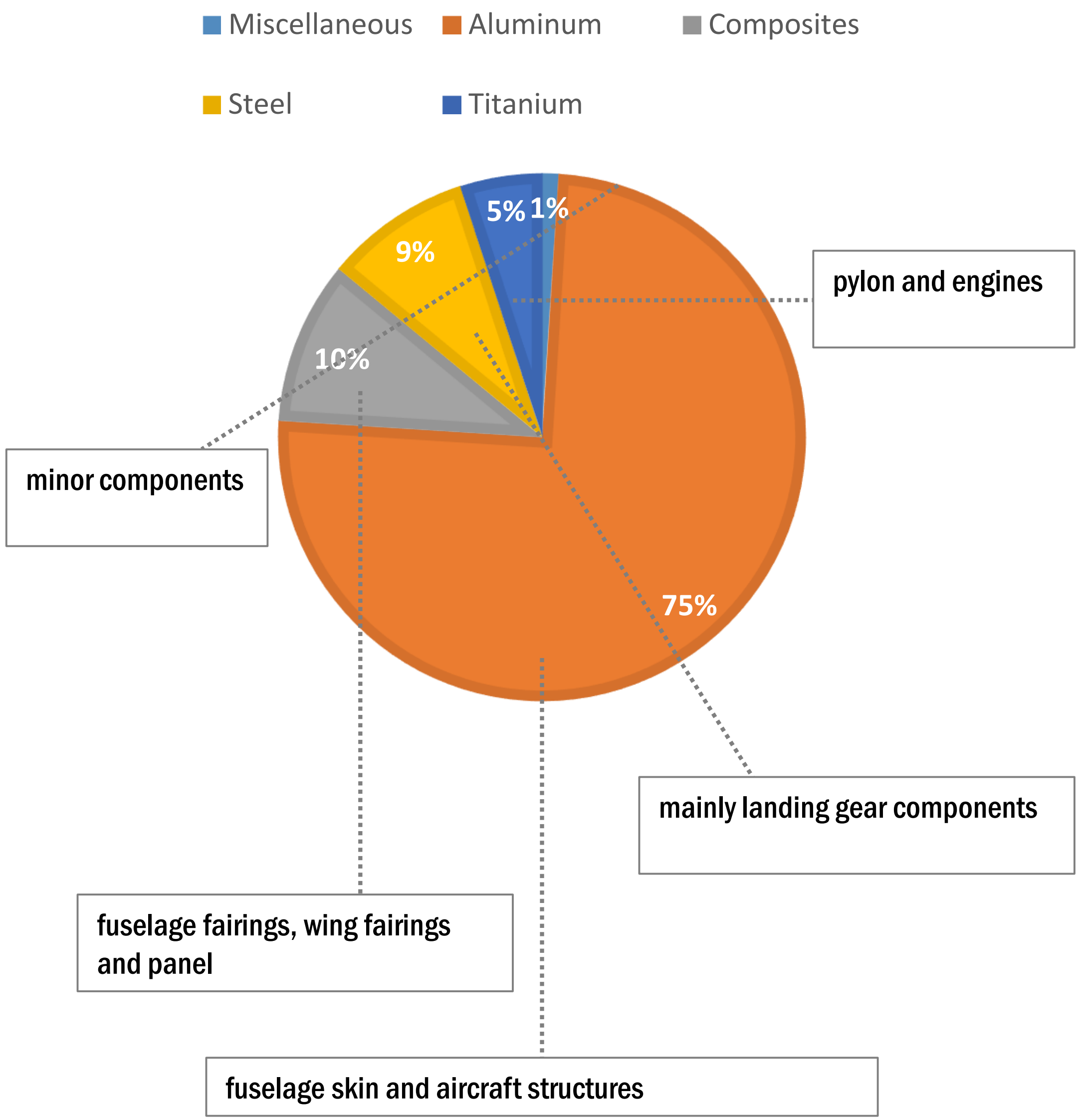
2.3 Materials for aircraft

2.3.4 Composites *state-of-the-art*

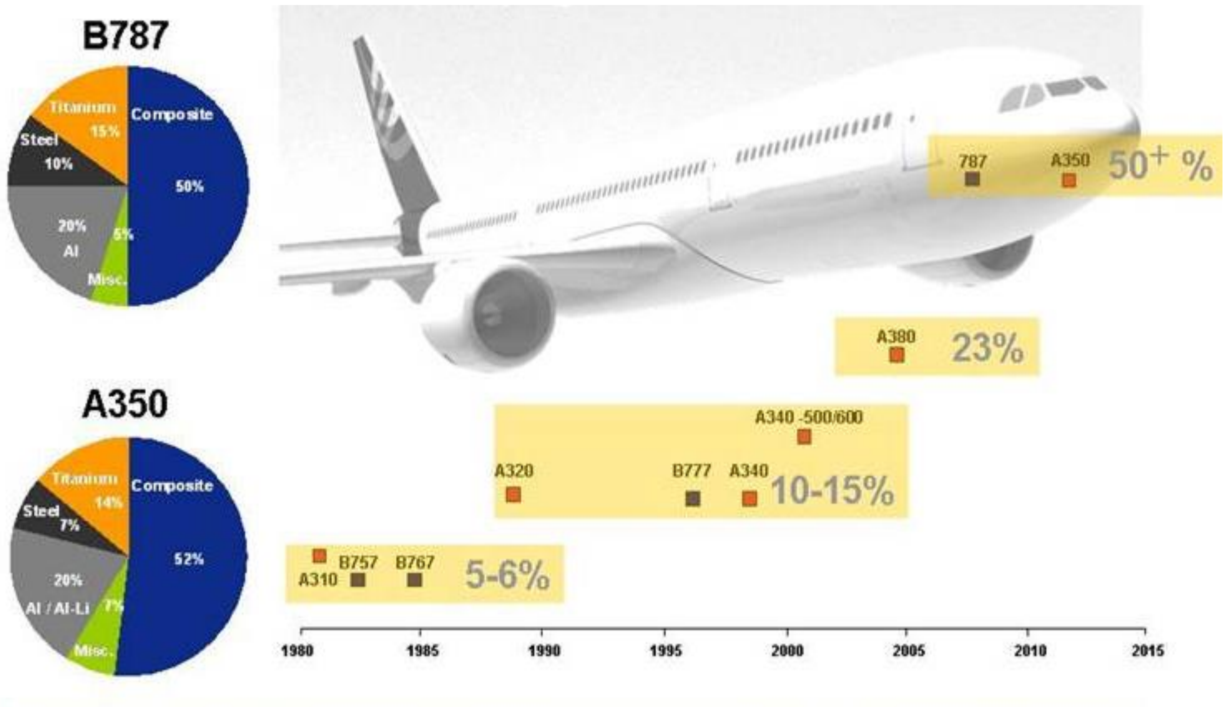
typical materials contents before 2009:



2.3 Materials for aircraft

2.3.4 Composites *state-of-the-art*

2009: 50% composites → Boeing 787 Dreamliner

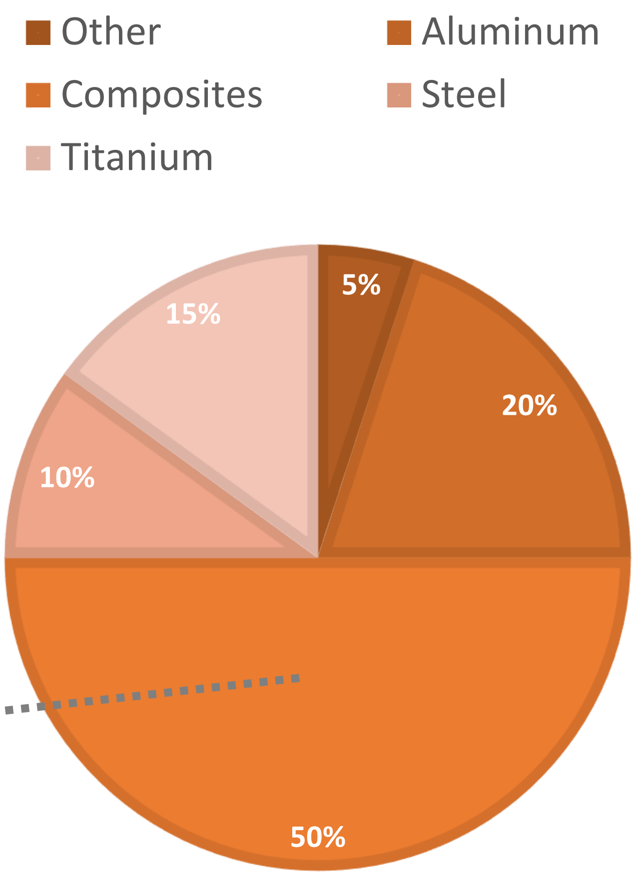


2.3 Materials for aircraft

2.3.4 Composites *state-of-the-art*

2009: 50% composites ⟶ Boeing 787 Dreamliner

- fuselage
- wings
- most other airframe components
- tail
- doors
- interior
- horizontal and vertical stabiliser
- engine's inlets
- bulkhead
- fuel tanks
- floors



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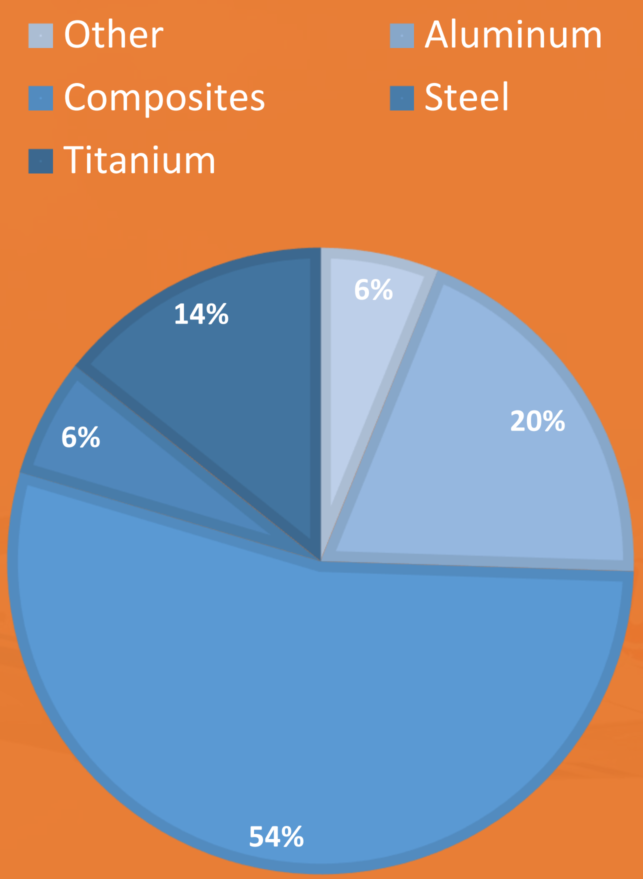
2.3.4 Composites *state-of-the-art*

2013: over 50% composites → Airbus A350



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2.4 Materials requirements for the challenge

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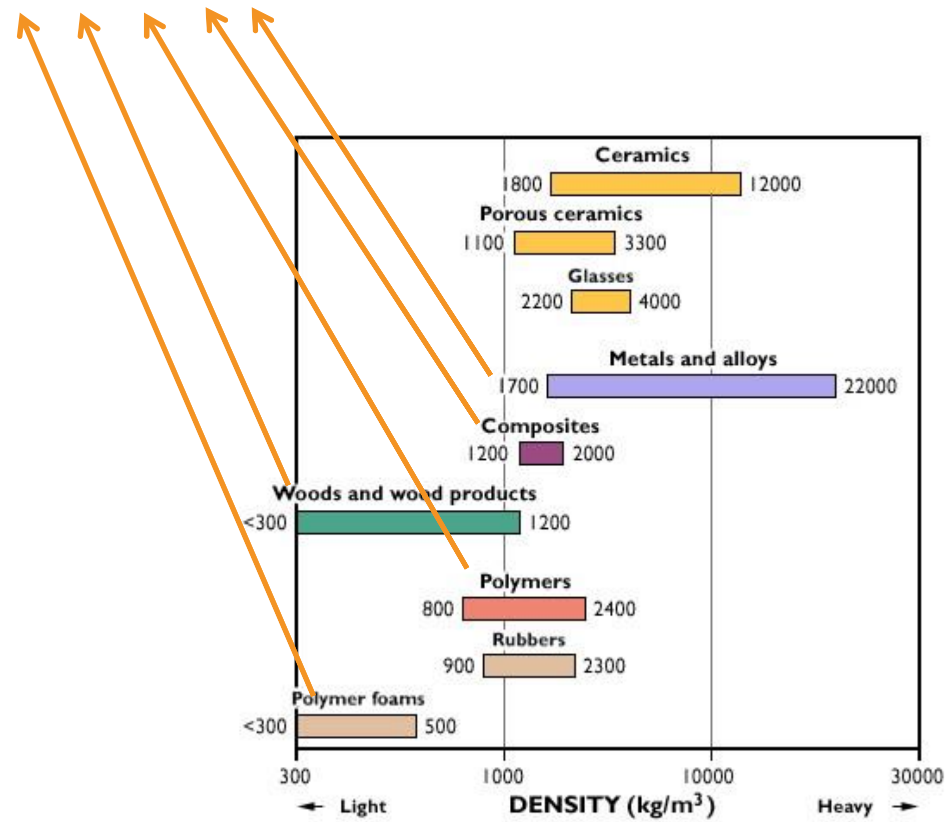
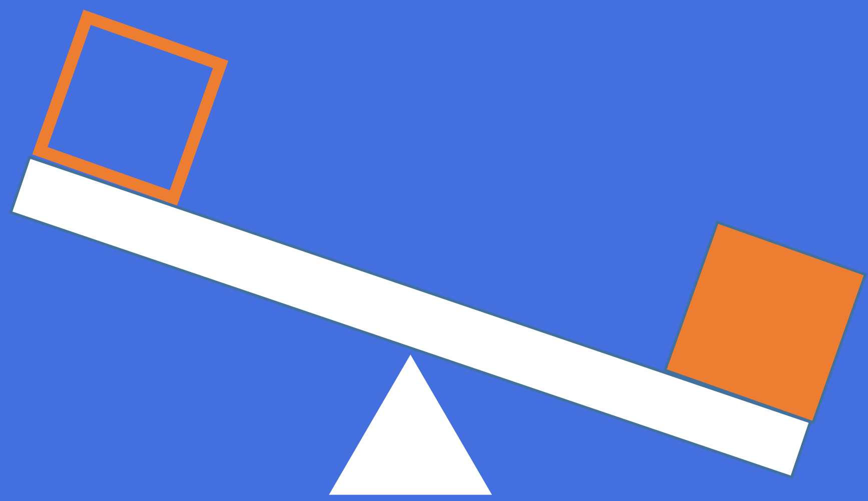
2.3 Materials for aircraft

2.4 Materials requirements for the challenge

Low density



available for the challenge



Low density

High density

2. Materials

2.5. The challenge: materials available in the kit

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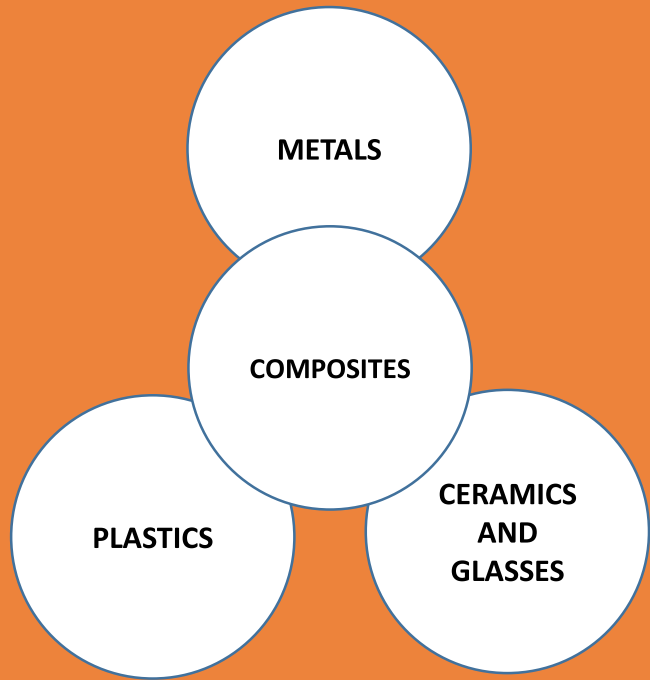
2.3 Materials for aircraft

2.5. The challenge: materials available in the kit

list of supplied materials

Material	Type
K-line cardboard	polymer (cellulose-based)
Glue for polystyrene foam	polymers (synthetic)
High density polystyrene foam	polymers (synthetic)
Velcro strip	polymers (synthetic)
Payload	metal
Fibre-glass tubes and rods	composite



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Take the Challenge!

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