SNS COLLEGE OF TECHNOLOGY
(An Autonomous Institution)

Department of Aerospace Engineering

23AST101-Fundamentals of Aerospace Engineering

UNIT-3:

AIRCRAFT STRUCTURES AND MATERIALS

Use of aluminium, Titanium and Composites in aircraft

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Use Of Aluminium

Aluminium alloys are **critical materials** in the aerospace industry due to their **lightweight, high strength, corrosion resistance, and cost-effectiveness**. They are widely used in **aircraft structures, engines, and components**.

Why Aluminium Alloys Are Preferred in Aircraft?

High Strength-to-Weight Ratio – Lighter than steel but strong enough for structural integrity.
Corrosion Resistance – Forms a protective oxide layer, reducing maintenance.
Good Fatigue Resistance – Can withstand repeated stress cycles (important for flight cycles).
Machinability & Formability – Easily shaped into complex aircraft parts.
Cost-Effective – Cheaper than titanium or composites for many applications.

Common Aluminium Alloys Used in Aircraft

Alloy	Key Properties	Aircraft Applications
2024 (Al-Cu)	High strength, good fatigue resistance	Aircraft skins, wings, fuselage structures
6061 (Al-Mg-Si)	Good weldability, corrosion resistance	Wing fittings, landing gear components
7075 (Al-Zn)	Very high strength, used in critical parts	Wing spars, fuselage frames, landing gear
7050 (Al-Zn-Cu)	Improved stress-corrosion resistance	Military aircraft, thick wing sections
6063 (Al-Mg-Si)	Good extrudability, lightweight	Interior components, hydraulic systems

Key Applications in Aircraft

1. Fuselage & Airframe Structure

2024 & 7075 alloys are used for fuselage panels, ribs, and bulkheads due to their high strength and fatigue resistance.

Aluminium-lithium (Al-Li) alloys (e.g., 2090, 2195) reduce weight further (used in Airbus A380 & Boeing 787).

2. Wings & Wing Boxes

7075 & 7050 alloys are used in wing spars and load-bearing structures because they handle high stress.

Al-clad alloys (thin pure Al layer) improve corrosion resistance.

3. Landing Gear

High-strength 7075 & 7050 alloys are used due to their ability to withstand heavy loads and impacts.

4. Engine Components

Al alloys (e.g., 2618) are used in engine housings, pistons, and compressor blades (where temperatures are moderate).

5. Interior & Secondary Structures

6061 & 6063 alloys are used for seats, overhead bins, and hydraulic systems due to their lightweight and corrosion resistance.

Advantages Over Other Materials

✓ Lighter than steel → Better fuel efficiency.

✓ Cheaper than titanium & composites → Cost-effective for mass production.

✓ Easier to repair than carbon fiber composites.

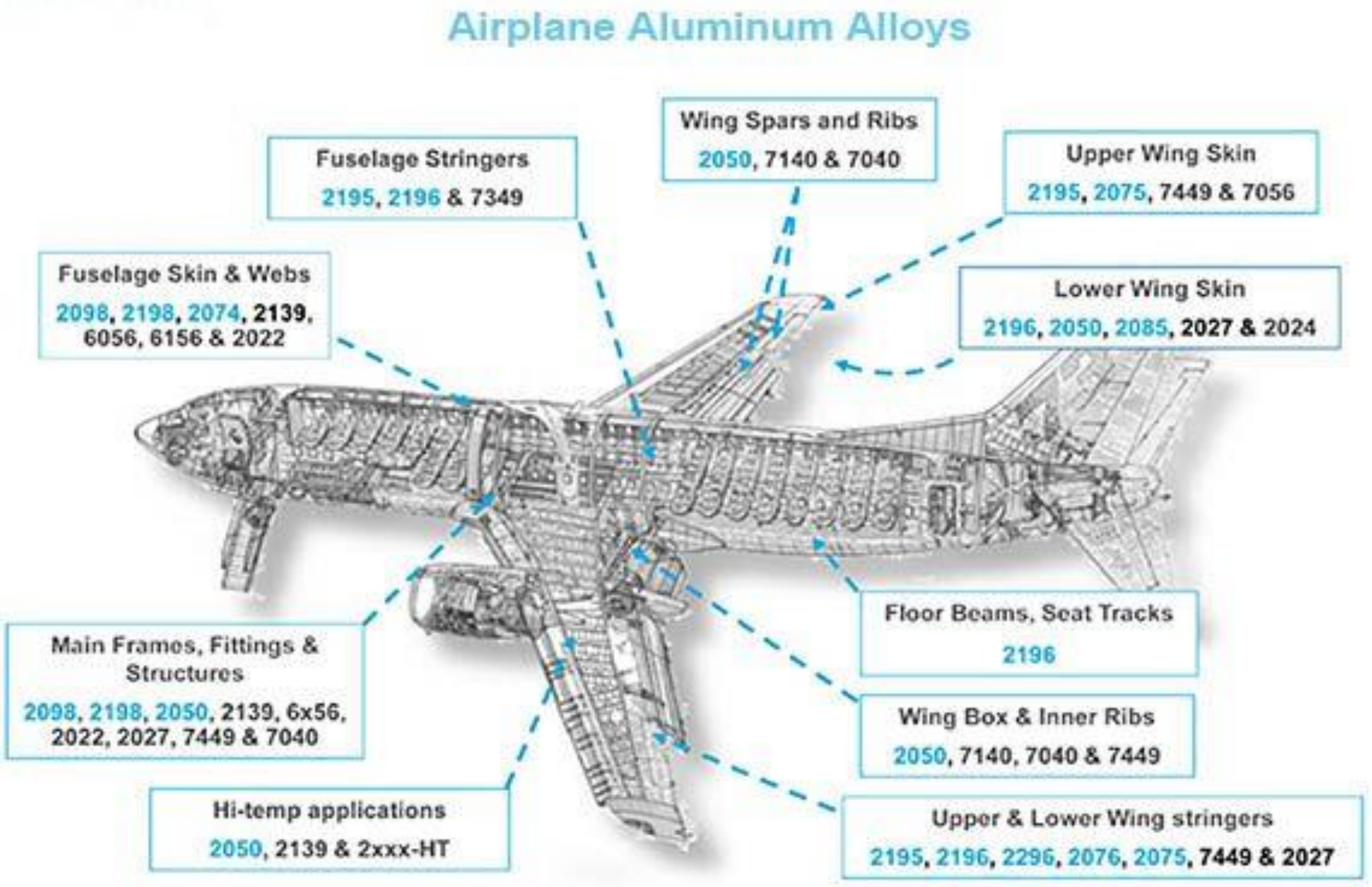
Challenges & Future Trends

Competition from Composites: Carbon fiber is replacing Al in some modern aircraft (e.g., Boeing 787).

New Al-Li Alloys: Reduce weight further while maintaining strength.

Additive Manufacturing (3D Printing): Allows complex Al alloy parts with reduced waste.

Use Of Aluminium



Use Of Titanium

Titanium alloys are **critical materials** in the aerospace industry due to their **high strength-to-weight ratio, corrosion resistance, and ability to withstand extreme temperatures**. They are widely used in both **commercial and military aircraft**, as well as in **spacecraft and jet engines**.

Key Properties of Titanium Alloys for Aerospace Applications

✓ **High Strength & Lightweight** – Comparable strength to steel but **45% lighter**, improving fuel efficiency.

✓ **Excellent Corrosion Resistance** – Resists oxidation, saltwater, and jet fuel exposure.

✓ **High-Temperature Performance** – Retains strength at temperatures up to **600°C (1112°F)**.

✓ **Fatigue Resistance** – Withstands repeated stress cycles without cracking.

✓ **Biocompatibility** – Non-toxic, used in aircraft components exposed to passengers.

Common Titanium Alloys Used in Aerospace

Alloy	Composition	Key Applications
Ti-6Al-4V	90% Ti, 6% Al, 4% V	Jet engines, airframe structures, fasteners
Ti-6Al-2Sn-4Zr-2Mo	Ti + Al, Sn, Zr, Mo	High-temperature engine components
Ti-3Al-2.5V	Ti + Al, V	Hydraulic tubing, aircraft piping
Ti-15V-3Cr-3Sn-3Al	Beta-phase alloy	Wing structures, springs

Major Applications of Titanium Alloys in Aircraft

1. Airframe Structures

Fuselage & Wing Components – Used in high-stress areas like landing gear, wing spars, and bulkheads.

Fasteners & Joints – Titanium bolts, rivets, and brackets reduce weight while maintaining strength.

Seat Tracks & Floor Beams – Provides durability without adding excessive weight.

2. Jet Engines (Aero-Engines)

Fan Blades & Compressor Disks – Withstand high rotational speeds and temperatures.

Engine Casings & Exhaust Ducts – Resists heat from jet exhaust (e.g., Ti-6Al-4V alloy).

Afterburner Components – Used in military jets due to heat resistance.

3. Military & High-Performance Aircraft

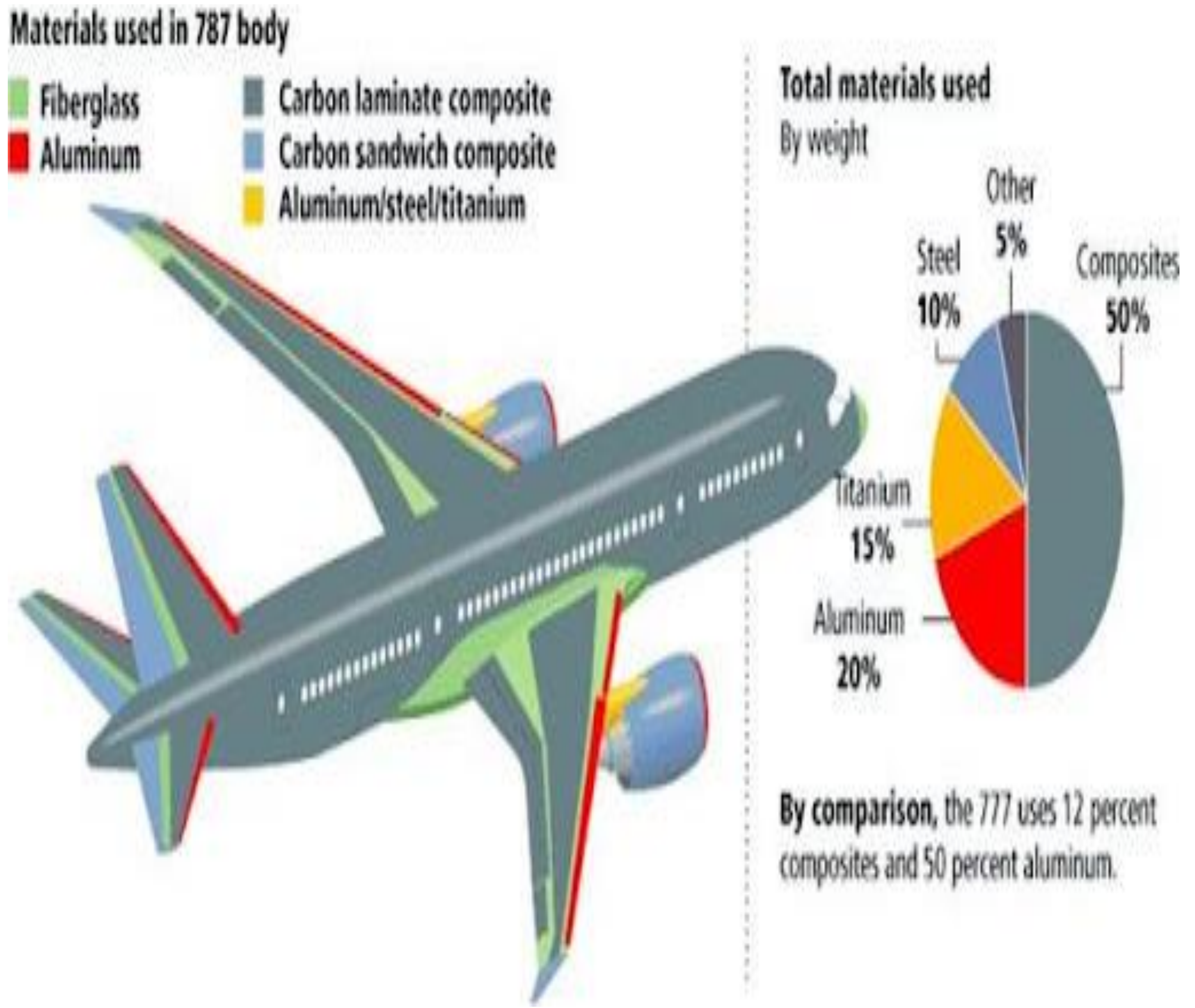
Stealth Aircraft (e.g., F-22, F-35) – Titanium's radar-absorbing properties enhance stealth.

Supersonic Jets (e.g., SR-71 Blackbird) – Titanium airframes handle aerodynamic heating at Mach 3+.

4. Spacecraft & Hypersonic Vehicles

Rocket & Satellite Components – Used in fuel tanks, heat shields, and structural parts.

Re-entry Vehicles – Resists extreme thermal stress during re-entry.



Advantages Over Other Metals

✅ Better than Aluminum – Stronger at high temps (aluminum weakens above 150°C).

✅ Better than Steel – Lighter with similar strength, reducing fuel consumption.

✅ Better than Composites – More damage-tolerant in critical load-bearing parts.

Use Of Composite Materials

Composite materials have revolutionized the aviation industry by offering **high strength-to-weight ratios, corrosion resistance, and design flexibility**. They are now extensively used in modern aircraft, replacing traditional metals like aluminum and steel.

Why Composites in Aircraft?

✅ **Lightweight** – Reduces fuel consumption and increases efficiency.
✅ **High Strength & Stiffness** – Better structural performance than metals.
✅ **Fatigue & Corrosion Resistance** – Longer lifespan with less maintenance.
✅ **Design Flexibility** – Can be molded into complex shapes (e.g., wing curves).
✅ **Radar Transparency** – Useful for stealth military aircraft.

Key Aircraft Components Made from Composites

Component	Material Used	Benefits
Wings & Wing Box	CFRP (Carbon Fiber)	Reduces weight, improves aerodynamics
Fuselage	CFRP, Honeycomb Core	Lower fuel burn, higher payload
Tail Fin (Empennage)	CFRP/GFRP	Lighter, more durable
Interior Panels	GFRP, Kevlar®	Fire-resistant, lightweight
Engine Nacelles	CFRP, Kevlar®	Heat & impact resistant
Rotor Blades (Helicopters)	CFRP, GFRP	High fatigue resistance

Common Composite Materials Used in Aircraft

1. Carbon Fiber Reinforced Polymer (CFRP)

Composition: Carbon fibers + Epoxy resin.

Properties: Extremely strong, lightweight, and stiff.

Applications:

- **Boeing 787 Dreamliner** (50% composites by weight).
- **Airbus A350 XWB** (53% composites).
- **Wings, fuselage, tail sections, and rotor blades.**

2. Glass Fiber Reinforced Polymer (GFRP)

Composition: Glass fibers + Polyester/Epoxy resin.

Properties: Good strength, cheaper than CFRP, but heavier.

Applications:

- **Interior panels, radomes, and secondary structures**.
- Used in **smaller aircraft and helicopters**.

3. Aramid Fiber (Kevlar®) Composites

Composition: Kevlar fibers + Epoxy resin.

Properties: High impact resistance, lightweight.

Applications:

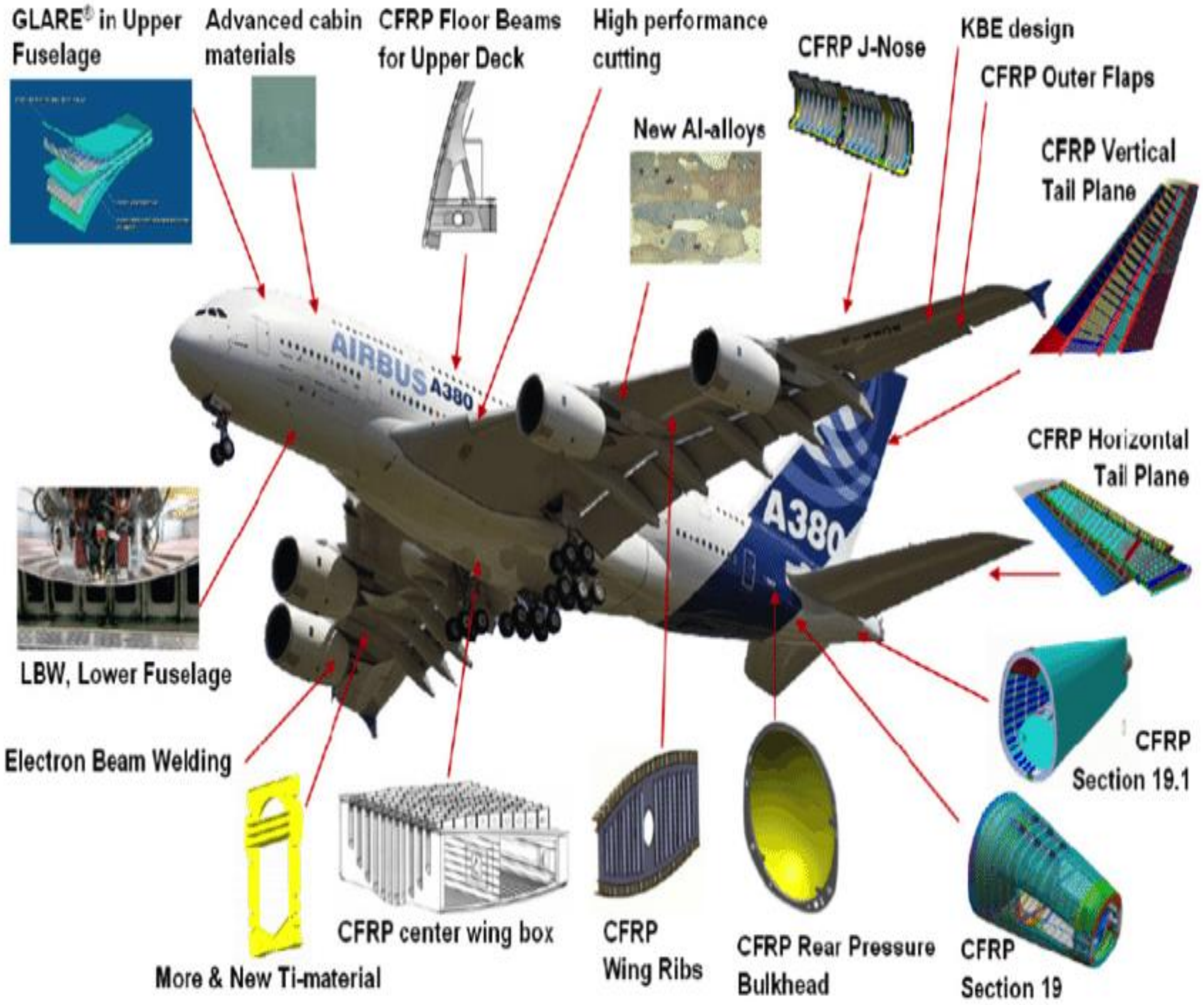
- **Bulletproof cockpit doors, rotor blades, and engine nacelles**.
- Used in military aircraft like the **F-35 Lightning II**.

4. Hybrid Composites (Combination of Fibers)

Example: Carbon-Kevlar or Carbon-Glass hybrids.

Applications:

- Used in **fighter jets and UAVs** for optimized performance.



Advantages Over Traditional Metals

🔹 **50-70% lighter than aluminum**, leading to **20-30% fuel savings**.
🔹 **Fewer joints & rivets** → Lower maintenance costs.
🔹 **Better fatigue life** → Longer operational lifespan.
🔹 **Customizable properties** (e.g., directional strength for wings).

Challenges & Limitations

⚠ **High manufacturing cost** (compared to aluminum).
⚠ **Repair complexity** (requires specialized techniques).
⚠ **Susceptibility to impact damage** (e.g., bird strikes).
⚠ **Recycling difficulties** (most composites are not easily recyclable).

Future Trends

🚀 **3D-Printed Composites** – Faster prototyping & complex part manufacturing.
🚀 **Self-Healing Composites** – Automatic repair of micro-cracks.
🚀 **Nanocomposites** – Enhanced strength & thermal resistance.

THANK YOU!