INTRODUCTION TO AIRCRAFT STRUCTURES

Prof. Ian Lane
Senior Structures Expert, Airbus

il14001@Bristol.ac.uk

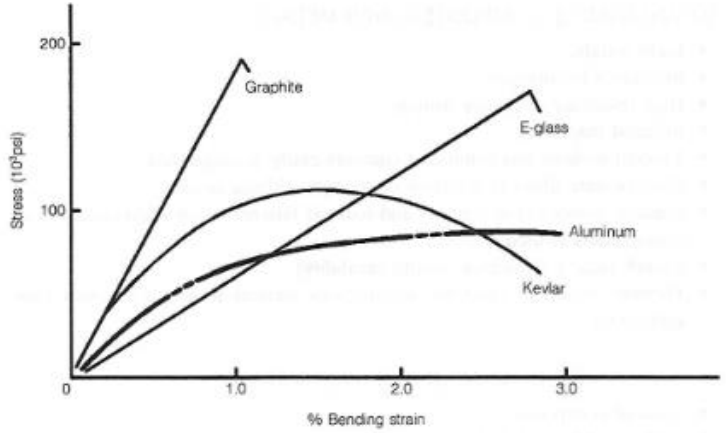
INTRODUCTION TO AIRCRAFT STRUCTURES : COMPOSITE STRUCTURES

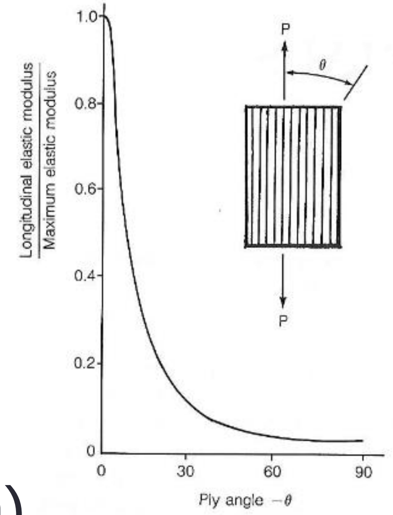
Or ‘A weight saving alternative to a metallic structure’

COMPOSITE STRUCTURES

- Reference: Composite Materials in Aircraft Structures, Ed. D.H.Middleton, Longman

- **Material Characteristics**



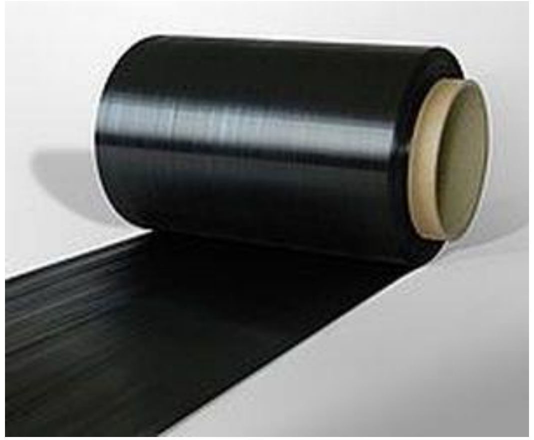


- Orthotropic
- Excellent fibre direction properties (Fibre in tension / compression)
- Transverse properties much reduced (Resin in tension / compression)
- Linear Elastic strain to failure
- Notch sensitive for static loads but less sensitivity under cyclic loads
- Can be prone to delamination if structure design and manufacture is not good

COMPOSITE STRUCTURES

- **Materials**

- **Carbon/epoxy**
- Good strength and stiffness
- Can be expensive

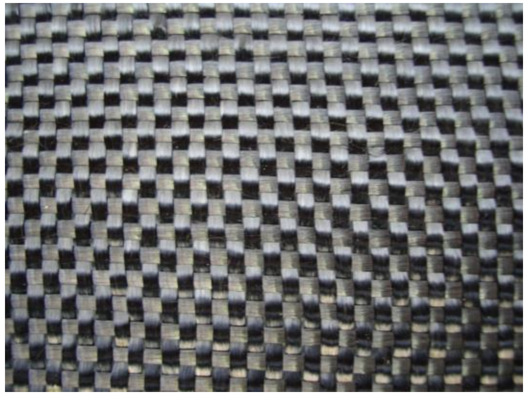



- **Glass/epoxy**
- Properties generally not as good as Carbon
- Generally cheaper
- Radar transparent


COMPOSITE STRUCTURES

- **Kevlar**
- Good in tension
- Poor compressive strength
- Good energy absorption in laminate form
- More sensitive to Environment & difficult to machine

- **Woven Materials**
- Tows (bundles of fibres) woven to make 0/90 blanket
- Easier to handle
- Easier to lay on curved surfaces
- Crimping reduces properties

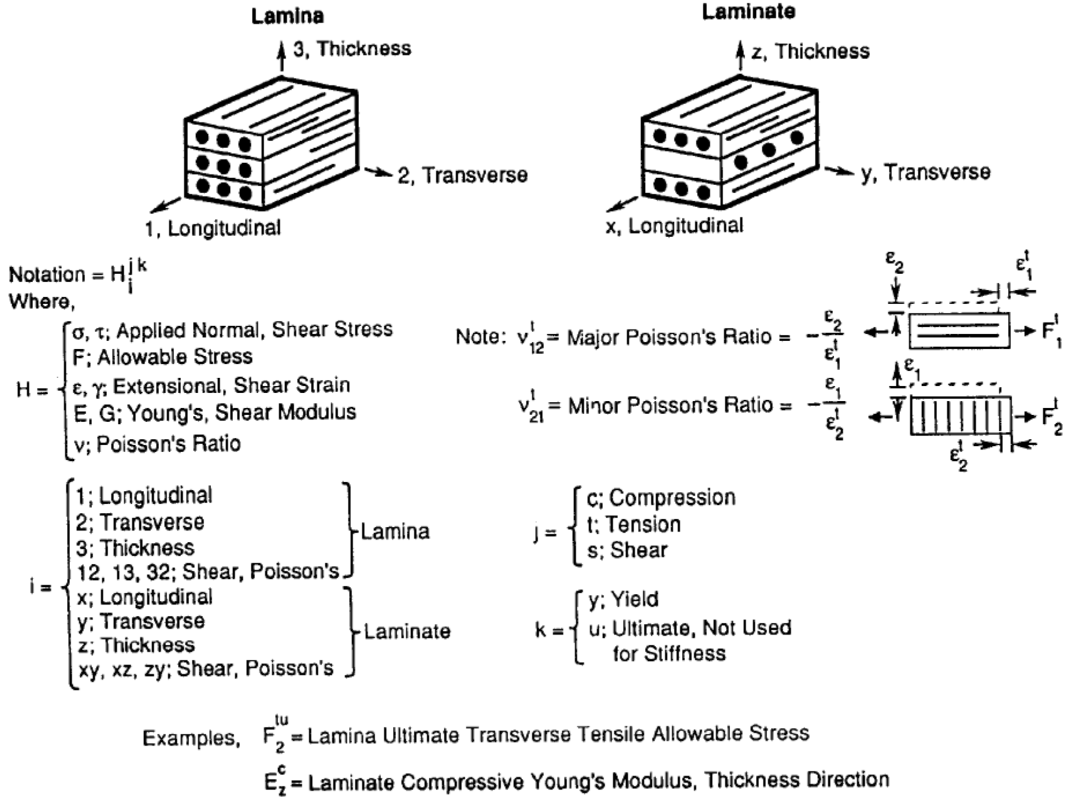


COMPOSITE STRUCTURES

- **Typical Composite Material Property notations**

- **Ref MIL-HNDBK-17-3F**

- US DEPARTMENT OF DEFENSE HANDBOOK
- COMPOSITE MATERIALS HANDBOOK
- VOLUME 3. POLYMER MATRIX COMPOSITES
- MATERIALS USAGE, DESIGN, AND ANALYSIS



COMPOSITE STRUCTURES

- **Typical Composite Material Properties vs Other Aerospace Materials**

Material	Density ρ g / mm ^{3} * 10 $^{-3}$	Tensile Modulus E (Gpa)	Tensile Strength σ (Mpa)	Specific Modulus (E / ρ)	Specific Strength (σ / ρ)
Aluminium 7075 T6	2.8	72	570	26	204
Titanium 6Al 4V	4.5	114	1000	25	222
Steel S 300	8.0	207	2000	26	250
Carbon / Epoxy T800 UD	1.8	154	2570	86	1427

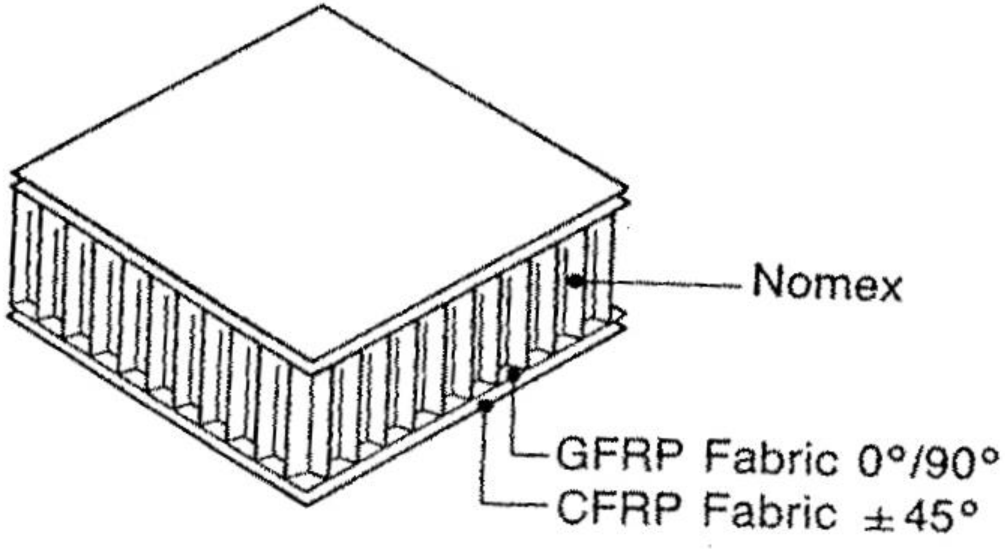
COMPOSITE STRUCTURES

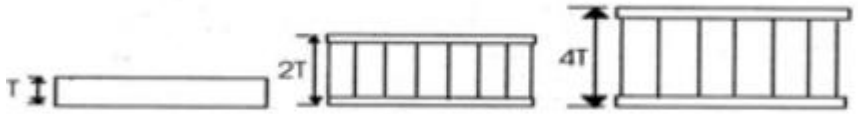
- **Sandwich Construction**

- **Core materials:**

- Aluminium honeycomb
- Nomex honeycomb
- Foam (closed & open cell)

- Good bending stiffness and light weight





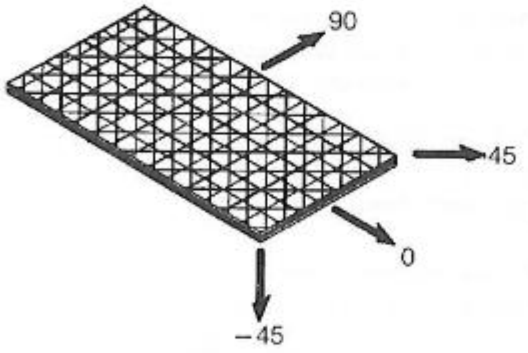
COMPOSITE STRUCTURES

- **Sandwich Construction**

- **Manufacture**
- Co-cured – skins cured and bonded to core in single operation.
- Secondary bonded – procured skins bonded to core in second step.

- **Potential Additional problems**
- Core failure
- Debonding
- Moisture ingress

COMPOSITE STRUCTURES



- **Layups**
- Standardised ply orientations normally used: 0/+45/-45/90

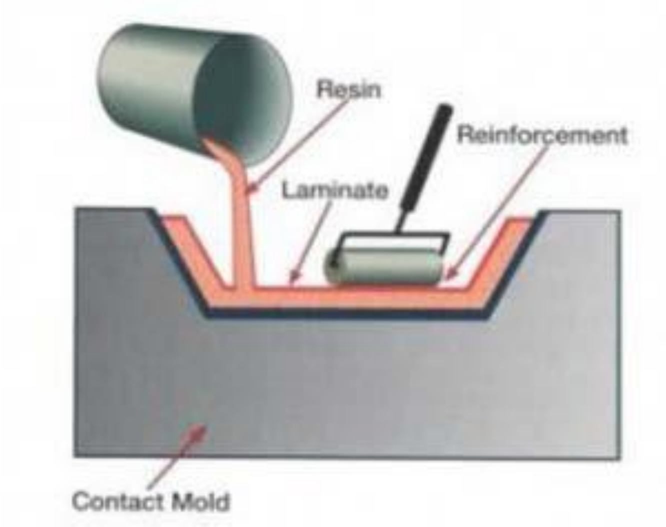
- Quasi-isotropic – “black aluminium” (25/50/25 Lay-up)
- Equal thickness of 0/90/+45/-45 plies

- Balance and Symmetry preferred – avoids distortion during cure and bending under in-plane loading.
- Orthotropic – layup tailored to loads in different directions e.g. 0/+45/-45
- Unidirectional – structurally most efficient if loads are in one direction, but must avoid excess transverse loading.

COMPOSITE STRUCTURES

- **Typical Spar & Cover Layups can be derived by thinking about what type of loading the structure has to carry**
- **Skin / stringer 'wing cover' carries axial load and torsional shear :**
- **Typical layup would be 50/40/10 or 60/30/10 (dominance of 0 deg fibres)**
- **Spar webs carry shear load :**
- **Typical layup would be 10/80/10 (dominance of ± 45 deg fibres)**

COMPOSITE STRUCTURES

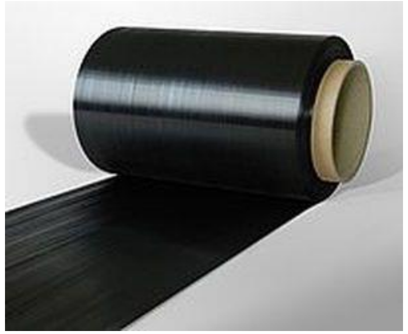


- **Manufacturing Methods**

- **Wet lay-up**

- Resin is applied to dry fibre blankets in a mould, and cured under a vacuum bag at room temperature or with a heater mat.
- Labour intensive and relatively low technology approach, used mainly for boats, gliders and light aircraft.
- Quality is not so high due to difficulties in controlling resin content, maintaining fibre geometry and avoiding porosity.

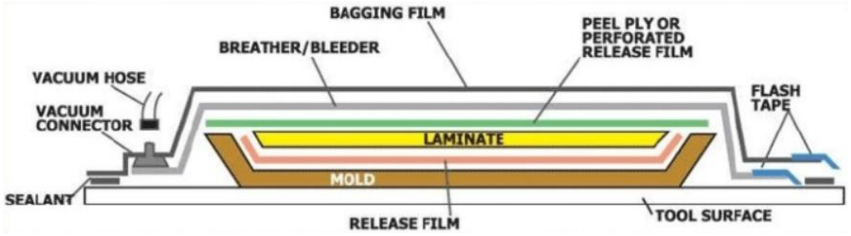
COMPOSITE STRUCTURES



- **Prepreg**

- Fibres are pre-impregnated with resin and partially cured to form plies typically 0.125 mm to 0.25 mm lamina thickness.
- Plies are laid up over tooling and cured in an autoclave at temperature, under pressure and with a vacuum bag.
- Much higher quality than wet lay-up, but more expensive.
- Lay-up can be automated with tape laying or fibre placement machines.

- Most widely used process for aerospace structures.



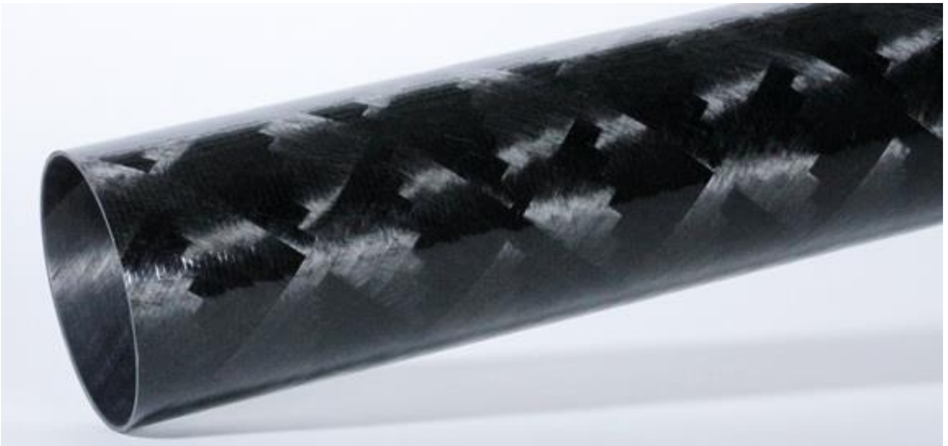
COMPOSITE STRUCTURES

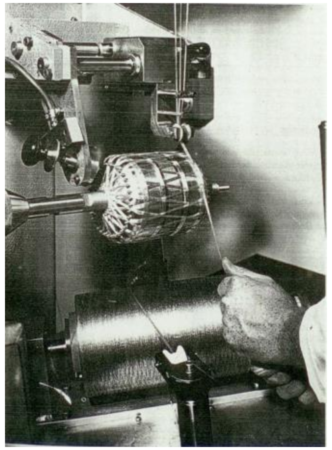
- Coriolis Automated Fibre Placement at UK NCC (Bristol)

COMPOSITE STRUCTURES

- **Filament winding**

- Tow of resin impregnated fibres wound onto a mandrel under tension. Can also be done with strips of prepreg tape.
- Good for components which are axisymmetric e.g. pressure vessels, but geometry and lay-ups are restricted.

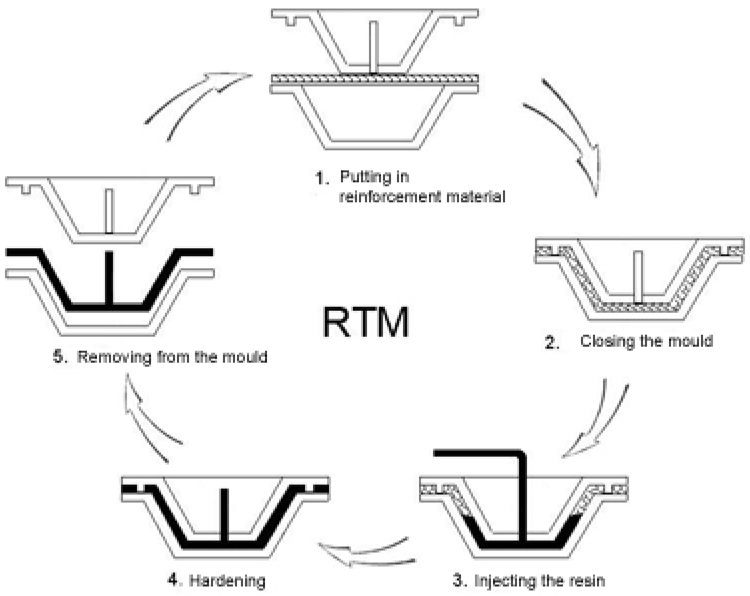




COMPOSITE STRUCTURES

- **Resin Transfer Moulding**

- Liquid resin is infused into a dry fibre preform in a closed mould.
- Can produce complex parts in a single process.



COMPOSITE STRUCTURES

- **Critical design issues**
- **Delamination**
- Delamination due to low through thickness strength is a major cause of failure in composite structures.
- Through thickness stresses arise from out-of-plane loading or from geometrical features such as bends and changes in thickness.
- **Compression after impact (CAI)**
- Composites are susceptible to impact damage due to low through thickness strength.
- Damage may not be visible, but can greatly reduce compressive strength due to buckling between delaminated plies.

COMPOSITE STRUCTURES

- **Notched strength**

- Composites are more brittle and show large reductions in static strength when notched.

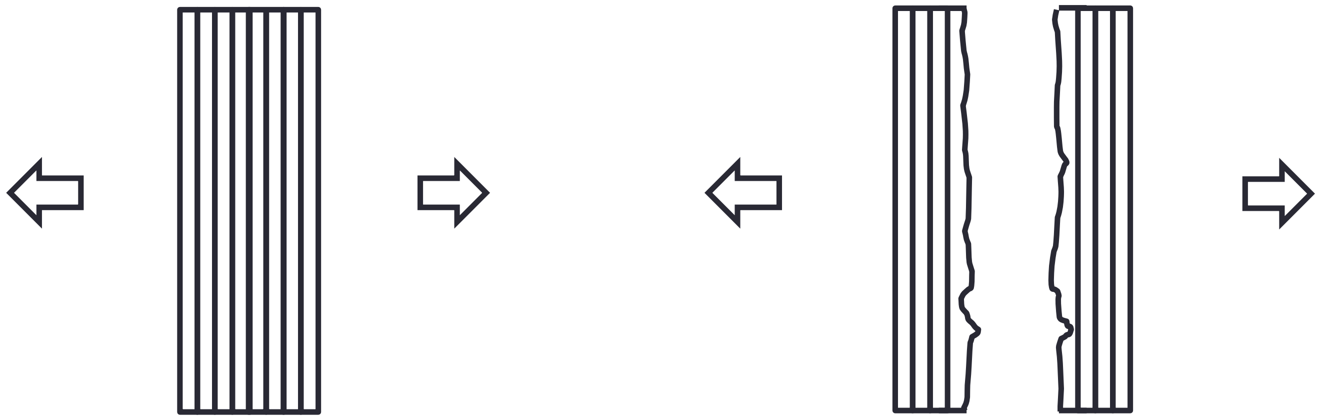
- **Hot/wet properties**

- Matrices soften at high temperatures and in the presence of moisture, leading to reduction in strength, especially in compression.

COMPOSITE STRUCTURES

- **Transverse cracking**

- 90º ply cracks can occur at relatively low stresses. These generally have little effect on static strength, but may cause delamination in fatigue or leakage in pressure vessels.
- Transverse cracking can be reduced by avoiding thick blocks of plies of the same orientation.



COMPOSITE STRUCTURES

- **Repair**

- Repair needs to be taken into account at the design stage. For example in a bonded structure it may be necessary to allow enough space and strength margin for a bolted repair.

- **Lightning strike**

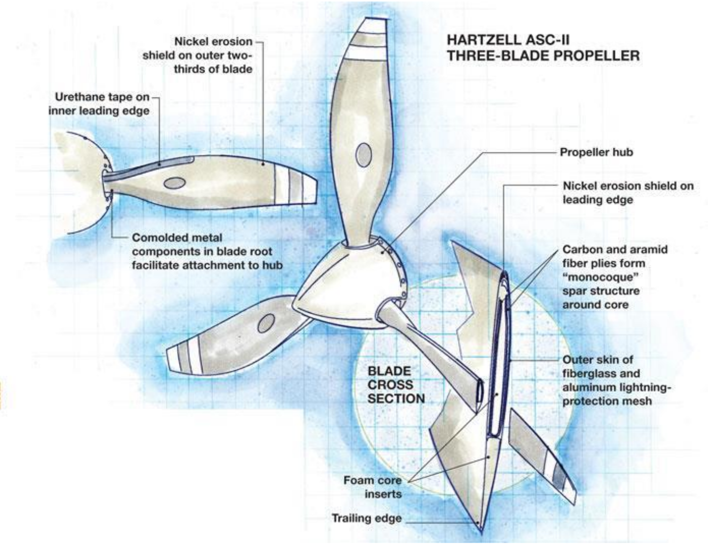
- Lightning can cause large local damage due to poor conductivity. Metal strips or meshes need to be incorporated in vulnerable areas to provide a conducting path.

COMPOSITE STRUCTURES

- Composite Structure Examples – AH NH90 & Grob 520

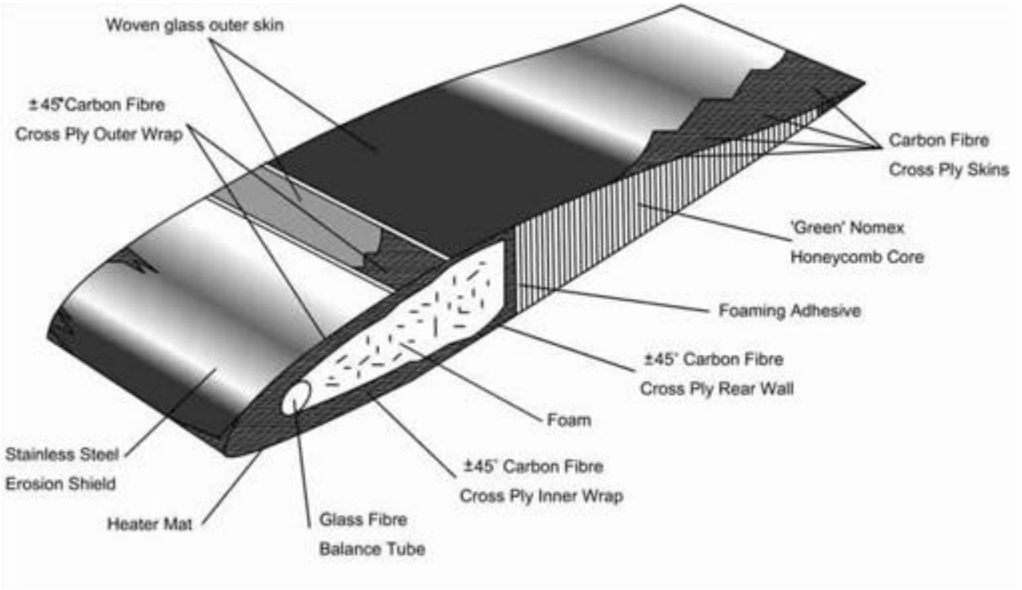
COMPOSITE STRUCTURES

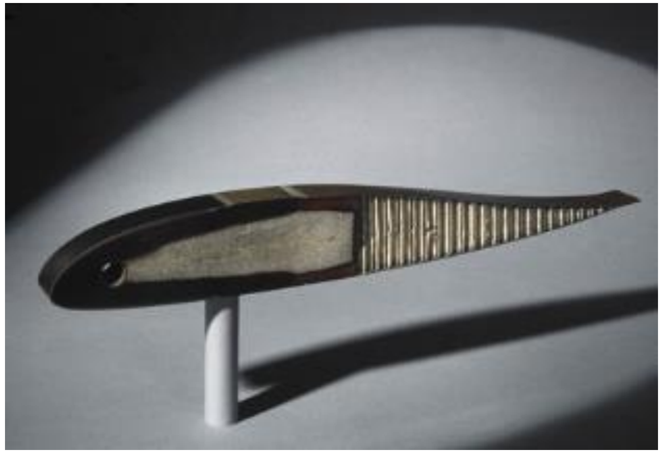
- Composite Propeller Blades



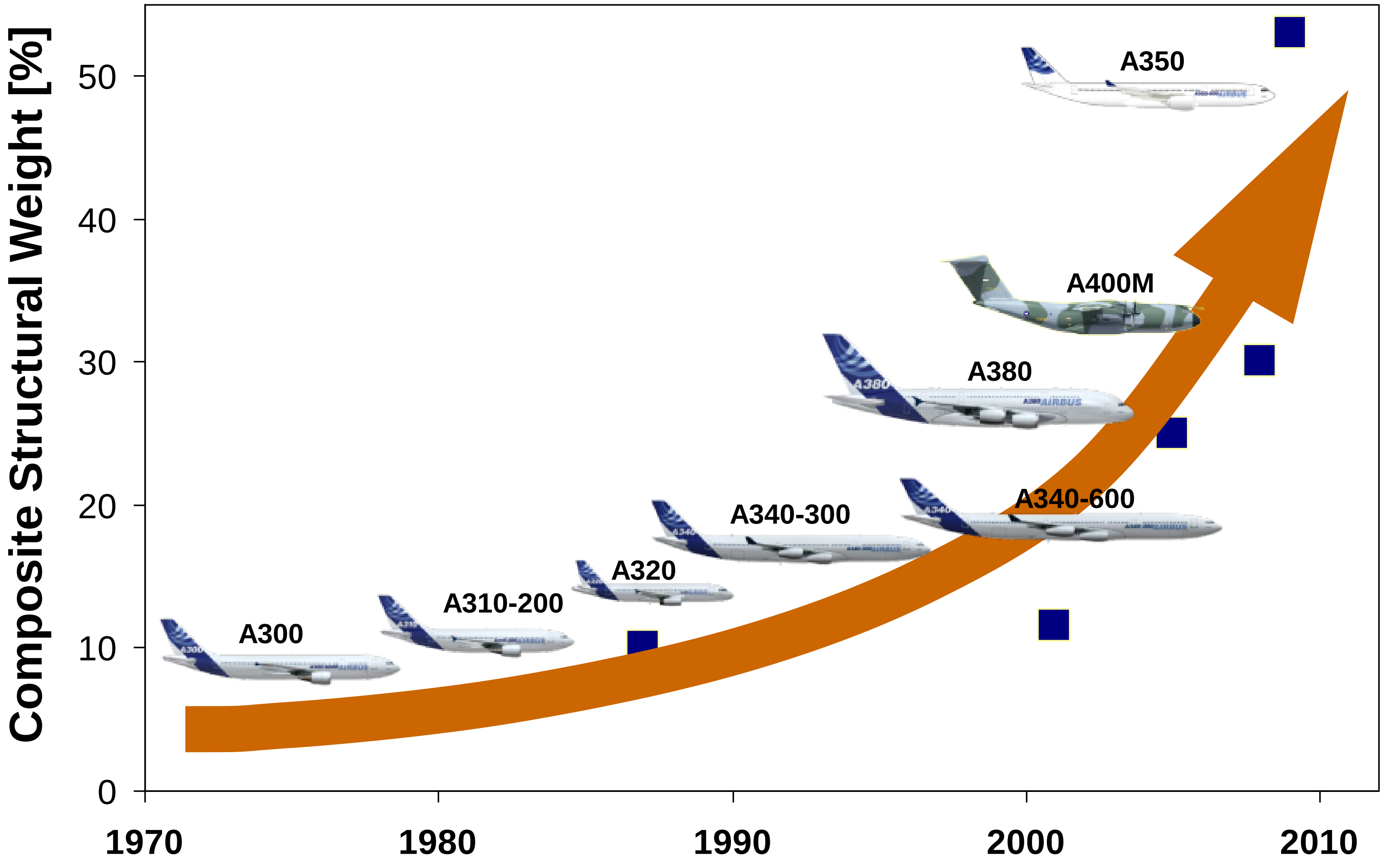
COMPOSITE STRUCTURES

- Composite Rotor Blades

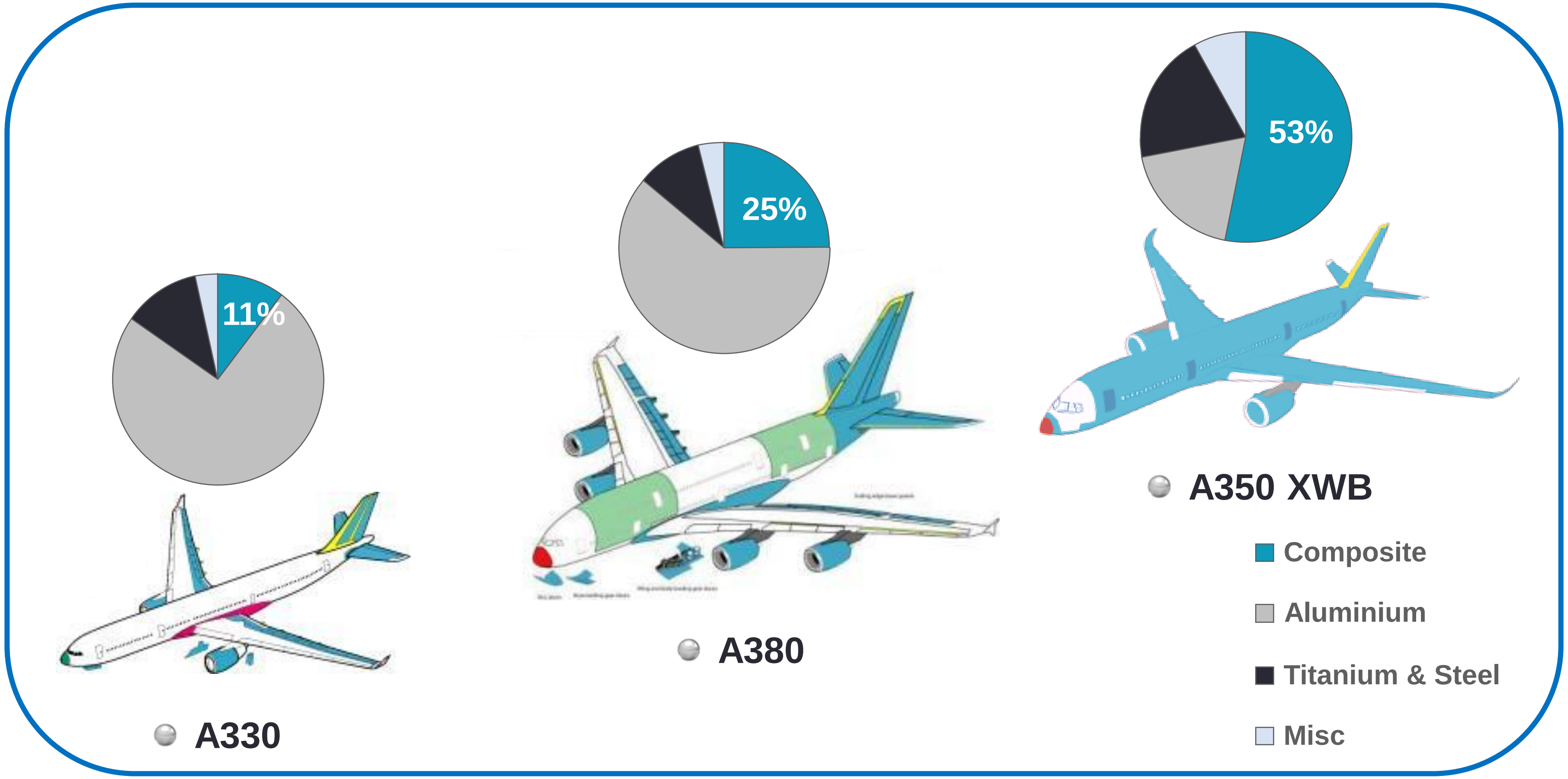




COMPOSITE STRUCTURES



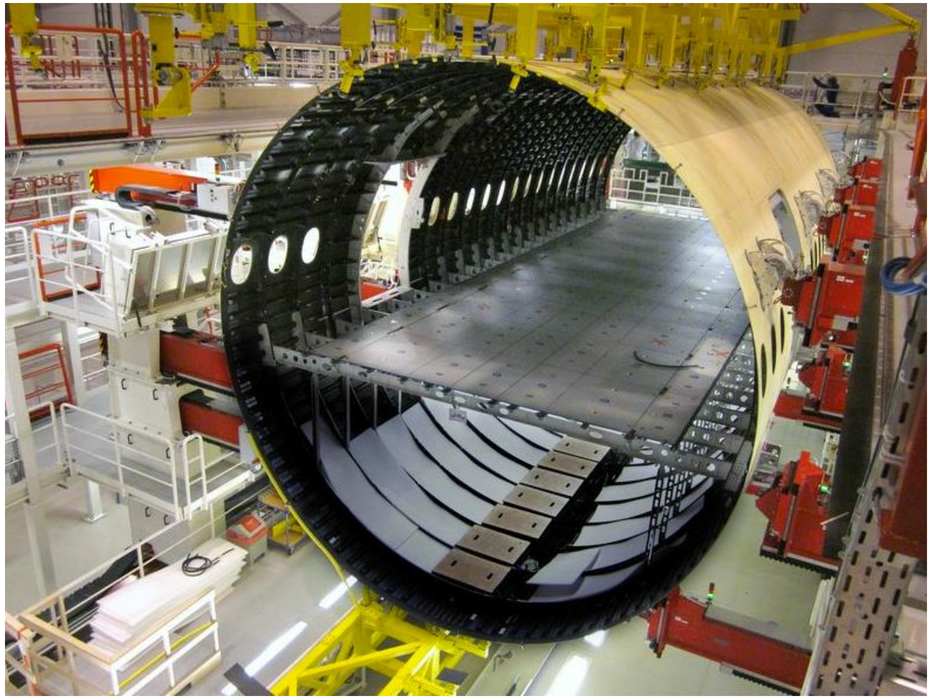
COMPOSITE STRUCTURES



From A330 to A350XWB: progressive introduction of composite structure

COMPOSITE STRUCTURES

- A350 XWB-900 Composite Fuselage Structure



COMPOSITE STRUCTURES

- A350 XWB-900 Composite Fuselage Structure

COMPOSITE STRUCTURES

- A350 XWB-900 Composite Wing Structure

COMPOSITE STRUCTURES

- A350 XWB-900 Composite Wing Structure – Upper & Lower Covers

COMPOSITE STRUCTURES

- Cleansky 2 BLADE Natural Laminar Flow Flight Test A/C
- Integrally moulded wing skin and leading edge panel manufactured by SAAB