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Composite, skills challenges and trends

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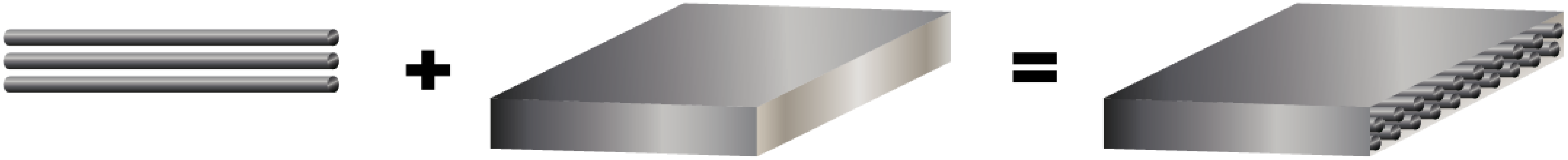
WHAT ARE COMPOSITE

- **Composites** are mixtures of two materials which, when appropriately combined, have new properties possessed by neither of the individual parts taken alone.

Fiber-reinforced composite.



Fibers

- Tensile strength
- Flexural stiffness
- Somewhat brittle

Matrix

- Compressive strength
- Interlaminar shear
- Controls shape
- Low density

Composite

- Increased strength
- Increased stiffness
- Increased toughness
- Lightweight

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The composite properties are often highly attractive **for manufacturers** in various industries, and include:

- **Low weight - savings on Running Costs and Carbon Emissions.**

  (Aerospace applications)

- **High strength-weight ratios**

  (Turbine blades for wind energy production);

- **Excellent resistance to fatigue and corrosion**

  (Products have to work well in extreme environments)

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Main advantages of composite materials

- **High strength and stiffness-to-weight ratio:**
  Composite structures can attain ratios 4 to 10 times better than those made from metals.
- **Optimized Structures.**
  Fibers are oriented and layers are placed to achieve required structural performance.
- **Composites do not corrode:** Applications which must withstand chemical attack.
- **Easily molded to shape:**
  Composites can be formed into almost any shape.
- **Fewer Parts:**
  Sometimes adhesively bonded or welded thermoplastic assemblies can almost completely eliminate fasteners, further reducing part count and production time.
- **Aerodynamically smooth surfaces.**
  Bonded structures offer smoother surfaces than riveted structures.

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Main disadvantages of composite materials

- **Expensive materials:**

High performance composite materials and processes typically cost more than wood, metal and concrete.

- **Special storage and handling:**

Many materials such as film adhesives and prepregs typically have a limited working time (out-time), usually measured in days. Most prepregs also require frozen storage, and may have a limited shelf life of a few months to a year.

- **Not always recyclable.**
- **Labor-intensive.**

Tailoring properties typically requires exact material placement, either through hand layup or automated processes. This all requires a skilled workforce which can be expensive in some cases.

- **High capital equipment costs.**

Ovens, autoclaves, presses, controllers and software are expensive to buy and to operate. Automated machines and programming costs can be a considerable investment.

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Main disadvantages of composite materials

- **Easily damaged.**

Thin-skinned sandwich panels are especially susceptible to damage from low-energy impacts.
Such impacts can produce delaminations which are structurally damaging yet invisible to the eye. Moisture intrusion is a special problem in honeycomb sandwich panels, which is also not apparent by visual inspection.

- **Special training and skills are required:**

A high degree of knowledge and skill is required to properly fabricate and repair advanced composite structures.

- **Health and safety concerns**

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Applications of composite materials in the industry

wind turbines (Rotor blades)

Made from fiberglass reinforced polyester or epoxy resins.
Use resin infusion to make their wind blades, the two who use prepreg — Vestas and Gamesa — are also using carbon fiber in their largest 44 m/144-foot blades' spar caps. However, the industry's longest 61.5 m/200-foot blade, made by LM Glasfiber, remains fiberglass only.

(Left) Despite its length, the LM 61.5P blade weighs only 17,740 kg/39,110 lbs. (Photo courtesy of LM Glasfiber)

(Right) Blades made for the V90 wind turbine. (Photo courtesy of Vestas Wind Systems A/S)

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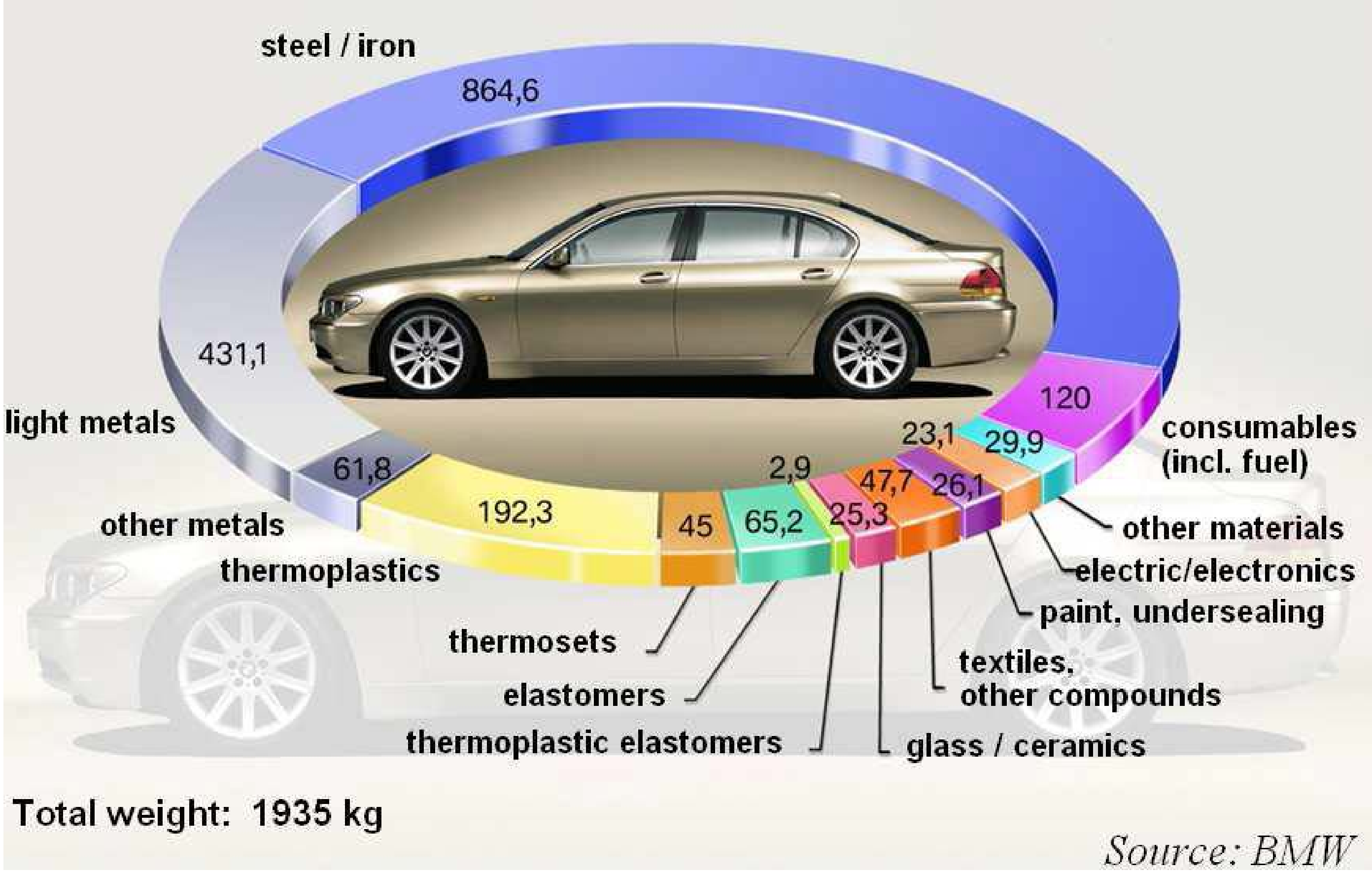
Automobile/Transportation Sector

CFRP composites — are the next-generation materials for making cars lighter, more fuel efficient and safer



Overview of different materials in cars. Source BMW

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Large Marine vessels and structures

including military and commercial vessels, as well as composite masts.

(Left) The *Mirabella V* is the world's largest composite ship. (Photo courtesy of Select Charter Services)

(Right) The Visby class of corvettes is built using carbon fiber reinforced composite sandwich construction. (Photo courtesy of Kockums AB)

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Civil Construction

- Hybrid Fiber Reinforced Polymers FRP structures in civil engineering has developed.

- All the structural elements have been made with Hybrid Fiber Reinforcement Plastics (GFRP & CFRP).

Chemical Industry

- The composite materials have better resistance against fire and show resistance to chemicals.
- Storage tanks, exhaust stacks and blowers, columns, pumps, reactors etc. for acidic and alkaline environments.

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Orthopedic Aids

- Composite material has been known as the innovative class of synthetic bio-materials
- Materials intended for such prosthetic aids must non-toxic, chemically and biologically stable and have adequate mechanical reliability and strength to withstand physiological loads.
- A vital improvement has been the usage of carbon fiber reinforced polymer matrix for composite limb.
- artificial leg

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Electronics and Electrical

- The composites are fitted with high quality electric insulation, spark-free and good antimagnetic agents.

- Composite also is used to prevent short circuits etc….

Telecommunication Applications

- Hybrid cable: power transmission along with data transmission are increasing in telecommunication industries.

- Hybrid aerial, underground cable is advanced and versatile cabling solution inside constructed power transmission required for network equipments

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Aviation Industry

- The air transport industry has widely adopted carbon fibre reinforced plastics (CFRPs)
- Major changes have taken place in the way CFRPs are made, their properties and the uses to which they are put in commercial aircraft.
- Major changes are exemplified by the Boeing 787, Airbus 350
- New generation large aircraft are designed with all composite fuselage and wing structures, and the repair of these advanced composite materials requires an in-depth knowledge of composite structures, materials, and tooling.

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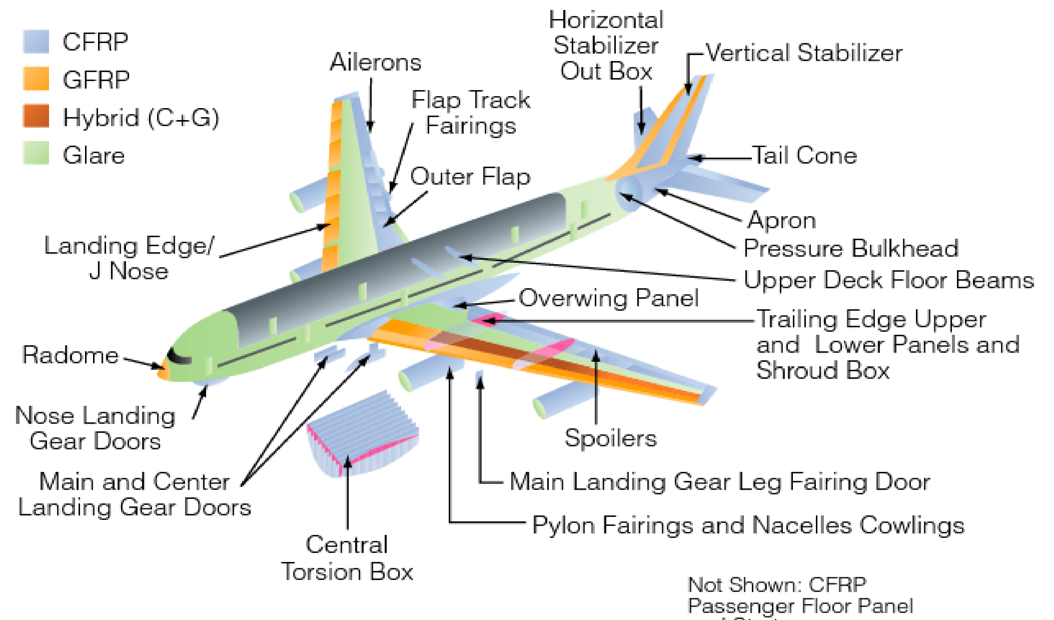
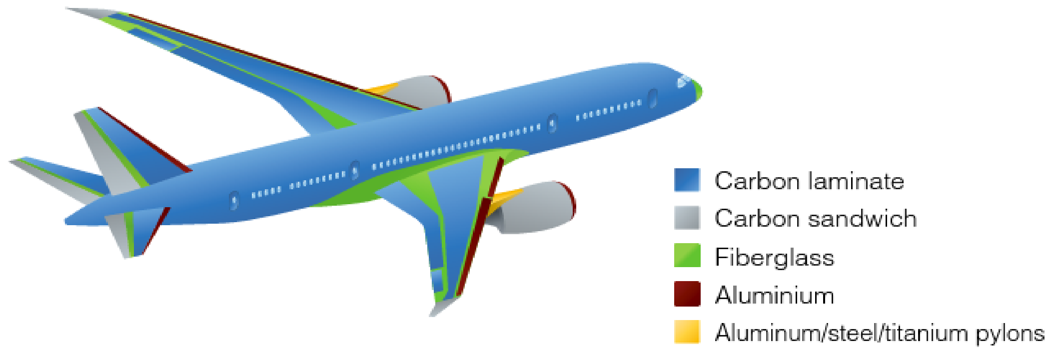


Airbus A380 Composite Components



Boeing 787 Dreamliner Composite Components

Large components of commercial airliners

such as the Boeing 777 and the 787 Dreamliner, the Airbus A330/340, A350, and A380 aircraft, and many smaller craft such as the Bombardier Canadian Regional Jet (CRJ).

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Composite materials application in B787

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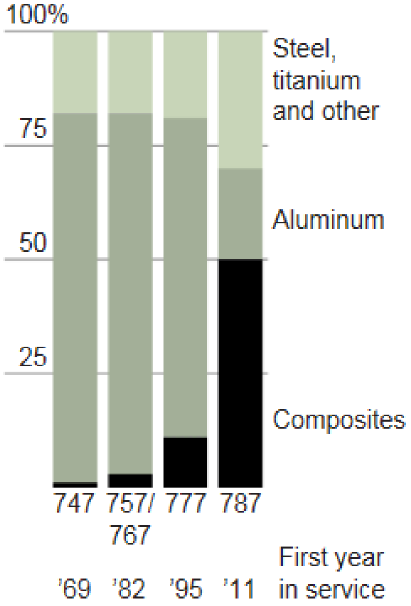
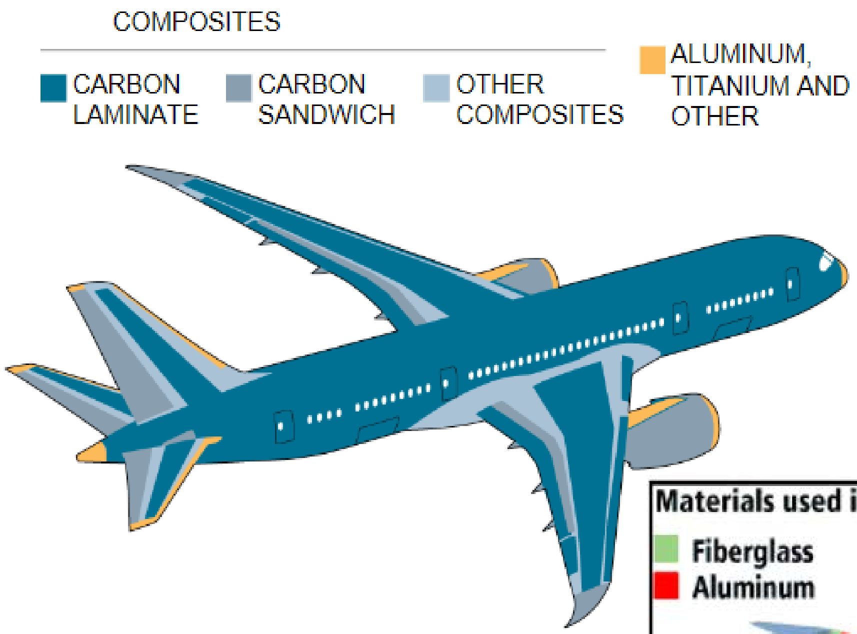
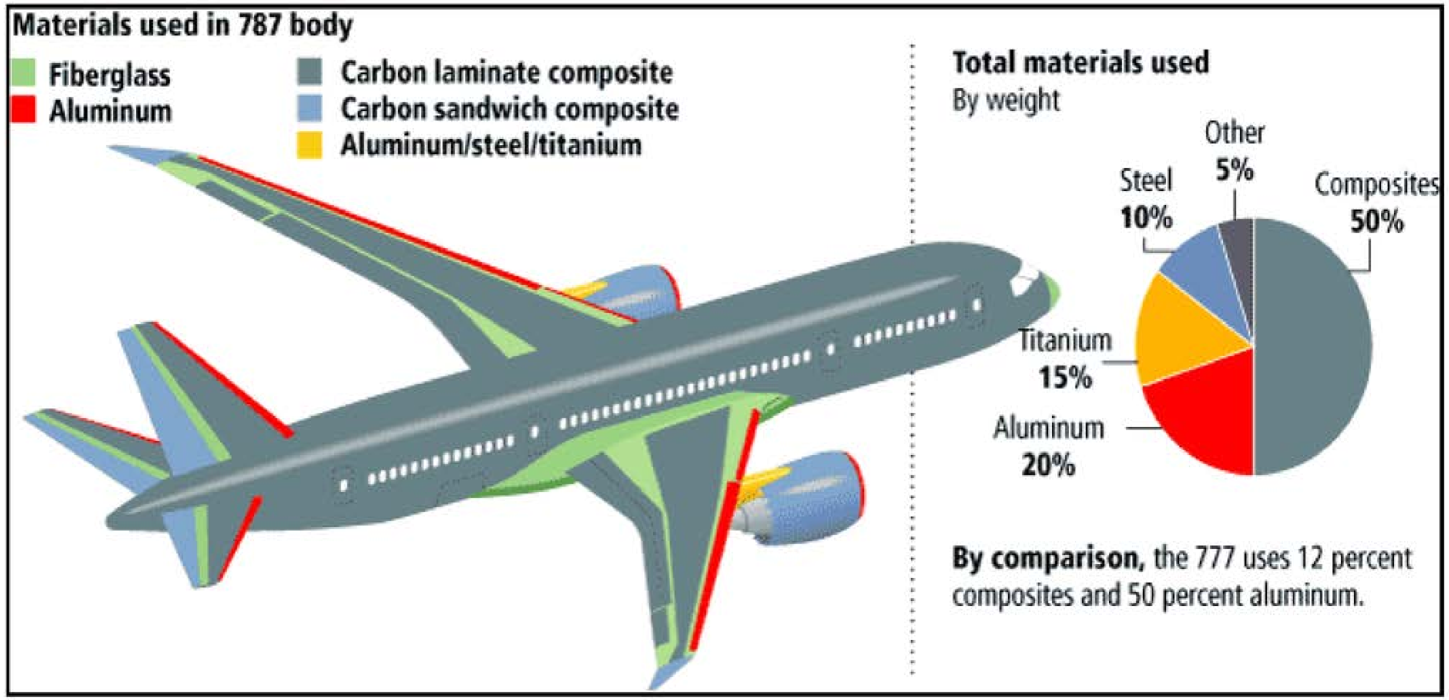
Materials used in Boeing planes



Boeing 787 Dreamliner skin structure






Alu alloy
CFRP Monolithic
CFRP Sandwich
Quartz, Glass
Misc.
8%
Al/Al-Li
19%
Steel
6%
14%
Titanium
53%
Composite
A350 XWB
AIRBUS
AN EADS COMPANY

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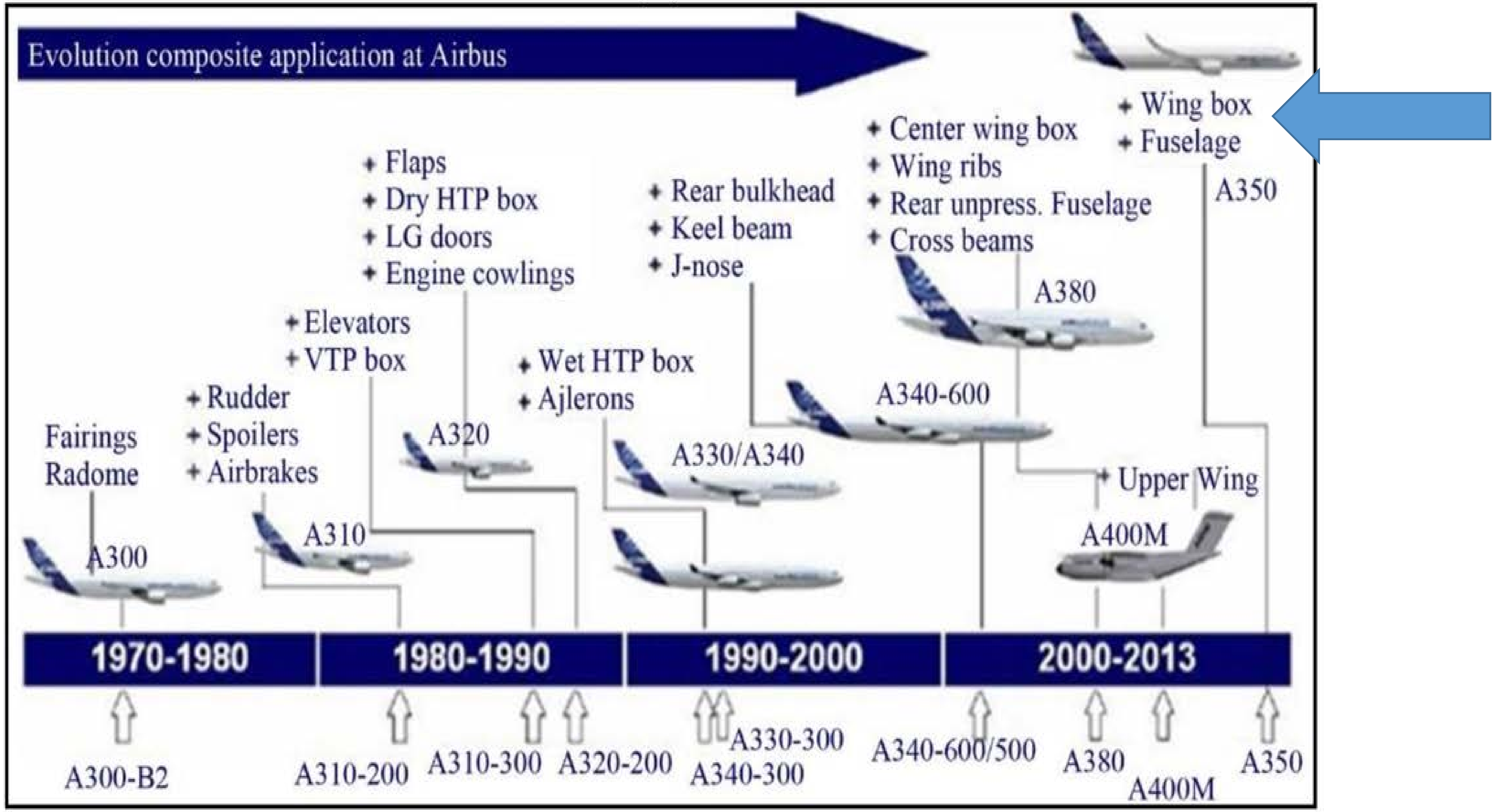
Evolution composite application at airbus



Boeing makes the 787's fuselage out of strands of carbon fiber layered around a rotating mold by a computer-controlled robot that looks like a spider. Boeing

- Boeing's 787 skin is a mix of carbon fibers and epoxy molded into large barrel-shaped sections.
- Airbus has taken a somewhat different approach in building its A350. Airbus is using 40-foot to 60-foot composite panels for each section of the fuselage.

Importance Composite Repair

- In 2013, THE FIRE ON A BOEING 787 at Heathrow Airport provided THE FIRST TEST of how difficult and costly it will be to repair serious damage.
- A SECTION OF THE FUSELAGE had to be replaced, because of the inability to repair the damage made by the fire.
- The aircraft was back in service TOW MONTHS LATER.
- Each day a jet remains grounded costs an airline tens of thousands of dollars.
- the composite materials have created new challenges for airline mechanics, who need new maintenance tools and skills

Damage due to fire on the Boeing 787 Dreamliner

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Composite Repair Process Analysis

Damages in aviation composite materials are caused by three main cases:

- ❑ **Fatigue/cycle loading**
- ❑ **Impact on the material**
- ❑ **Manufacturing induced defects (errors)**

Damage Detection

Surface Preparing

Repairing

Post repair inspection

Composite Materials repair concerns:

- ❑ **The damage on the outside is not representative for the inner structure (detection process)**
- ❑ **complex damage characteristics during loading.**
- ❑ **what types of damages occur in aviation composite materials!**
- ❑ **Find the solution when the damage dimensions exceed the limits in SRM documentation?**
- ❑ **Is there a way to repair all damages?**
- ❑ **The quality of the damage surfaces preparing (machining/scarfing)depend on the technician skills.**
- ❑ **The applied conventional machining forces and tool generated heat which could lead to material damage.**

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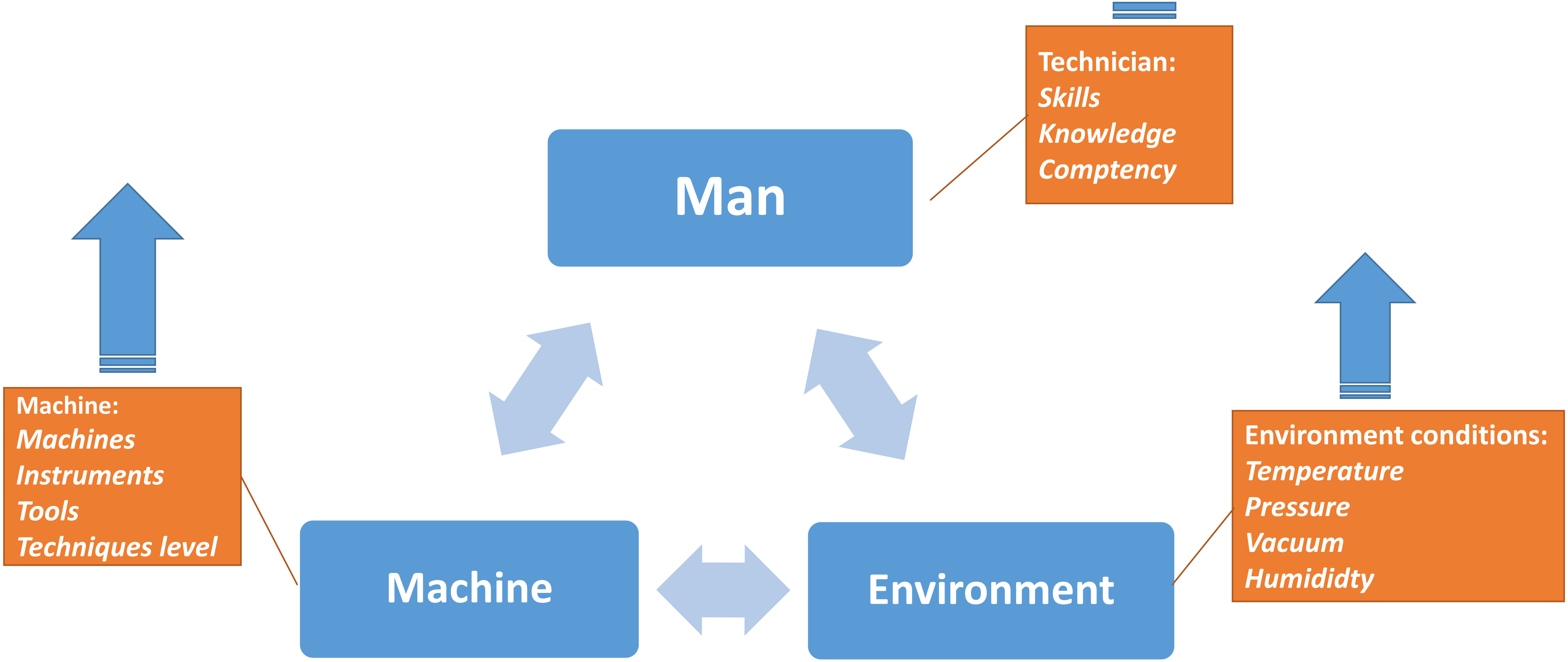
Composite Repair System

(Man-Machine system)



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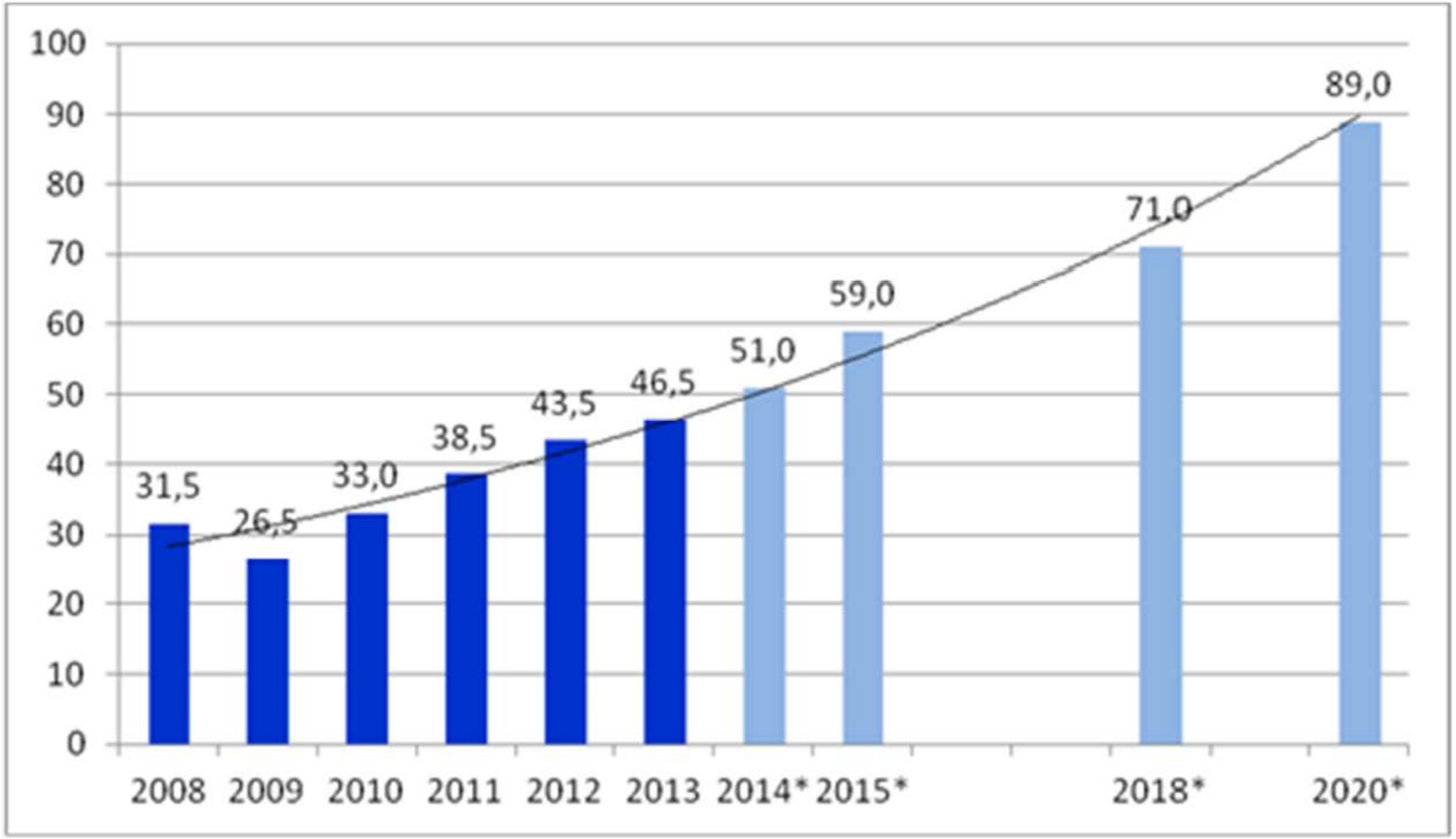
MAIN TRENDS IN COMPOSITE

- Increasing of carbon fibres
- Intelligent fibre construction
- Sustainable composites
- Automated manufacturing
- Recycling

Inceasing of Carbon Fibres

- Global usage of carbon fibre is growing in many industry sectors and the growth rate is accelerating.
- The aerospace sector is not the only sector increasing use of carbon fibre. There massive expansion in the wind and automotive sectors too.
- Although current producers are increasing production and new producers are coming online at high rate, aerospace grade fibres are the most expensive to produce and need to be certified before use therefore increase production may be limited.



Global demand for carbon fibre in 1,000 tonnes 2008 – 2020 (*estimate).

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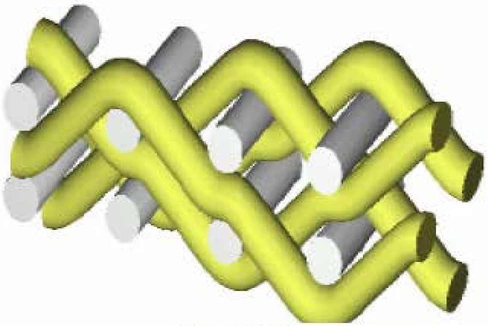
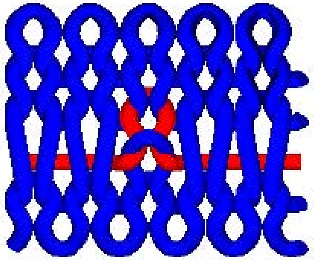
intelligent fibre architectures

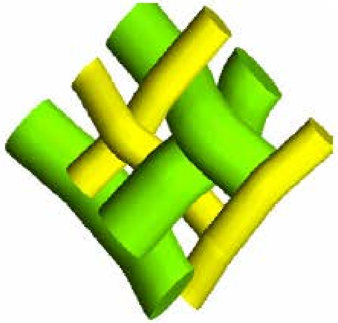
- From individual textile layers… to structurally stitched components!



3D Weaves

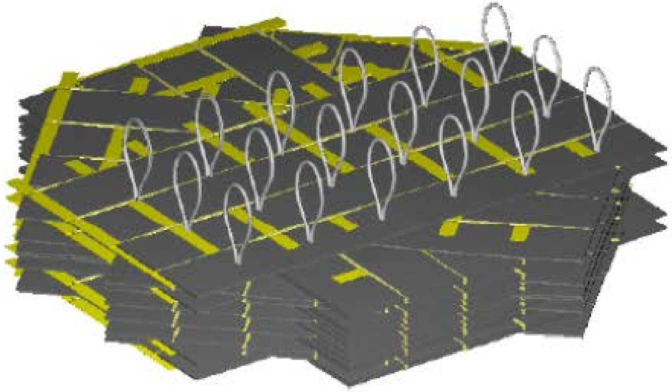


Knitted fabrics



2D Weaves

Braids



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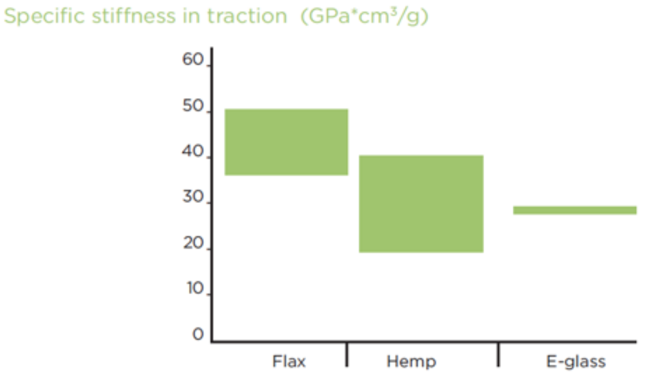
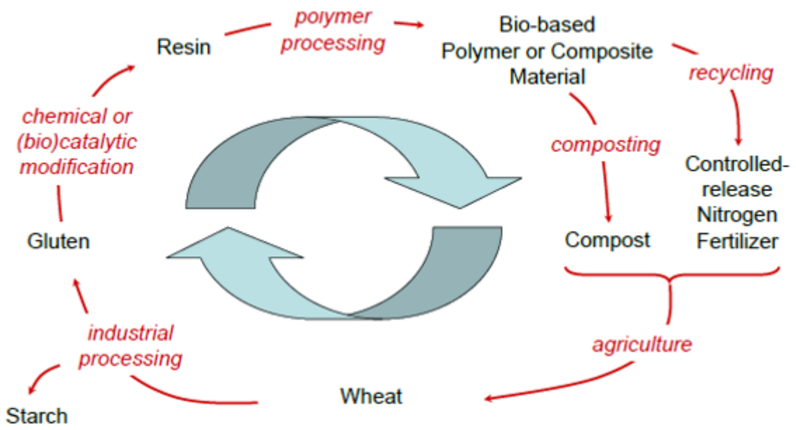
Sustainable composites

- Natural fibres: strong increase in
    - Developments for composites
    - Industrial interest

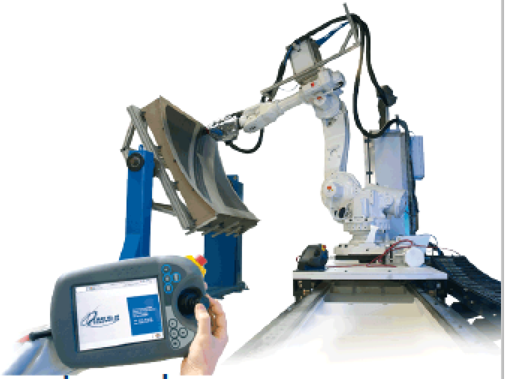
- Biopolymers
    - Preferred route should
        - No compete with food
        - Add little 'chemistry'





automated manufacturing

- Driven by trend to ‘high volume applications’
  - Already happening in
    - Sports equipment
    - Aerospace:
      - at hundreds of composite aeroplanes/year
      - Thousands for similar components have to be produced
      - Hence automation is needed!



  - Soon expected in automotive!

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One the major issues in Composite Repair is:

- Time
- Labor

Manual repairs are time-consuming, and therefore, expensive.

The goal of Automated Repair Technology:

- Reduce time
- Reduce cost
- Reduce the risk of human error.

There are several automated repair technologies in development

Composite Repair Automation (Robotics) might eventually carry out an entire repair cycle:

- damage detection
- surface preparation,
- repair patch creation,
- patch application
- quality assurance checking.

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- The planes are still very young. Experts say the real test in the field of MRO will come in the next 5-10 years.
- Airlines and MROs, accordingly, are gearing up to meet these coming composites maintenance demands.

- Major airlines and MRO providers foresee several challenges:
  - The need to perform an increasing number of repairs *on* the aircraft vs. in the repair shop.
  - The need to reduce the *duration* of repair processes without sacrifice of repair quality.
  - The need to increase the size limit for approved bonded repairs and to make progress toward the application of bonded repairs to more complex and primary structures.

Research and development of automation composite repair

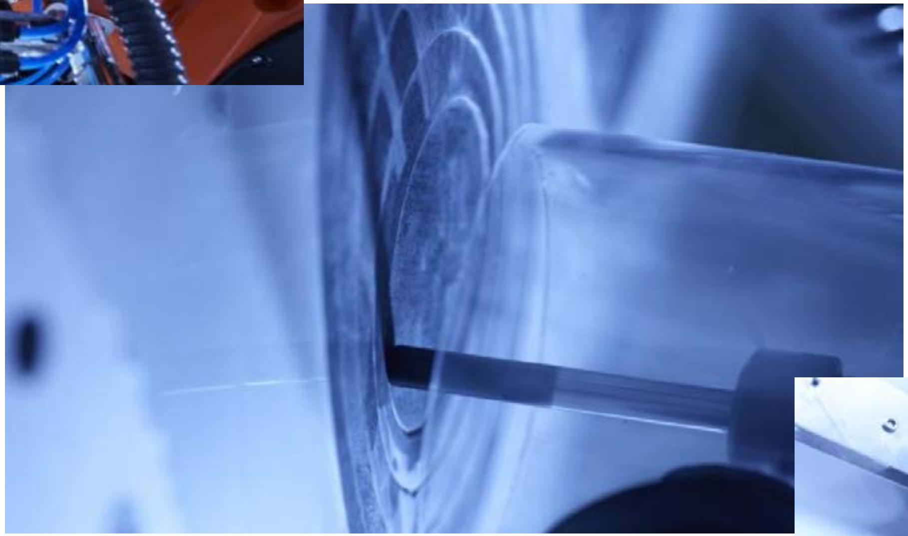
- Lufthansa Technik AG and partners (In the research project, "Rapid Repair“) successfully developed a complete process chain for the rapid, automated, reproducible repair of CFRP materials.

- The project, "Composite Adaptable Inspection and Repair" (CAIRE), has further enhanced the original stationary milling robot to allow for mobile repairs.

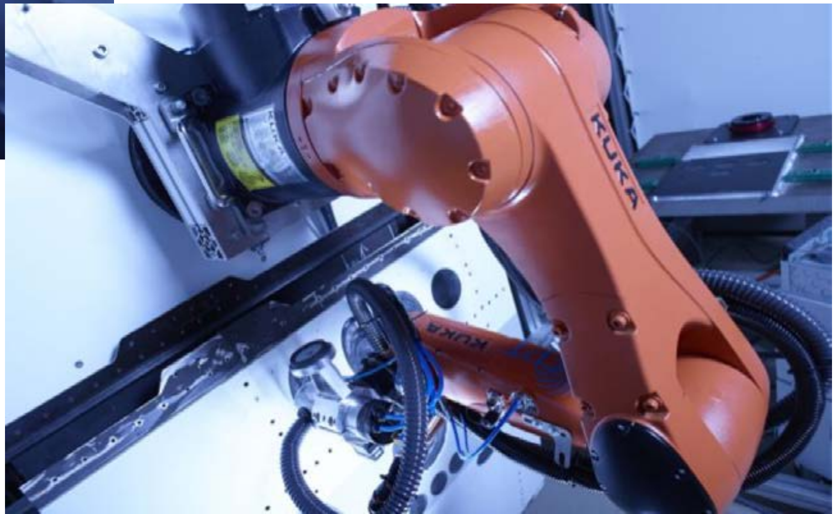
- Lufthansa Technik: The NEW ROBOT enables mobile teams to diagnose and repair large areas of fuselage and wing damage "on wing".

Building on the results of "Rapid Repair", and funded by the German Federal Ministry of Economics and Technology (BMWi), a MOBILE ROBOT has been developed

MOBILE ROBOT has been equipped with the special software needed to recognize free-form 3D surfaces.

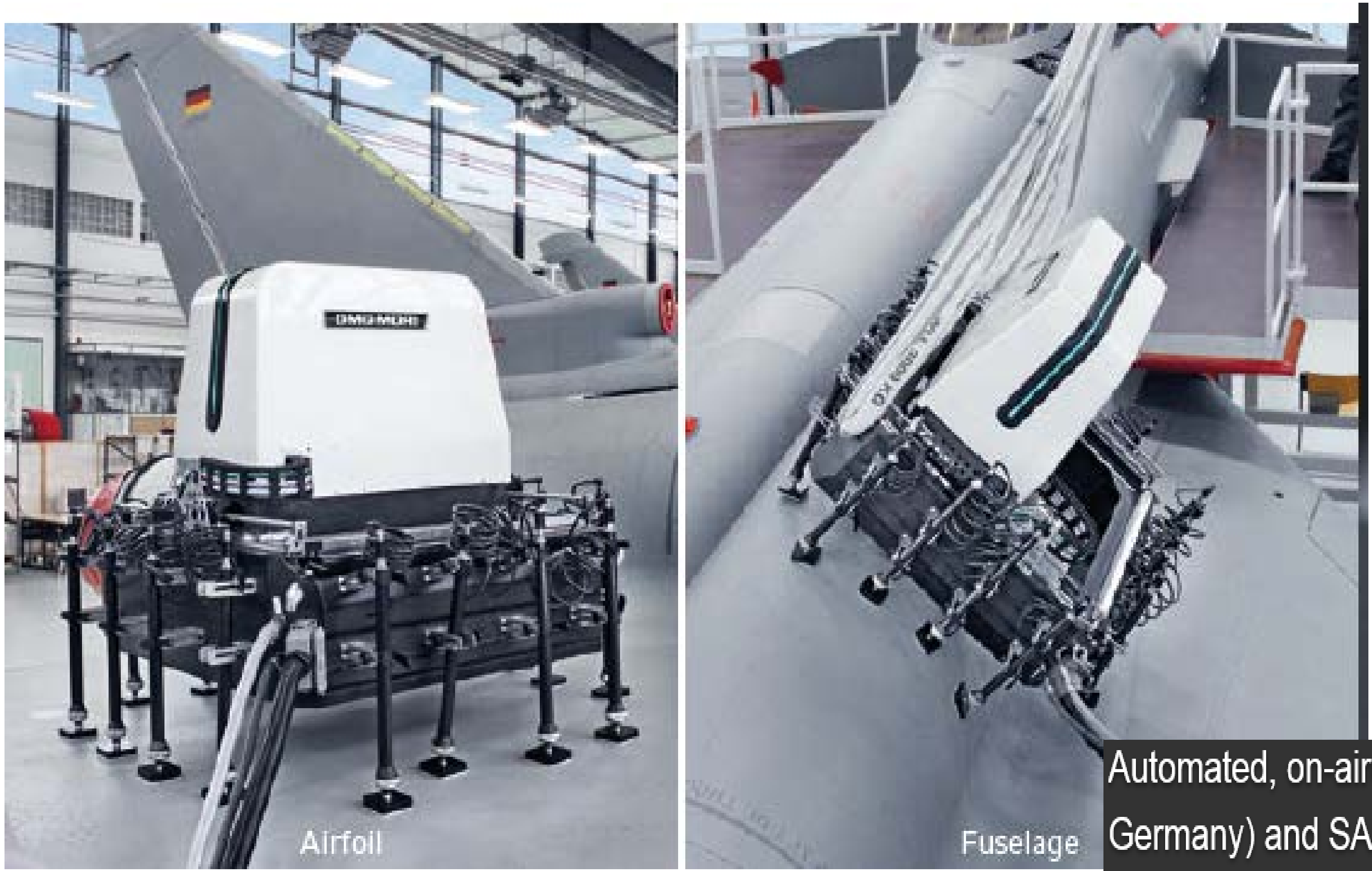


- ✓ After the damage has been scanned and the surface modelled, the form of the scarfing and the milling path are calculated.



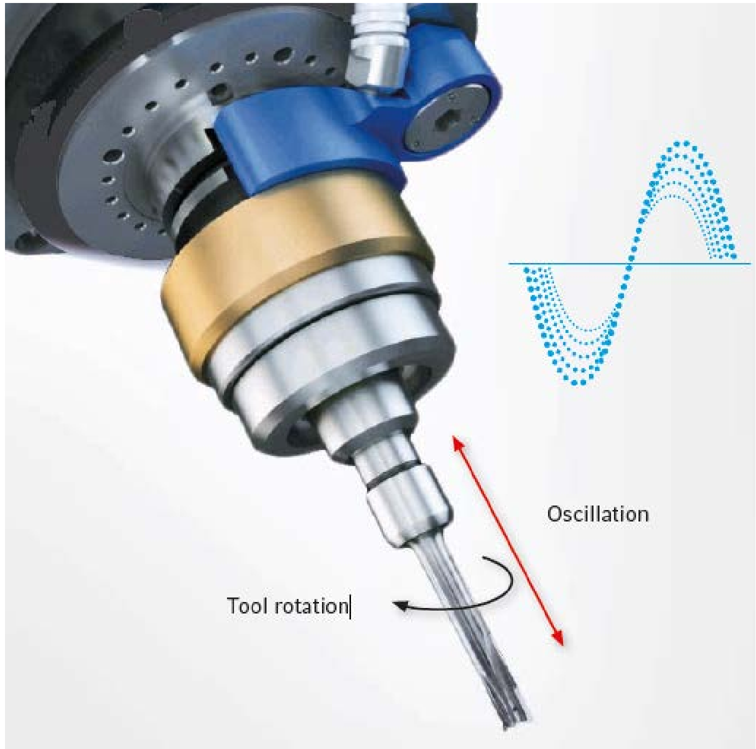
- ✓ For scarfing, MOBILE ROBOT is placed on a stand attached to CFRP component with suction cups.
- ✓ The robot grinds out the damaged material, after which the pre-cut fitting of the repair layers is produced.

The ULTRASONIC MOBILE 5-AXIS MILLING UNIT



Automated, on-aircraft bonded patch prep. DMG MORI (Bielefeld, Germany) and SAUER (Stipshausen, Germany) have co-developed this ULTRASONIC mobileBLOCK 5-axis milling unit, which attaches to aircraft surfaces via 12 vacuum feet and provides multiple functions, including laser surface scanning, ultrasonic milling and plasma surface treatment. Source: DMG MORI/SAUER

Mobile and stationary ULTRASONIC-machining of COMPOSITES for MRO and Production.

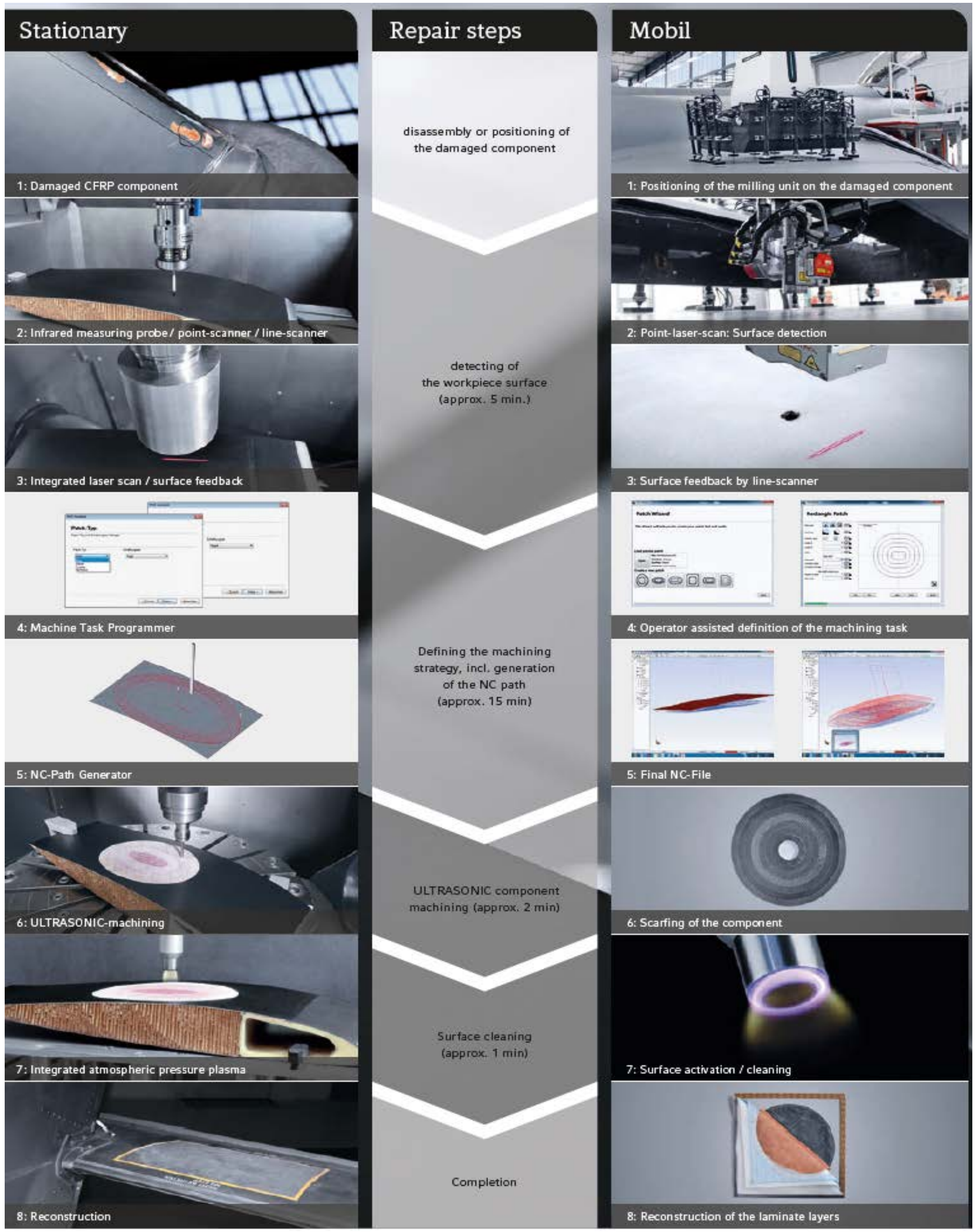


Mobile ULTRASONIC- machining of COMPOSITES for MRO

Allows to cut the material fibres with an increased cutting speed

- ✓ **Scarfing by accurately exposing the individual laminate layers**
- ✓ **Scarfing in a full section without fibre tearing or delamination**
- ✓ **Integrated laser scanner for surface recognition, feedback and re-measuring**
- ✓ **Integrated atmospheric pressure plasma: Surface activation/ cleaning for optimal preparation for the subsequent reconstruction process**

Maintenance, Repair & Overhaul (MRO)



Stationary as well as mobile repair solution with holistic process-know-how.

- **Positioning of the milling unit on the damage**
- **Point laser Detecting of the surfaces**
- **Defining the machining task**
- **Scarfing**
- **Surfaces cleaning**
- **Reconstruction of the laminate layers**

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Composite Recycling

Increasing composite production coupled with reduced landfill availability mean that it is essential to develop efficient and cost-effective recycling routes, with associated supply chains.

3000 tones CFRP (carbon fibre reinforced plastics) scrap produced annually, 6000 to 8000 commercial planes expected to reach end-of-life dismantlement by 2030.
Therefore work has been done to develop methods that can be used to recycle carbon fibres.
There is currently no real market for the recycled product that is produced.

Research has demonstrated feasibility for using composite recyclate in several other applications. Ground GFRP can be used in concrete and rubber compounds for the construction industry, and in moulding compounds for automotive products and sanitary ware.

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The problems in recycling thermoset composites

- Thermosetting polymers cannot be remoulded, in contrast to thermoplastics which can easily be remelted.

- Composites are mixtures of different materials:
  - Fibre reinforcement,
  - Resin matrix
  - Fillers

- Composites are often manufactured in combination with other materials (Foam cores, metal inserts).

- The need be able to deal with contamination and the difficulty of collecting, identifying, sorting and separating the scrap material.

- The more common thermosetting resins, such as polyester and epoxy are not practical to depolymerise to their original constituents.

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Composite Repair challenges

- The growing use of multi-layered carbon fiber panels has on the other hand revealed an important drawback: repairing localized damage becomes complicated and time-consuming

- The US Government Accountability Office (GAO) report also identified four central safety-related concerns with the repair and maintenance of composites:
  1. Limited information on the behaviour of aircraft composite structures;
  2. Standardization of repair materials and techniques;
  3. Training and awareness;
  4. Technical issues related to the unique properties of composite materials.

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Limited information

- The limited information on the behaviour of composite structures due to limited in-service experience with composite materials used in the airframe structures of commercial airplanes
- Less information is available on the behavior of these materials than on the behaviour of metal
- **Suggestion:** More experimental data would help better predict the behaviour of damaged composite structures through more analytical methods
- Limited information on how composite structures age and fatigue

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Limited Standardisation

- composite materials and repair techniques are less standardised than metal materials and repairs
- Less standardisation can have a negative economic impact for airlines and repair stations because a repair facility might have to keep a large stock of repair materials and parts in house.
- Composite materials generally need to be stored at a specific temperature, and the materials also have shelf lives (i.e. expiration dates)
- Commercial Aircraft Composite Repair Committee (CACRC) stated mission is: “to reduce the cost of maintaining composite structures through standardization of materials technique and training
- CACRC - Repair Technique Task Group is active in the development of standard repair process documents from current best practices

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Level of training and awareness

- Repair Technicians <u>are aware</u> of and <u>can evaluate</u> the differences between metal and composite materials".

- CACRC's 'Training Task Group' purpose is to develop standard curricula for non-NDT inspectors, technicians, and engineers.

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Technical Conserns

Challenges in detecting and characterising damage in composite structures, as well as making adequate composite repairs”

- ❑ **Specific defect types due to inhomogeneous nature of composites.**
- ❑ **The difficulty of detecting damage**
- ❑ **Defects are started during manufacturing as well as in-service.**
- ❑ **Inspection regime usually involves use of several NDT techniques.**
- ❑ **Using new techniques for improvements need to be validated and certified**
- ❑ **Impact damage to composite structures is unique in that it may not be visible.**

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Human factor

- New Composite repair skills will be demanded,
- Required background education like gluing, carbon and composite cloth handling.
- Know-how in vacuum and heat treatment techniques for curing of repairs
- NDT skills to verify repairs will be needed as well.

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Nanotechnology

- **The Composite materials have a wide range of applications in the field of Nanotechnology.**
- **Nanocomposite materials are greatly used in automotive, electronic parts and in industrial equipments etc.**

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- A more recent trend of evolution pursued by scientific research is toward substitution of metals and macro composite materials with micro and nano composites materials.
- Nanostructure deals with objects and structures that are in the 1—100 nm range. In many materials, atoms or molecules agglomerate together to form objects at the nanoscale. This leads to many interesting electrical, magnetic, optical and mechanical properties.
- Graphene is the most recent and most promising of carbon-based nanostructured materials
- Graphene has been widely used as a nano-additive in polymer composites to enhance mechanical properties, electrical conductivity, and resistance to temperature or solvents

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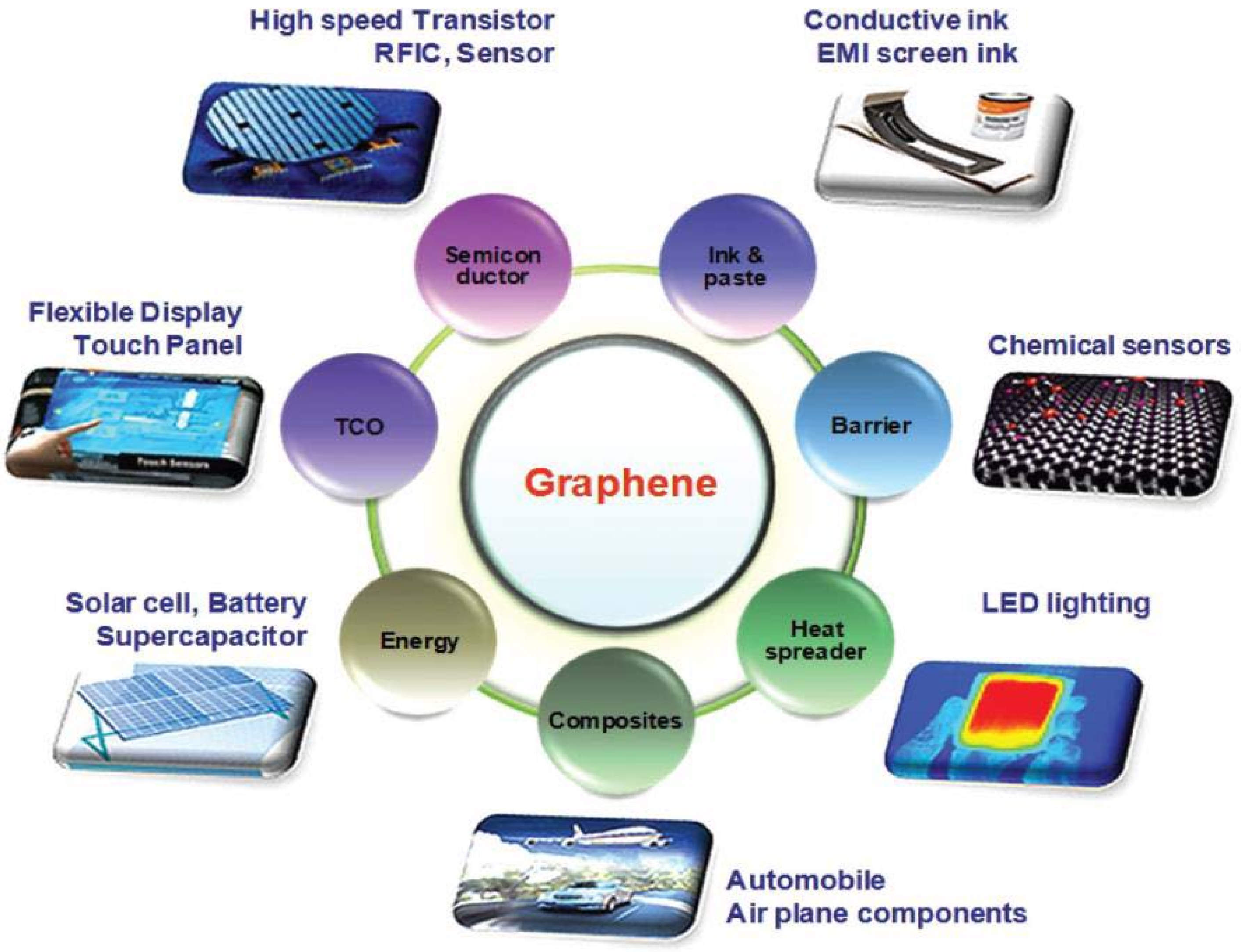

Graphene potential deployment strategies