ALMA MATER STUDIORUM
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CAMPUS DI FORLÌ

I NUOVI MATERIALI PER L'INDUSTRIA MECCANICA E AEROSPAZIALE

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Agenda

- Is there still room for light alloys in aerospace and lightweight structures?
- New materials
  - → New light alloys
  - → High temperature alloys
  - → Composites
- Composites Behavior
- Impacts on Composites
- Additive Manufacturing

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Question: Is there still room for light alloys in aerospace?

Fifty years ago, **aluminum alloys** dominated the aerospace industry.

As the new kid on the block, it was considered to be **lightweight**, inexpensive, and state-of-the-art (70% of an aircraft was once made of aluminum).

Other new materials such as composites and alloys were also used, including titanium, graphite, and fiberglass, but only in very small quantities (less than 10%).

Readily available, aluminum was used everywhere from the fuselage to main engine components.

But today?

Question: Is there still room for light alloys in aerospace?

Times have changed.

A typical aircraft built today is as little as 20% aluminum.

In last generation aircraft, most of the structural material now consist of even lighter-weight **Carbon Fiber Reinforced Polymers (CFRPs)** and **Honeycomb** materials.

Meanwhile, for engine parts and critical components, there is a simultaneous push for lower weight and **higher temperature resistance** for better fuel efficiency, bringing new or previously impractical-to-machine metals into the aerospace material mix.

Question: Is there still room for light alloys in aerospace?

The new generation engines, with temperature potentials as high as 2,100°C (melting point of current superalloys is 1,800°C), have helped drive demand for new materials.

To meet these temperature demands, **Heat-Resistant Super Alloys (HRSAs)**, including titanium alloys, nickel alloys, and some non-metal composite materials such as **Ceramics**, are now being brought into the material equation.

These materials tend to be more **difficult to machine** than traditional aluminum, meaning shorter tool life and less process security.

→ New production technologies

Question: Is there still room for light alloys in aerospace?

Composite materials represent a growing piece of the aerospace material pie.

They *reduce weight* and increase fuel efficiency while being easy to handle, design, shape, and repair.

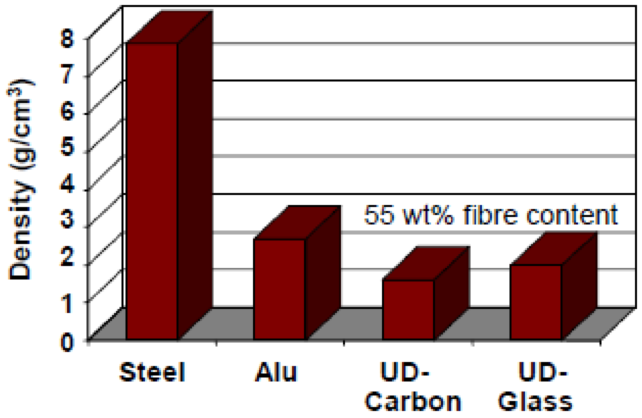
Composite components can be *formed into complex shapes* that, for metallic parts, would require machining and create joints.

Pre-formed composite components reduce the number of fasteners and joints – which are potential failure points – within the aircraft.

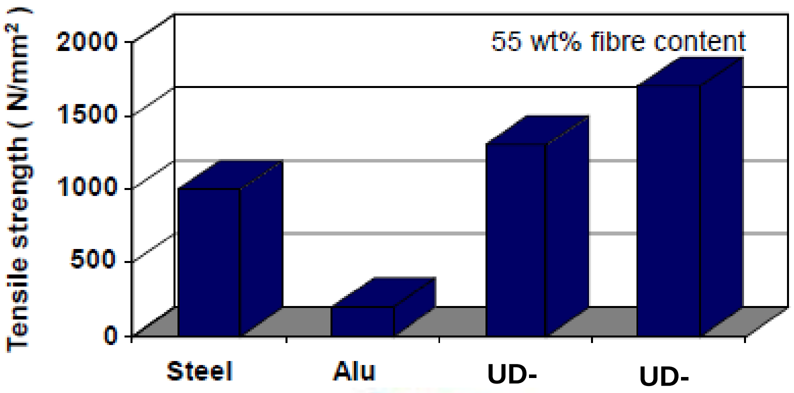
Trend of fewer components in overall assemblies, using *one-piece designs* wherever possible.

Composite Materials

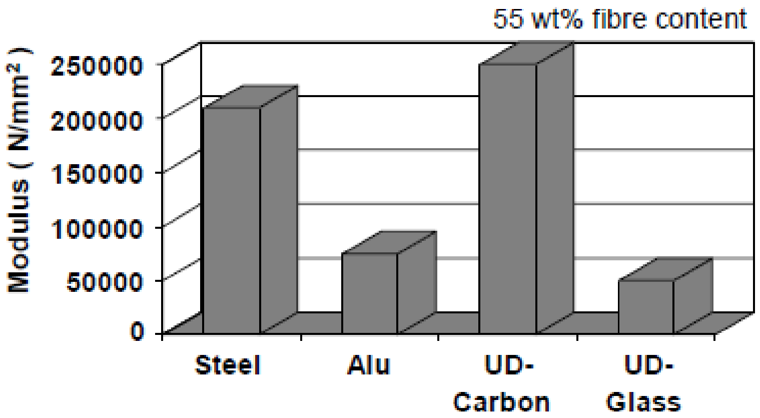
Composites are lighter

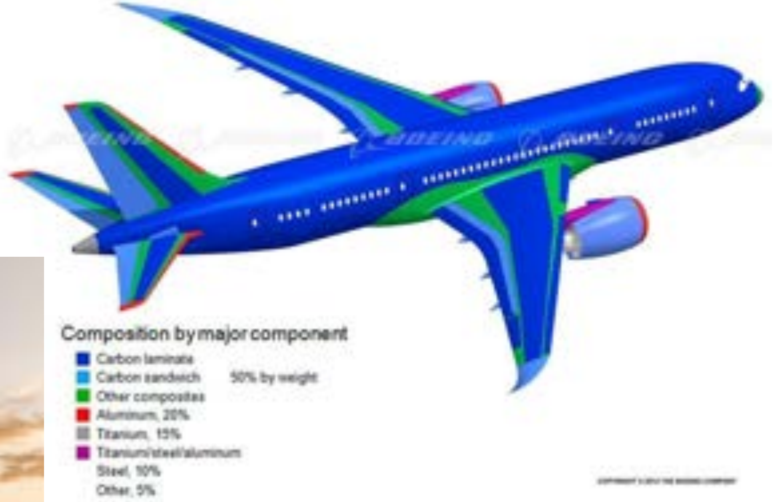


Composites are stronger



Composites are stiffer





Composite Materials

But….

All that glitters is not gold

Faster Production Technologies

Impact Behavior

Fatigue

Sustainability

End - Life

Recycling

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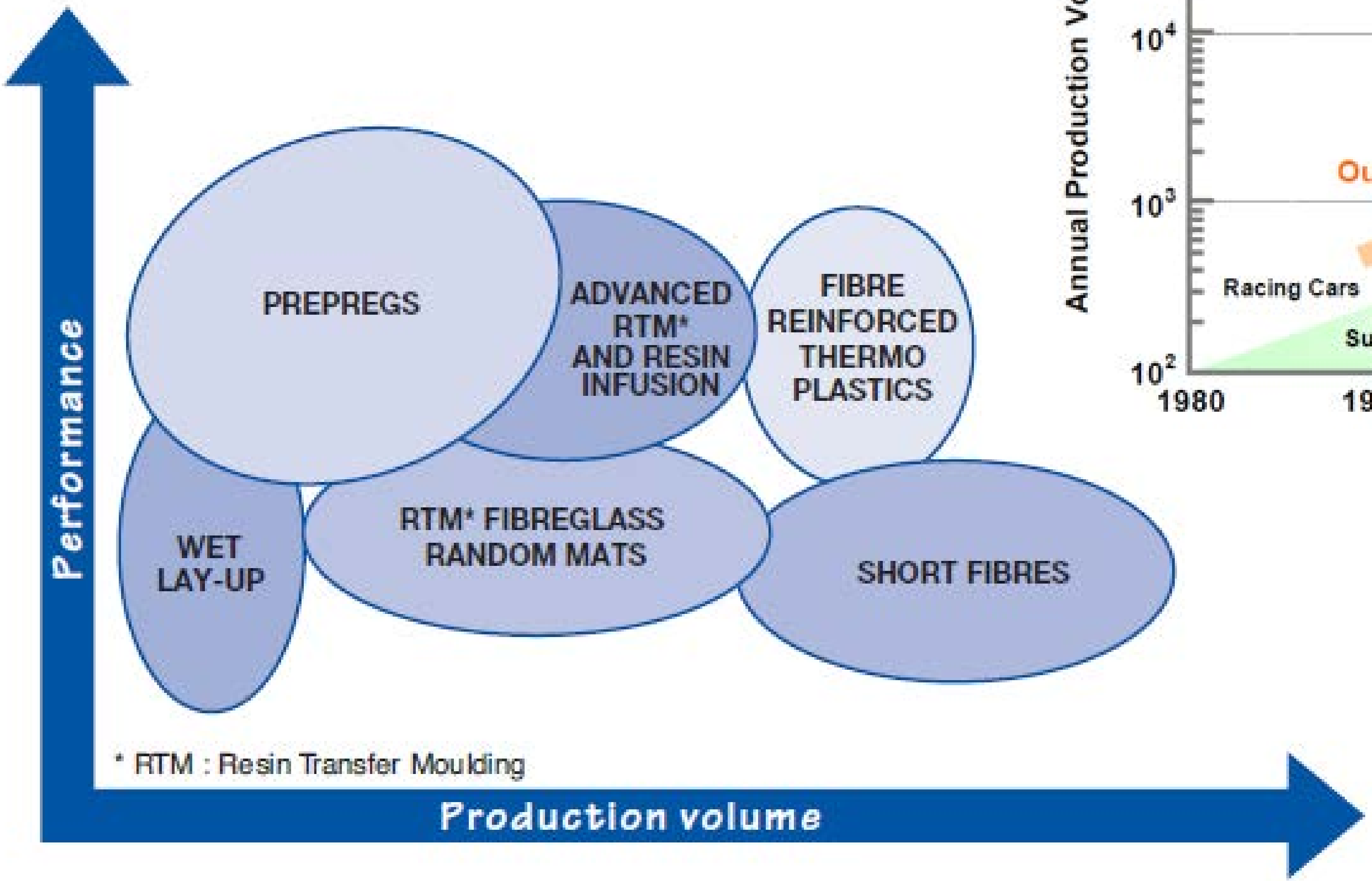
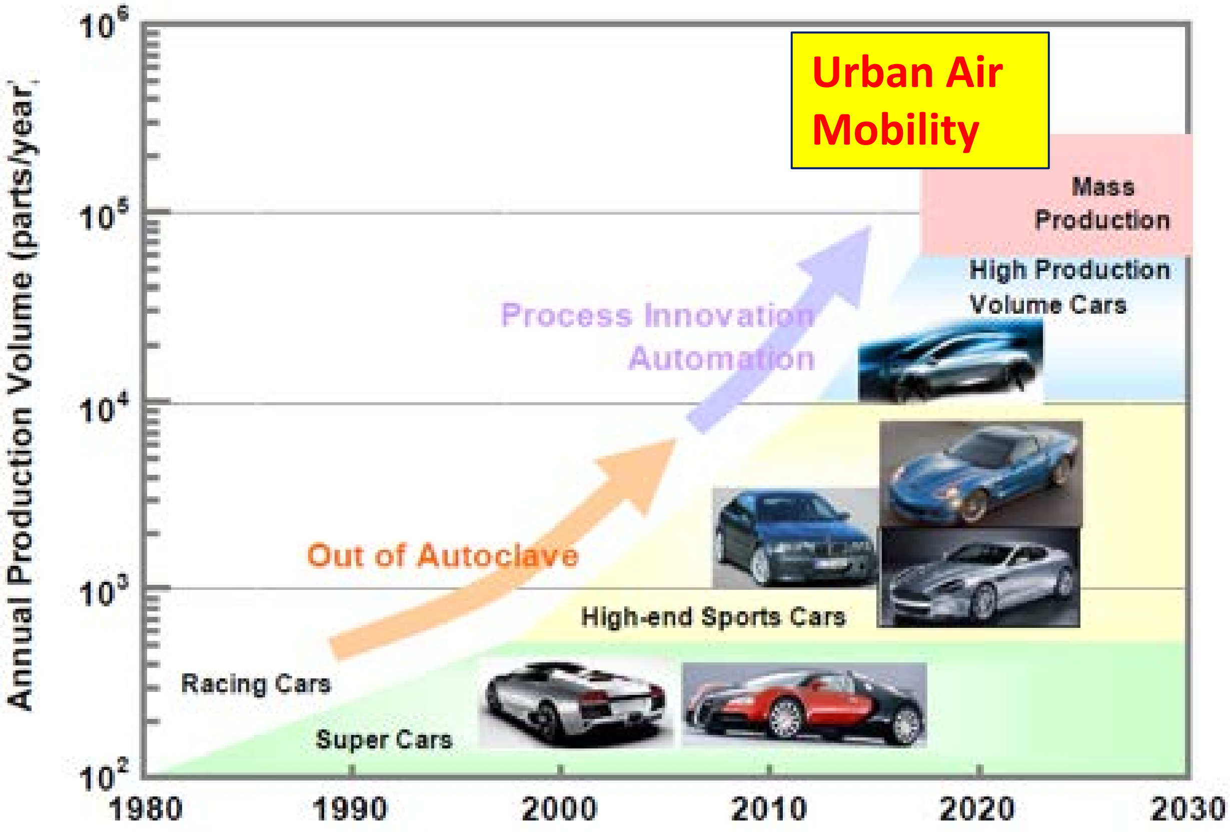
Production Technologies





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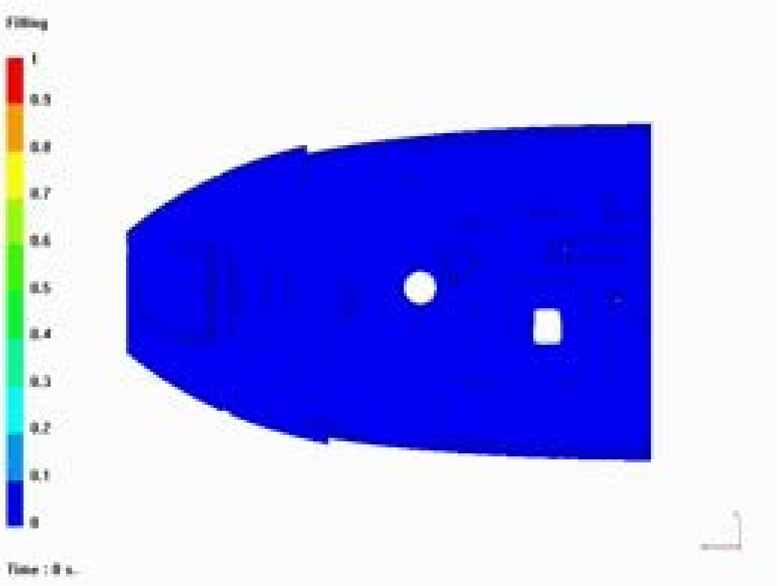
Production Technologies



RTM

VARTM

Autoclave

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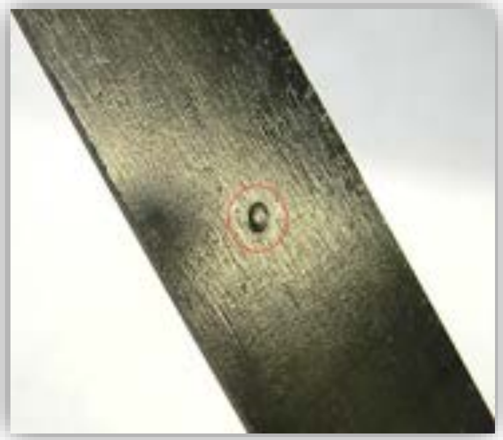
Impacts on Composites

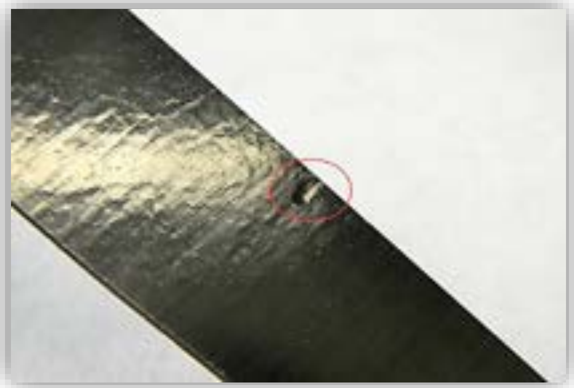
Impacts on composites could be due to:

- Debris on the landing field crash into vehicle by wheels
- Maintenance or assembly tools fall
- Bird impact
- Impacts during luggages loading and unloading



Damages:

- Matrix crack
- Delamination
- Fibre failure
- Fibre/matrix Interface



Impact reaction is up to:

- Composite thickness
- Stacking sequence
- Fibre and matrix kind
- Impact energies

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Impacts on Composites

- **Barely Visible Impact Damage (BVID)** can occur when laminated composite material is subject to free edge impact loads in the plane of the laminate and can result in a significant reduction in compressive and tensile strength

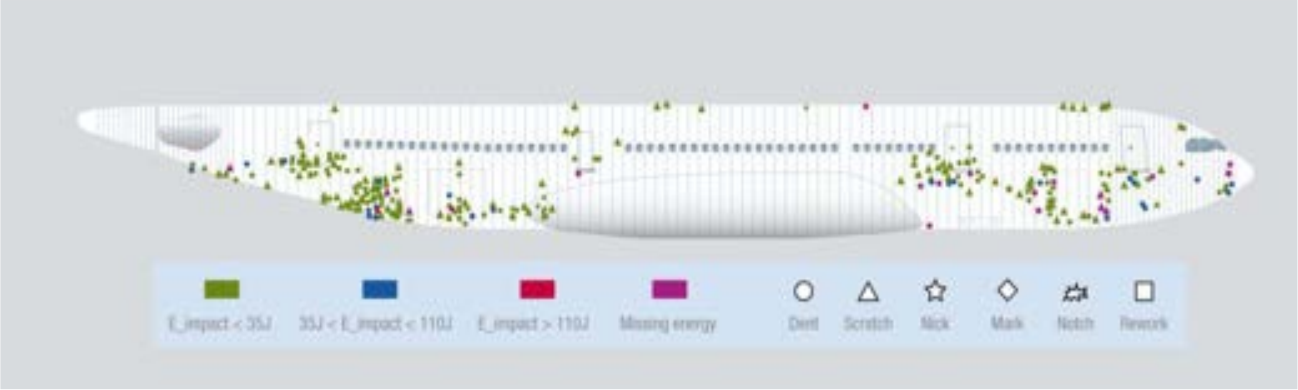
- This effect reduces the damage tolerant properties of the structure, leading to premature failure of the component

Fatigue in Composites

Current damage tolerance approach to composite aeronautical structures: "**no-growth**" concept of Barely Visible Impact Damage (BVID)

A damage threat assessment is crucial in order to understand in which area of an aircraft the probability of an impact is higher and of which magnitude this impact can occur.

More than two thirds of impacts are registered in the door or door surrounding area



→ Definition of an **inspection program**.

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Question: Is there still room for light alloys in aerospace?

Answer: YES!

Even though the amount of aluminum is declining in aircraft, its use is not completely disappearing.

In fact, **aluminum is coming back**, especially in cases where the move to CFRP has been cost prohibitive or unsuccessful.

Titanium aluminide (TiAl), **aluminum lithium** (Al-Li) or **aluminum scandium** (Al-Sc), for example, have only been gaining traction in aerospace since the turn of the century.

The re-introduction of aluminum to aerospace is found in weight-saving **Al-Li**, specifically designed to improve properties of 7050 and 7075 aluminum. Overall, the addition of lithium strengthens aluminum at a lower density and weight, two catalysts of the aerospace material evolution.

Question: Is there still room for light alloys in aerospace?

Al-Li alloys' high strength, low density, high stiffness, damage tolerance, corrosion resistance, and weld-friendly nature make it a better choice than traditional aluminums in commercial jetliner airframes.

Airbus is currently using AA2050. Meanwhile, Alcoa is using AA2090 T83 and 2099 T8E67. The alloy can also be found in the fuel and oxidizer tanks in the SpaceX Falcon 9 launch vehicle.

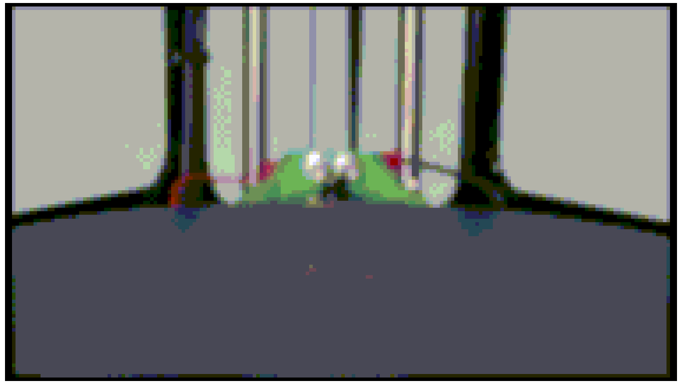
Next step: **Additive Manufacturing**

Additive Manufacturing

AM (or 3D Printing) is one of the most potentially transformative technologies in the production of aircraft parts

Process of constructing complex metal or plastic structures from powders, one layer at a time

General Electric: "within this decade, 3D printing will become not just an effective way of rapidly creating one-off or low volume parts, but competitive for volume production of even large metal components"



Modern printers can engineer **highly complex parts in one piece**

Additive Manufacturing

To become truly mainstream, AM has to scale up and make the leap from lab to factory floor.

Get the cost down and be competitive against incumbent technologies.

The AM is not new to aerospace: early 1990s GE Aviation and Pratt & Whitney introduce 3D rapid prototyping

Late 2010s it starts part production:

- GE received an “engineering change proposal” **approval** for AM sump cover on F-16 engine. First engine component in AM **certified** by US Dept of Defense
- Materialise (Belgium) cleared by Airbus to produce flight-ready parts for its supply chain using **laser sintering**

Additive Manufacturing

Fused Deposition Modelling approved for more than 100 parts on Airbus A350

Example: **A350 tail bracket** (Sogeti High Tech GmbH)

- from 30 parts to 1
- -90% production time
- -135 grams

Boeing approves a new **thermoplastic material** from Stratasys for high-fatigue structural components in AM able to withstand high temperatures (Antero 800NA)

Additive Manufacturing

Aftermarket:

In February 2020 P&W achieved a maintenance, repair and overhaul first with a 3D-printed engine fuel system component.

The part would reduce dependency on the traditional supply chain

In 2020 Satair (Airbus) provided an US airline the first certified **metal printed** flying spare part, a wingtip fence: the cast manufactured original component was no longer available from the original supplier

In **MRO** additive manufacturing allows original manufacturers or repair specialists to make replacement parts quickly and as single items or in low volumes.

Additive Manufacturing

Rolls-Royce has engineered what will be R-R's first serially-produced additive parts, combustor tiles for the Pearl 10X, the new engine that will power Dassault's latest Falcon 10X.

The 1.4mm-thick **nickel alloy** tiles will be made using **laser powder bed fusion**, which requires thinner layers than electron beam melting.

Tiles must withstand extremely high temperatures. They are traditionally manufactured by casting and drilling hundreds of cooling holes. Using additive manufacturing the cooling efficiency increased by 20%.

More complicated design than is achievable with traditional manufacturing.

Additive Manufacturing

P&W made its first production part on the PW1500G engine actuation system in 2017.

It has made more than 100,000 additive manufactured prototypes, including several components on the geared turbofan family.

P&W has its own metal powder source and ability to create parts from design concept to repair.

However, there is still a calculation to be made when **evaluating what should be 3D-printed and what should be produced conventionally**.

Factors taken into consideration include:

- will additive-manufacturing a part reduce lead time, particularly in a repair scenario?
- and will the technology "optimize design" by allowing components manufactured conventionally in multiple sections to be created in one piece?

Additive Manufacturing

BAE Systems uses additive FDM techniques on Stratasys printers, with the aim to substitute parts made by forgings or casting.

Additive manufacturing gives the freedom to make complex components – and assembly of what would have been five or six parts – in a single piece.

Example: Eurofighter Typhoon's radar cooling system, made of **nylon**, traditionally comprised 16 elements. The new part is made by just two pieces and in 24 hours.

Speed and cost are the drivers.

Additive Manufacturing

Senior Aerospace recently replaced aluminum fixtures on low-pressure air ducts with additive manufactured versions it prints in-house.

Not only has the move reduced the component's weight, **but reduced lead times of up to 16 weeks with suppliers to a few hours**

Boeing has more than 70,000 3D-printed parts flying across its commercial, defence and space platforms, with production on more than 200 machines at 20 sites.

While reducing cost and shortening design times are crucial, additive manufacturing is also a step towards **sustainability** for the industry, as the process requires **less material to be used**.

Additive Manufacturing

Challenges:

- **Materials** suitable for additive manufacturing are not always commercially available,
- **Supply chain** is small because of the investment needed in machinery "making it difficult for small businesses to enter this space"
- **Training**, with few universities teaching additive techniques, requiring the incumbent workforce to learn on the job.

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Advanced Alloys for AM

New innovative alloy systems in **operational environment**

Development of advanced light alloys will be done by rational design, with focus on the combination of **theory** with large-scale **computational screening** and **multiscale modelling**.

Lab-scale production and testing.

Such **bottom-up approach** is particularly needed when aiming at innovative material systems that conjugate **optimal performance** in highly demanded aerospace conditions with sustainability requirements.

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