

★ Mass customisation & Delivery

Rapid Manufacturing case studies

→ Reduce Product development cycle time.

<u>TRL</u>	1	2	3	4	5	6	7	8	9
	<u>POC</u> & slightly advanced			Research Lab			industrial Production		

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2. Course recap

Proslab ensures absolute accuracy with additive manufacturing: medical application case

- Leading Australian dental laboratory, Proslab, has fully digitalised the manufacture of its cobalt chrome removable partial dentures (RPDs).
- The laboratory partnered with global engineering company, Renishaw, to install what is thought to be the first metal additive manufacturing machine for dental applications in Australia.
- Proslab turned to Renishaw to overcome issues with human error and accuracy by incorporating a state-of-the art AM 400 metal additive manufacturing machine.

Proslab ensures absolute accuracy with additive manufacturing

Background

- Proslab is a full service dental laboratory in Canterbury, Australia.
- The company was founded over 30 years ago and has always maintained a keen interest in cutting-edge technology.
- 15 years ago, Proslab became the first Australian dental laboratory to bring in CAD/CAM processes for metal frames for dentures.
- Before working with Renishaw, Proslab introduced a partially digital workflow, using 3D scanning and design tools to design dentures.
- Once designed in CAD, the dentures were printed in resin, then using traditional lost-wax casting were manufactured in cobalt chrome.
- It was this traditional, uncontrolled, process that reduced the accuracy of the parts, despite careful design.

Proslab ensures absolute accuracy with additive manufacturing

Background

- Training and support were our priority when purchasing the machine.
- Throughout the process, Renishaw offered outstanding technical support and training to meet this requirement.
- We were confident in our investment as we trusted the product from the very beginning.
- This trust, combined with the exceptional support, meant that there was not one moment during the process where we felt uncomfortable.

Proslab ensures absolute accuracy with additive manufacturing

Proslab dental laboratory



Proslab ensures absolute accuracy with additive manufacturing

Challenge

- At Proslab, the lost-wax casting technique started with producing a CAD design of the denture, which was then printed in resin and used to make the investment mould.
- The part would then be de-invested, trimmed and cast, before being cut and polished.
- During the process, accuracy can be reduced by dimensional changes as a result of uncontrolled heating and cooling, varied cross-sections and incomplete casting or gas porosity.
- “Achieving a high level of accuracy with lost-wax casting is difficult,” explained Damian Synefias, CEO of Proslab.
- “This means frameworks often need to be reworked after being sent to the dentist and fitted to a patient.”
- The most accurate method on the market to manufacture removable partial dentures is additive manufacturing.

Proslab ensures absolute accuracy with additive manufacturing

Challenge

- However, incorporating this technique involved significant change to the company's internal processes and business model.
- To successfully implement the new technology, Proslab required training and support, which is not universally offered by additive manufacturing system providers.

Proslab ensures absolute accuracy with additive manufacturing



RPD build plate inside Renishaw AM 400



Renishaw AM 400

- lasers
- EB

Proslab ensures absolute accuracy with additive manufacturing

Solution

- Proslab turned to global engineering company Renishaw to fully digitalise its manufacturing process using additive manufacturing.
- “To demonstrate the accuracy of the process, Renishaw manufactured sample parts at its Healthcare Centre of Excellence in Miskin, near Cardiff, UK,”

Alex Harris, Applications Engineer at Renishaw.

- “Our dental production facility runs daily, so there was extensive data to prove that additive manufacturing was a viable if not ideal solution.”

Proslab ensures absolute accuracy with additive manufacturing

Solution

- Impressed by the quality of the sample parts, Proslab purchased Renishaw's AM 400 metal additive manufacturing system.
- The machine enables the production of removable partial dentures directly from a CAD file, eliminating the additional casting step.
- Frameworks are built in 40-micron layers of CE marked cobalt chrome powder and built by laser Powder Bed Fusion (PBF), using a high-powered ytterbium fibre laser.
- To ensure the transition was smooth, Renishaw's dedicated additive manufacturing team conducted a week-long training course with Proslab's staff.
- Renishaw also offered ongoing support from Renishaw Oceania, in Mulgrave, Victoria.

Proslab ensures absolute accuracy with additive manufacturing

Solution

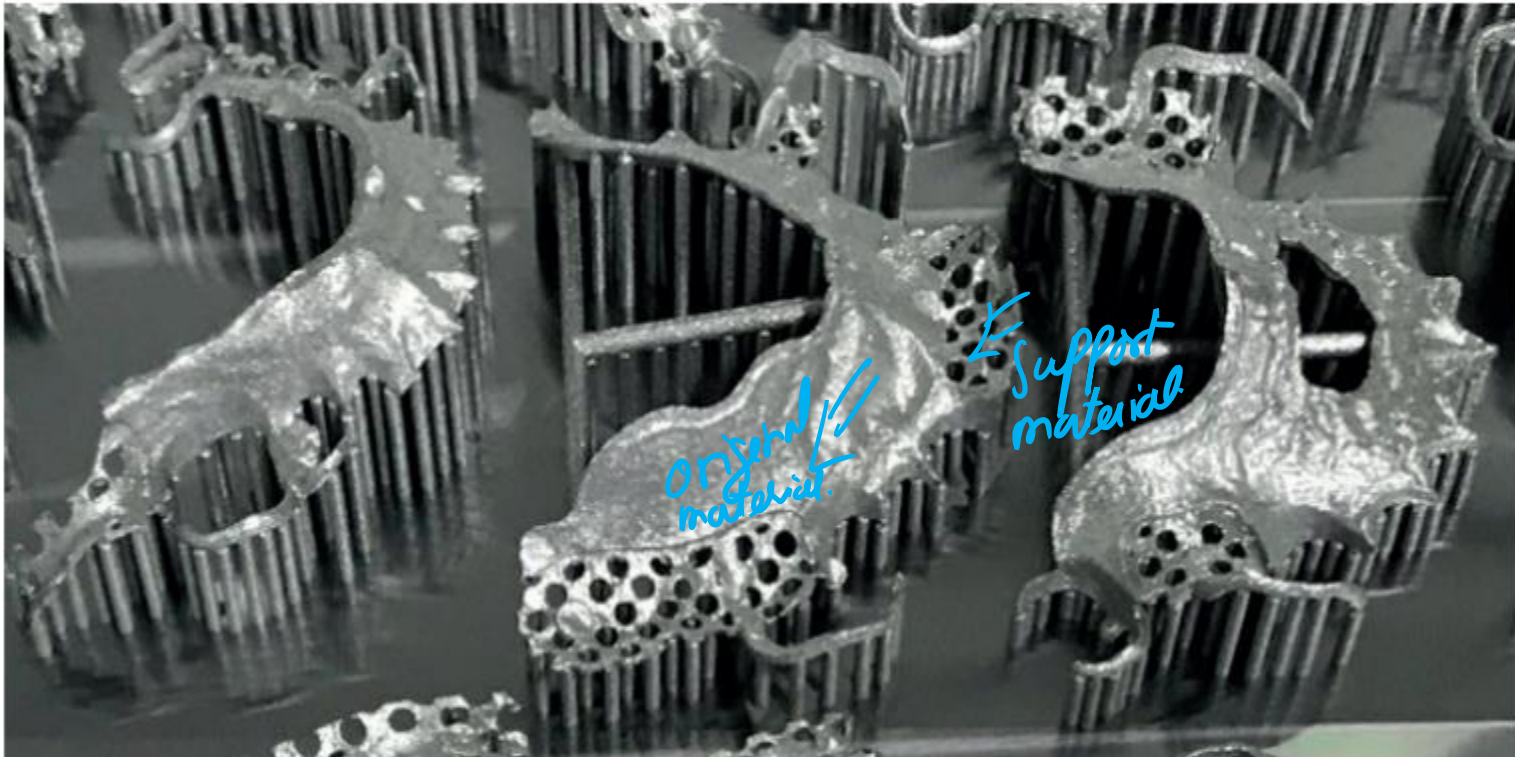
- The Australian team remains in contact with Proslab to answer any questions.
- “Training and support was our priority when purchasing the machine,”

Synefias.

- “Throughout the process, Renishaw offered outstanding technical support and training to meet this requirement.
- We were confident in our investment as we trusted the product from the very beginning.
- This trust, combined with the exceptional support, meant that there was not one moment during the process where we felt uncomfortable.”

Proslab ensures absolute accuracy with additive manufacturing

Proslab denture build plate



Proslab ensures absolute accuracy with additive manufacturing

Results

- “Proslab is now able to produce the most accurate frameworks possible,” continued Synefias.
- “Directly printing from a CAD file means we have reduced the number of in-house remakes due to error by 100 per cent.”
- If any error were to occur, we’d quickly be able to identify the source and amend it.”
- Because of the improvement in accuracy that the AM 400 offers, Proslab can now ensure each framework is a perfect fit for the patient.
- This helps to improve a prosthetist’s service and reputation, benefits patients by offering improved fit and removes any delays that may occur if the framework is not right first time.

Proslab ensures absolute accuracy with additive manufacturing

Results

- “The frameworks we produce are now guaranteed to fit every time, which means we have been able to raise turnover,” said Synefias.
- Partial dentures in half the time,” continued Synefias.
- “The difference in fit has been amazing – we are now gaining more customers for it as we can ensure that customers will receive the best possible fitted dentures.
- “By cutting out the casting step, we can now produce removable partial dentures in half the time,” continued Synefias.
- “We save an entire day of processing, which means we have been able to upskill our casting staff into manufacturing roles.

Proslab ensures absolute accuracy with additive manufacturing

Results

- Staff have responded well to the new format and we've had a significant boost in morale, as they have the peace of mind that parts will be correct.
- "Proslab is the first Australian dental laboratory to incorporate additive manufacturing, and we now have access to the most up to date technology in the world," added Synefias.
- "We have also improved turnaround times to a five-day cycle, improving the service to our clients.
- "We required a high level of support and the service we received has been excellent and, in my opinion, Renishaw has been perfect.
- The project has been such a success that we plan to purchase another machine," concluded Synefias.

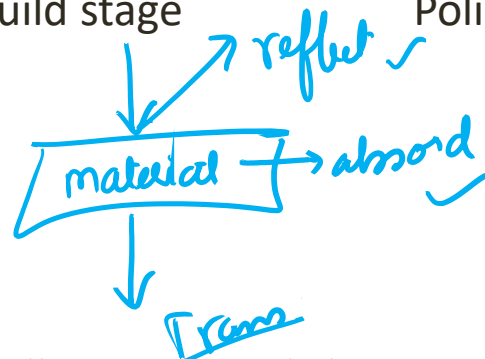
Proslab ensures absolute accuracy with additive manufacturing



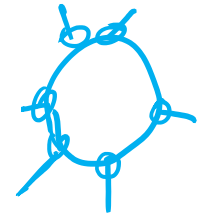
Laser melting during build stage



Polished RPD on stone model



Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation



- In the high-octane world of MotoGP™ motorcycle racing, technical enhancements can have a big impact.
- Race winning Moto2 team TransFIOrmers is using cutting edge additive manufacturing (metal 3D printing) technology in an unconventional front suspension system to gain a significant competitive advantage.

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

Background

- Motorcycles ridden in the MotoGP World Championships are special; the general public can't buy them and they can't be used on a public road.
- As prototype racing bikes they are custom-built to outdo their rivals and maximise performance on the track.
- Moto2, the second of the three MotoGP classes, was created in 2010.
- Its official engine is a 600cc four-stroke production engine, currently supplied by Honda.
- The French Moto2 team TransFIOrmers, based in Perigueux, South West France, is revolutionising front suspension design in order to stay ahead of the pack.

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

Background

- TransFIORmers is led by former 250cc World Championship rider Christian Boudinot, and the team's unconventional suspension system was inspired by the seminal work of the legendary French motorbike designer Claude Fior.
- Boudinot's former friend and mentor, Fior, recognised the gains to be made from isolating the front suspension from steering forces.
- Resolving issues of 'brake dive', the design enables later braking into a corner and faster acceleration out.
- The weight reduction that metal 3D printing has achieved for us in our wishbone component has enabled us to bypass traditional weight transfer phenomenon and the problems associated with 'brake dive'.

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

Background

- More than that, it's allowed us to design a part that is not only lighter, but far more rigid at the same time.
- Instead of the more traditional telescopic front fork suspension, the TransFIORmers motorcycle employs a rigid front fork suspension system separated from the chassis using two wishbones.
- To further advance the development of its innovative design, TransFIORmers approached I3D Concept, a world-class expert in metal additive design and manufacturing techniques.
- Using Renishaw's AM250 additive manufacturing system, I3D Concept worked in partnership with the TransFIORmers team to optimise the design of its upper wishbone component, one of two attaching the front fork to the chassis and critical to the bike's steering.

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

Challenge

- In the development of new components in Moto2 bike design, achieving a weight reduction is a priority.
- In particular, reducing the 'unsprung mass' of the bike is a key consideration.
- The lower the unsprung mass, the better the suspension is in terms of vibration management and responsiveness to both braking and acceleration.
- Of equal importance is the speed with which the design of a new component can be modified, and how long it takes to remanufacture.
- Achieving perfection in a highly competitive environment demands fast, accurate component iteration.
- In a high reliability environment, mechanical strength is a further prime consideration.

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

Challenge

- The TransFIORmers' wishbone component needs to assure best possible rigidity, while handling significant levels of dynamic steering force.
- “To improve overall motorcycle performance, reducing the weight of all components located behind the shock absorbers is absolutely vital.
- Failure to optimise component weights can have an adverse effect on vibration, braking and acceleration, so weight reduction is a really high priority”, says Jérôme Aldeguer, TransFIORmers.

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation



Original twelve part steel component



Metal 3D printed one part titanium component

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

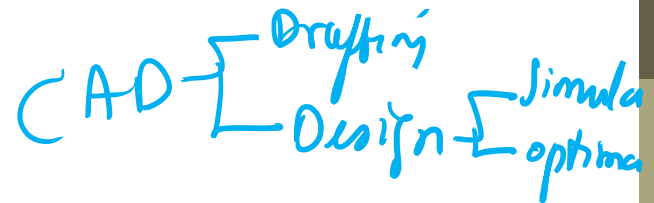
Solution

- TransFIORmers' original wishbone component was handfabricated in steel, with the assembly comprising twelve separately machined and welded parts.
- I3D Concept consolidated the design into a single piece component, greatly reducing assembly time.
- The company produced the metal 3D printed wishbone using a Renishaw AM250 additive manufacturing system; initially prototyping in stainless steel (inox) and finally manufacturing a lighter weight part in titanium.
- Key to the new 3D component design was an iterative process of topological optimisation, whereby the wishbone layout was successively rationalised in software within tight space constraints to withstand a set of predefined front fork loading conditions.

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

Solution

- Once the final component design was validated using digital CAD software, the build preparation file was prepared offline prior to export to the additive manufacturing system.
- Within the CAD software, I3D Concept was able to assess whether the parameters were effectively predetermined or whether they required tweaking to match the specific metal powder characteristics and the complex target geometries of the TransFIORmers wishbone. Importantly, using the AM250's dedicated Optical Control System (OCS) software, I3D Concept was able to very accurately control laser steering which helped to enhance precision, definition of features and surface finish.



Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

CAD development of additively manufactured titanium component



Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

Results

- By taking an additive manufacturing approach to Moto2 bike design, TransFIORmers succeeded in dramatically reducing the weight of its critical wishbone front suspension component by a factor of 40%.
- Comparing the one-piece titanium component with the original welded steel component, a weight saving of 600g was achieved.
- Metal 3D printing has also provided TransFIORmers with much finer control over component tolerances and the flexibility to very quickly iterate wishbone geometries to match specific chassis and kinematic requirements.
- “The weight reduction that metal 3D printing has achieved for us in our wishbone component has enabled us to bypass traditional weight transfer phenomenon and the problems associated with ‘brake dive’.

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

Results

- More than that, it's allowed us to design a part that is not only lighter, but far more rigid at the same time", explains Jérôme Aldeguer, TransFIORmers.
- With an ultimate tensile strength in excess of 1100 MPa when processed using additive manufacturing, and near perfect 99.7% densities, the titanium Ti6Al4V alloy used has delivered a radical new wishbone offering far greater rigidity than the original multi-part, hand-assembled steel component.
- Thanks to additive manufacturing, TransFIORmers' prototype wishbone development has become a highly efficient and cost effective process.

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

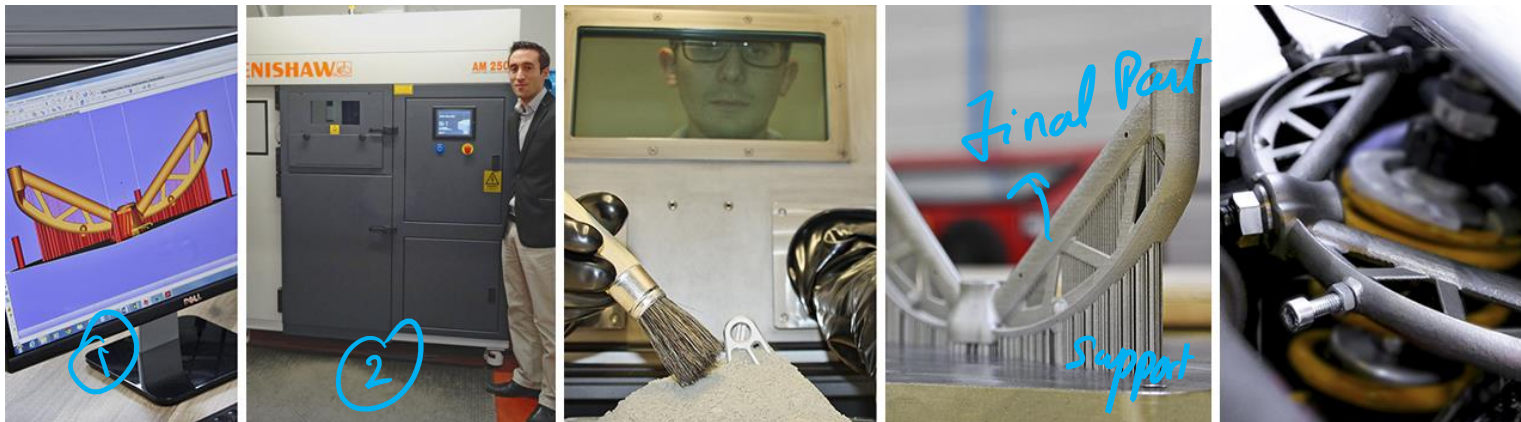
Results

- Extensive part machining and assembly time overheads have been removed and design iterations and manufacturing have been made many times faster.
- In June 2016, the team won its first ever Moto2 GP race at the CEV event in Barcelona.

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation

“The weight reduction that metal 3D printing has achieved for us in our wishbone component has enabled us to bypass traditional weight transfer phenomenon and the problems associated with ‘brake dive’. More than that, it's allowed us to design a part that is not only lighter, but far more rigid at the same time.”

TransFIORmers (France)



Steps in Additive Manufacturing of the component

Metal 3D printing pushes the boundaries in Moto2™ through defiant innovation



Metal 3D printed one part titanium component on the TransFIORmers bike



TransFIORmers race bike

Renishaw IPR notice:

(on Renishaw website)

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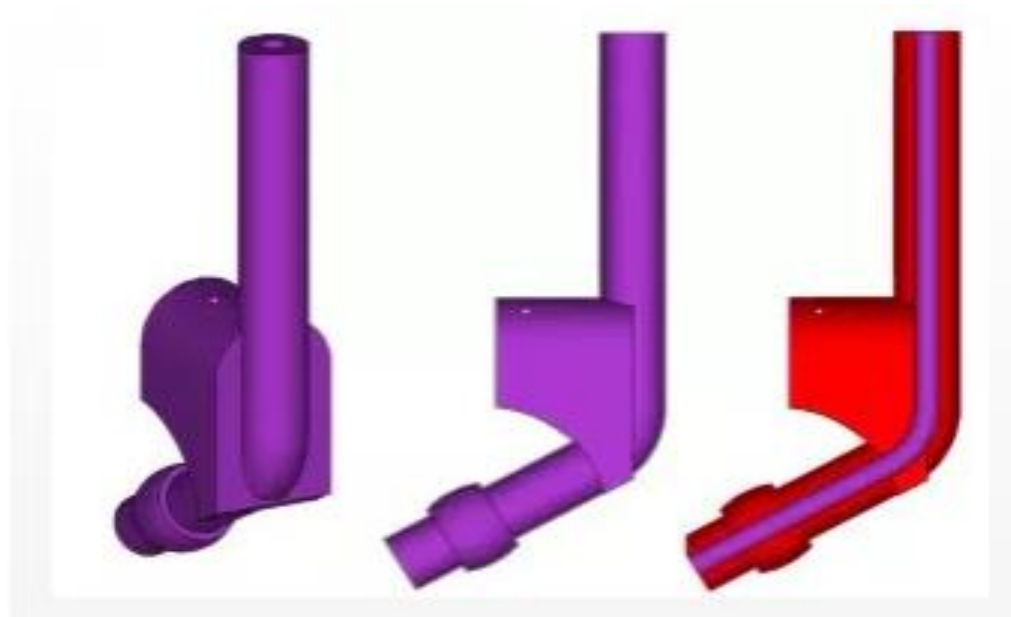
AM Production for Aerospace

The Brief:

- BAE Systems Regional Aircraft provides support and engineering services for its in-service fleet of some 500 commercial aircraft worldwide.
- As part of its ongoing spares support for the BAE 146 regional airliner, the company needed to replace a small pipe which forms part of the cabin windows and stops the windows misting up.
- The part, known as a 'breather pipe', had originally been made via injection moulding, but the tooling had become damaged and replacement tooling was expected to take months to produce and cost in the region of £14,000.
- It was important to produce the parts rapidly as without this small, but critical part, a plane could be grounded. BAE Systems Regional Aircraft turned to 3T RPD and Additive Manufacturing (AM) for the solution.

AM Production for Aerospace

CAD image of BAE Systems breather pipe showing smoothed angle on turn



AM Production for Aerospace

The Solution:

- The Regional Aircraft team at Prestwick realised that 3D manufacturing could provide an elegant solution to this problem.
- They designed the replacement breather pipes and these were prototyped by their colleagues at the BAE Systems' Military Air & Information.
- Then, Regional Aircraft worked with 3T to develop the product for production for 3T to build batches of the parts.
- 3T used the CAD drawings from the customer and produced a number of example parts.
- Quality Assurance inspections highlighted potential for improvement prior to going to production.
- The original pipe had a small diameter with a sharp bend.

AM Production for Aerospace

The Solution:

- Both these features caused problems as it made the removal of loose powder difficult and loose powder left in the pipe restricted the air flow thus making the part unreliable.
- 3T's QA, CAD and customer service teams worked with the team at Regional Aircraft to understand the part's critical features and then propose design amends to make the part suitable for AM production.
- The CAD was modified to widen the pipe diameter (without changing the external dimension) and smoothed the line of the pipe so that the radius of the bend was less acute and more rounded.
- Additionally, test builds completed at 3T, led the QA team to identify that placing the part in a specific build orientation resulted in more consistent production.

AM Production for Aerospace

The Result:

- After working with 3T, the parts are now in stock at BAE Systems Regional Aircraft's spares warehouse and are being used by its customers for use on in-service aircraft.
- The projected timeline for producing the part using injection moulding was six months yet using additive manufacturing, this was reduced to four weeks.
- Philip Beard, Structures Support Manager for In-Service Aircraft at BAE Systems Regional Aircraft said: "Not only was there significant time saving and the avoidance of the tooling cost, but the actual parts cost 60 per cent less than when manufactured using the traditional method."

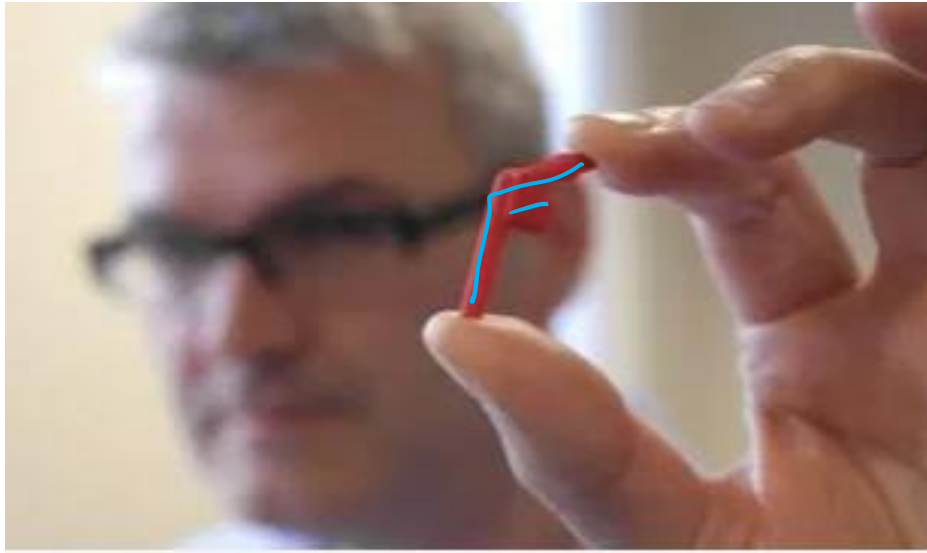
AM Production for Aerospace

The Result:

- “Having achieved this first breakthrough on the BAe 146 window breather pipe, we are now looking at a range of other 3D Printing opportunities to provide replacement parts across several different commercial aircraft types.
- This technology offers a potential solution for aircraft parts which are prone to obsolescence, where tooling is unavailable, for quick turn rounds and also for small batch production.”

AM Production for Aerospace

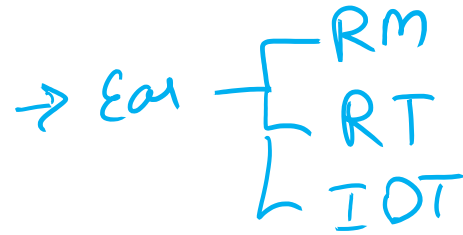
BAE Systems finished breather pipe



Recapitulate the course: 'Rapid Manufacturing'

The course flew in this fashion:

- Introduction to Rapid Manufacturing
- Product Design Process
- Design for Modularity
 - Design for Manufacturing ✓
 - Design for Assembly ✓
 - Design for Modularity ✓
- Subtractive versus Additive comparison



Recapitulate the course:

'Rapid Manufacturing'

The course flew in this fashion (continued..):

- Rapid Manufacturing processes
 - Polymerization processes ✓ — liquid
 - Powder based processes — SLS, SLM,
 - Extrusion and Liquid based processes — FDM
 - Sheet Stacking Processes — LOM
 - 3D printing processes — glue/additive
 - Beam Deposition Processes — laser
EB
- Laboratory demonstrations

Recapitulate the course: 'Rapid Manufacturing'

The course flew in this fashion (continued..):

- Post processing concerns
- Rapid manufacturing materials
- Costing for Rapid Manufacturing
- Rapid Product Development
 - Computer Aided Design and Manufacturing for Additive Processes
 - Plant Design and Simulation for Additive Processes
- Case studies on Rapid Manufacturing

Bio medical
Auto
Aero

Thanks