EPSRC CENTRE FOR INNOVATIVE MANUFACTURING IN ADDITIVE MANUFACTURING

The rise of 3D Printing as a Digital Fabrication approach

Diginova Meeting, Centi,

4 March 2013

EPSRC

Nottingham

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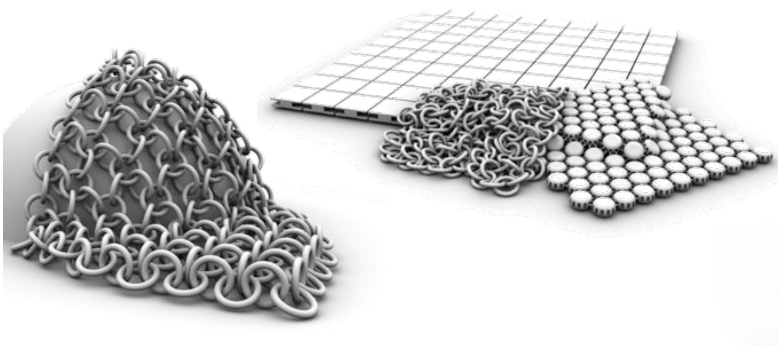
Contents

- The concept of 3D Printing (Additive Manufacturing / Digital Fabrication)
- Why it's important
  - Why does it change the way we think about stuff?
- The importance of design
  - Lightweighting, functionality
- What the future holds….



Additive Manufacturing

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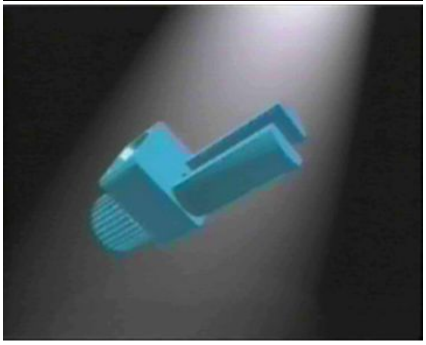
- Effectively "3D Printing"
  - Emerged from Rapid Prototyping type techniques (SL, LS, etc)
  - Conceptually simple – belies significance
  - AM is *very* different to RP – even if same systems are used
- Dedicated manufacturing systems beginning to emerge
  - Plastics
  - Metals (increasingly useful)
- Principal advantage?
  - No mould tooling
  - Un-paralleled Geometric freedom



Where it's being used

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- Increasingly being used in demanding applications
- Ideal for Complex, High Value, medium-low volume, customised products

Why is it important?

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1. Enabler for low volume production – democratising manufacture…..
2. Maximising **design** complexity & flexibility
3. Increasing part functionality
4. Product personalisation
5. Reducing environmental burdern
6. New business models and supply chain realignment

Identified as Key to UK…..

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- One of 22 TSB Core Technology Competences
- One of 12 EPSRC Centres for Innovative Manufacturing
- Identified by DSTL as strategic technology for defence and security
- UK currently leading AM / 3DP research domain
    - Innovation is important
        - needs underpinning with world-class research
        - Pipeline of activity
    - Needs translation and exploitation
    - Skills shortage a significant issue
        - Technician to PhD

The importance of design

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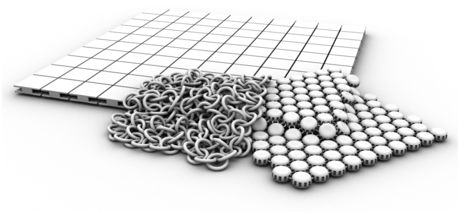
- Processes are just enablers
- The real potential of AM comes from the *Design* & *Implementation* areas
  - Design possibilities unlocked by AM capabilities
- AM can print from lots of data sources
  - scanning, CAD, MRI, CT
- We can print almost anything with no cost penalty
  - Designers greatly restricted with traditional manufacture
  - There are lots of funky design examples



Areas of interest (to me…..)

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- Biomemetics
  - Optimisation, Biological structures
- Customisation
- Micro level design
  - Textures, textiles & foams
- Design possibilities / restrictions
  - Polymers, metals, multifunctional systems

- All of these require new Design Tools to maximise potential

Problem with CAD*

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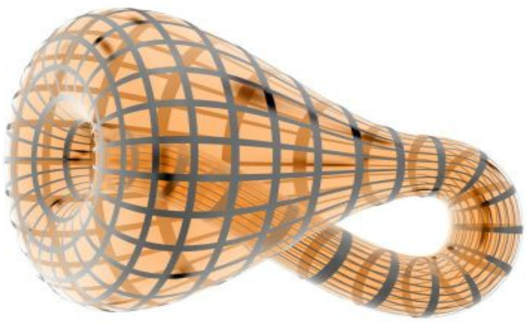
- CAD is seen as a great enabler, but……
  - Current CAD developed to suit traditional manufacturing techniques
  - AM able to produce virtually any complexity of parts
  - CAD not suitable for geometrical freedoms of AM
  - *New design tools required*



  - ** Computer Aided Design*

Design Optimisation / Lattices

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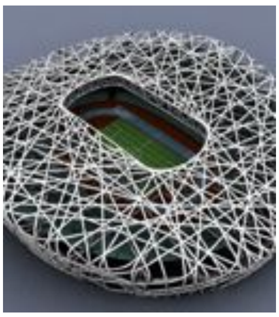
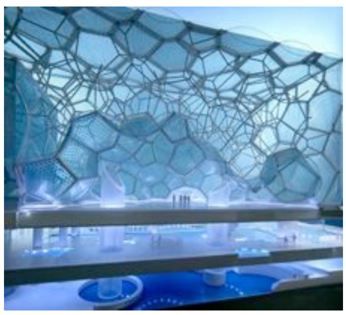
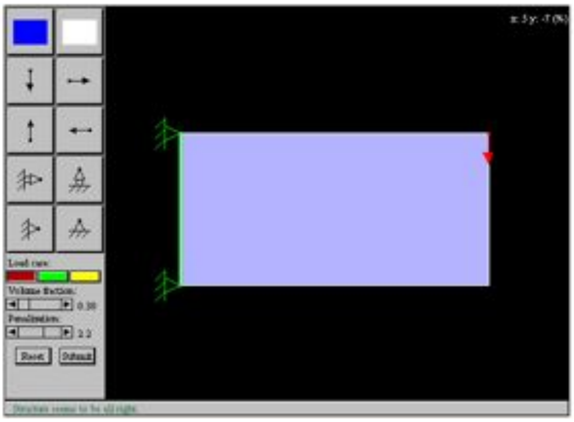
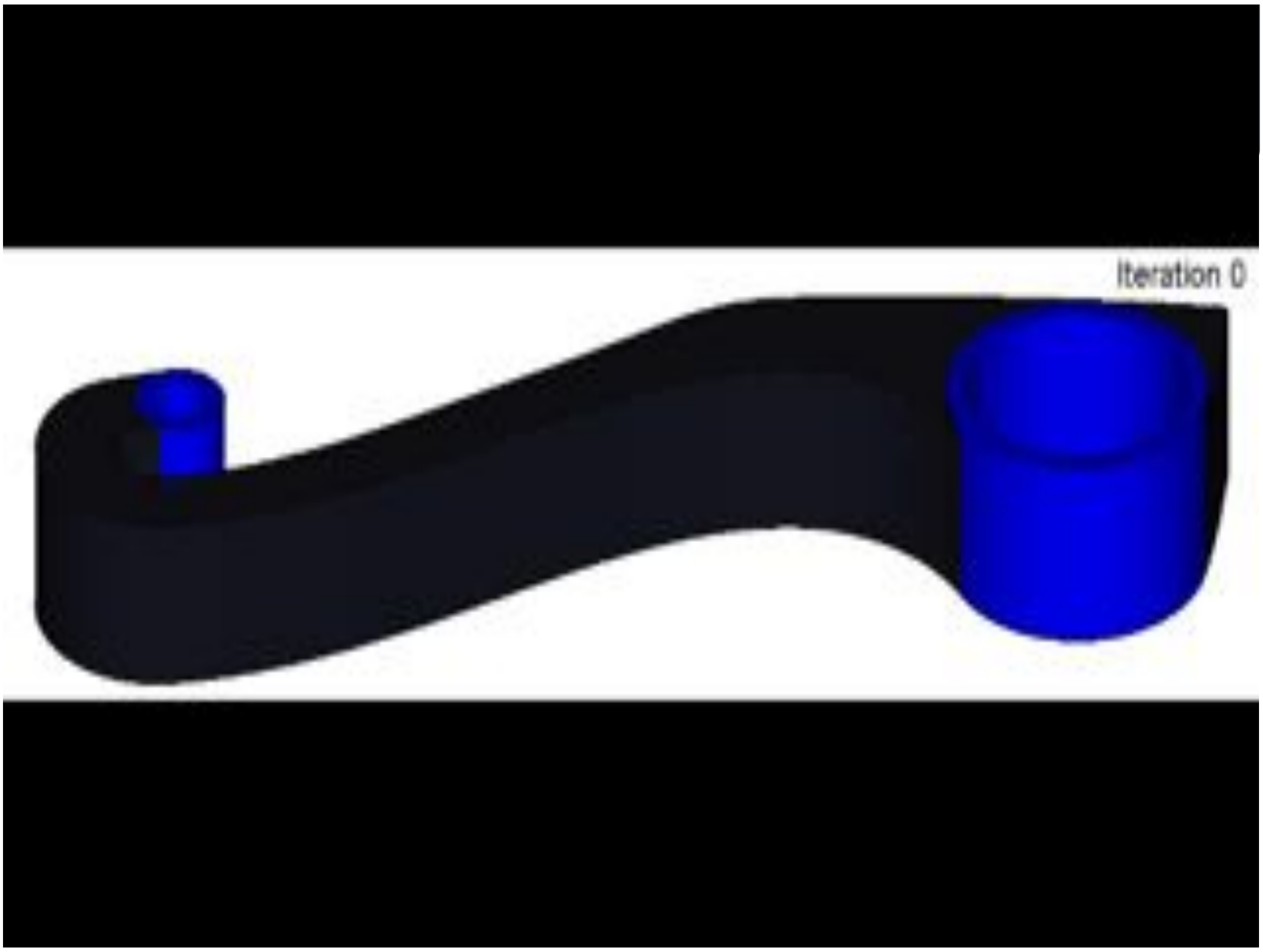
- Use of Optimisation / lattices to minimise material usage
- Potential for skeletal designs (minimisation of materials)
  - Common in construction industry due to fabrication
  - Not generally used in product manufacturing





Topology Optimisation





Incorporation of stochastics: fast determination of optimum

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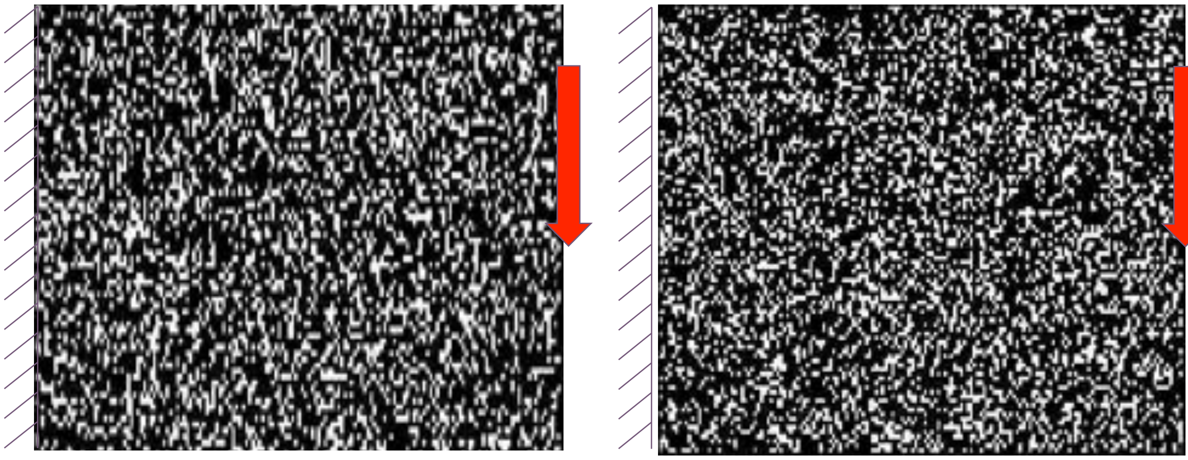

Both solutions have same compliance of 1.87mm/N and volume fraction of 0.5

Intelligent iterative mesh refinement

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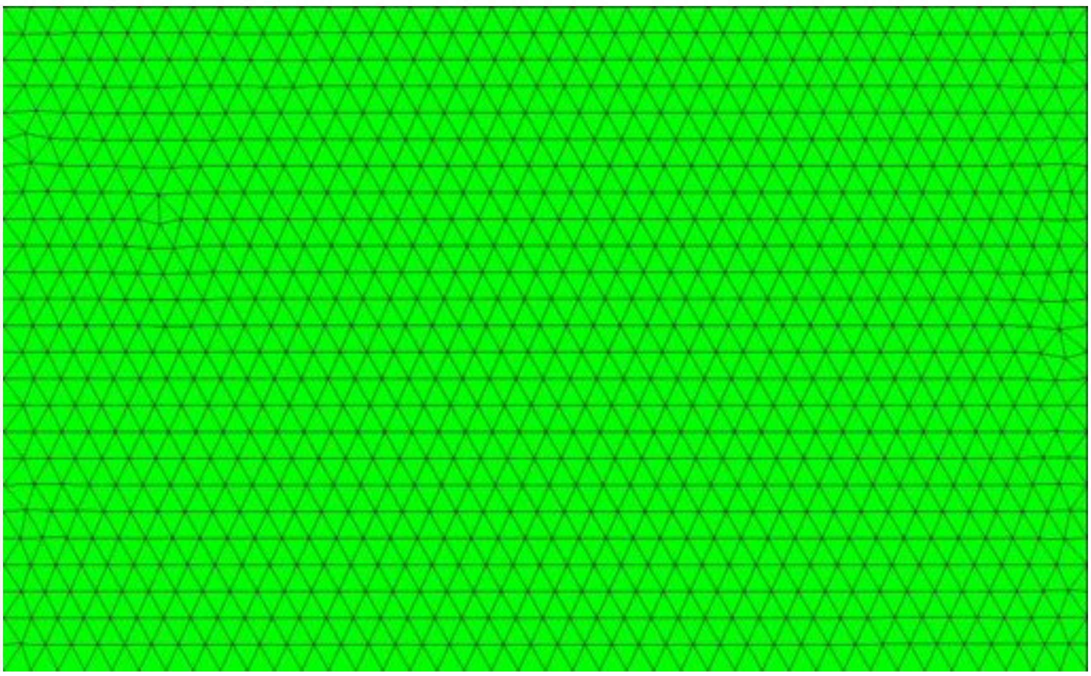
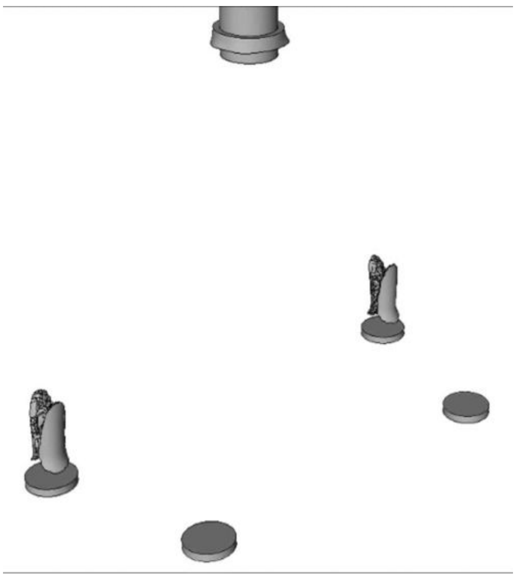
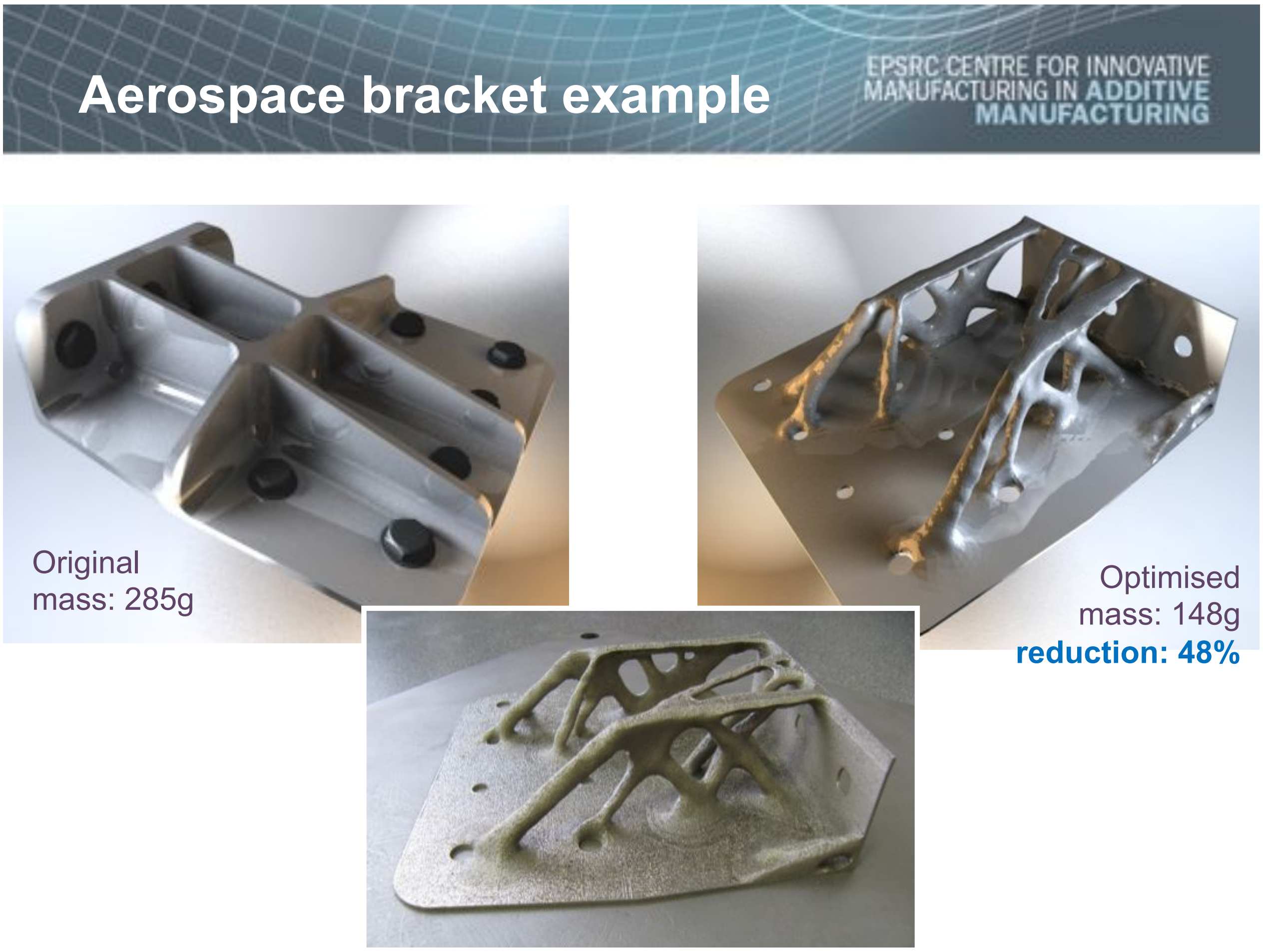


Aesthetic Topology Optimisation: Walking Aid Example



Aesthetic Topology Optimisation: Walking Aid Example


Aerospace bracket example
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Original
mass: 285g
Optimised
mass: 148g
reduction: 48%

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Flow optimisation

Flow optimisation

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Flow optimisation

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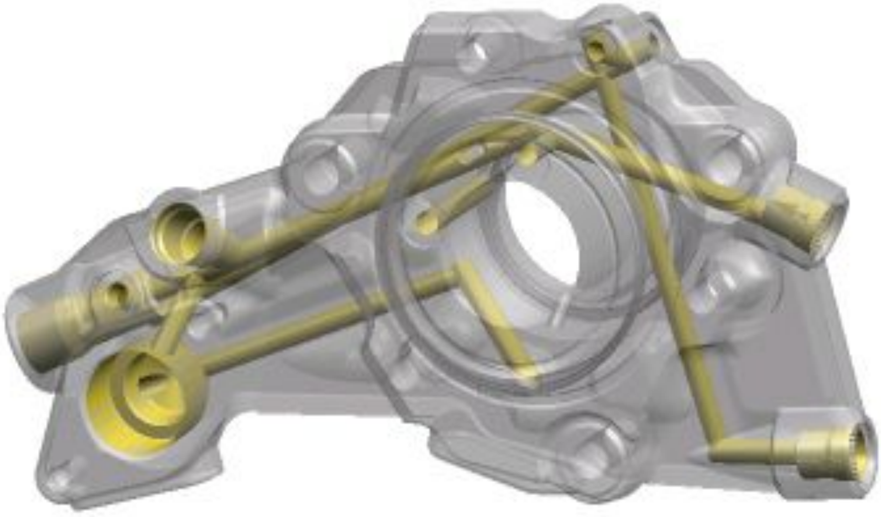

Flow optimisation

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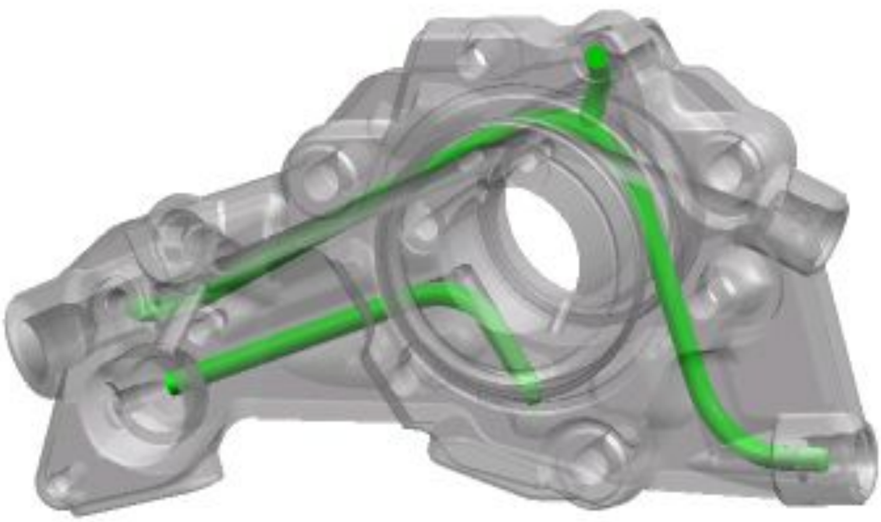

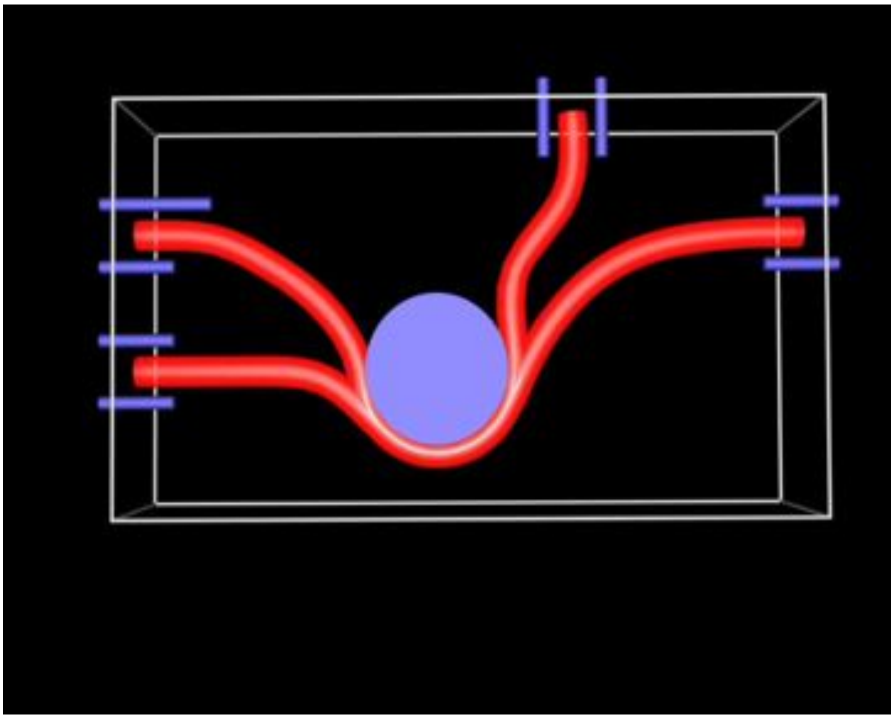

Design for Low Carbon

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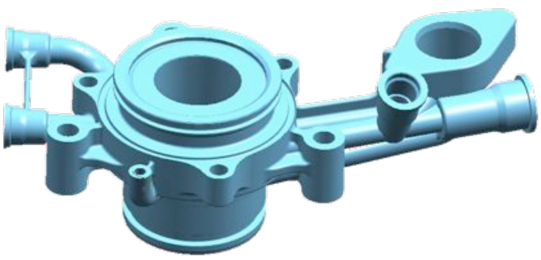

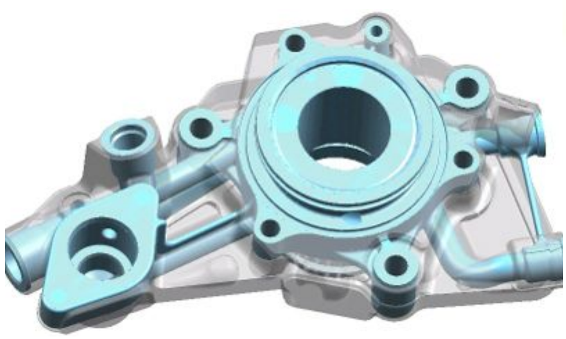

40% weight saving over original component design

Example – conceptual heat exchanger

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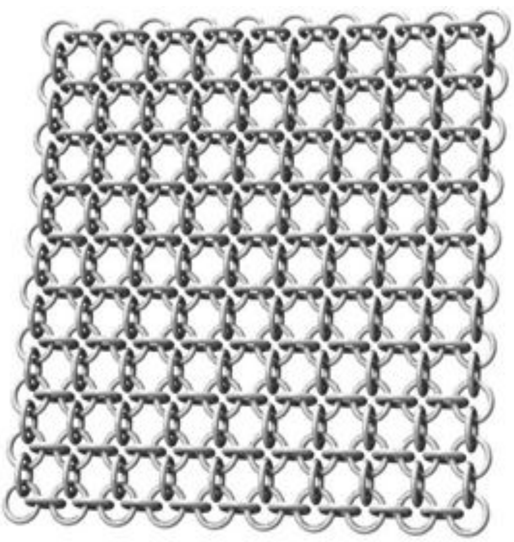
3D Conformal Textiles

- Currently relatively easy to produced flat sheets



3D Conformal Textiles

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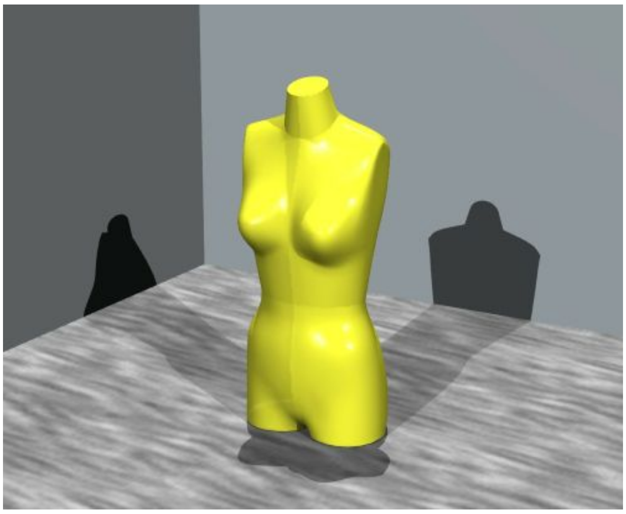
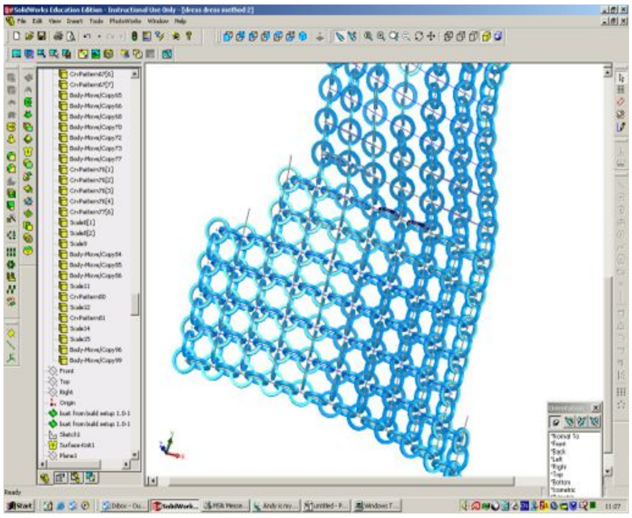
- Entirely different matter when moving to fitted apparel





And now a reality….

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End Goal

- Customised Personal Protective Equipment, incorporating intelligent design, novel materials and integrated sensors

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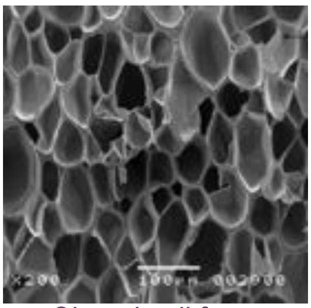
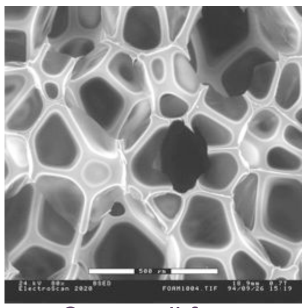
Structure of Polymeric Foam

- Characteristic compressive behaviour due to cellular structure



Closed cell foam

- Cell walls form between struts
- Isolated cells of gas
- Walls, struts and gas contribute to compressive behaviour



Open cell foam

- Cell walls receded into struts
- Gas moves freely through structure
- Struts alone contribute to compressive behaviour

Images from: Mills, N.J., Fitzgerald, C., Gilchrist, A., Verdejo, R. Polymer foams for personal protection: cushions, shoes and helmets. Composites Science and Technology. 2003;63:2389-400

IARMS – Straight Strut Design

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- An open-cell arrangement of struts forming a Kelvin structure
- File size a genuine limitation in the generation of lattice structures

IARMS – Helical Strut Design

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- Same underlying structure with a helical strut applied to it
- Very large file sizes
- Helix utilised to increase the length of the strut, making the structure more flexible

Straight Strut Compression

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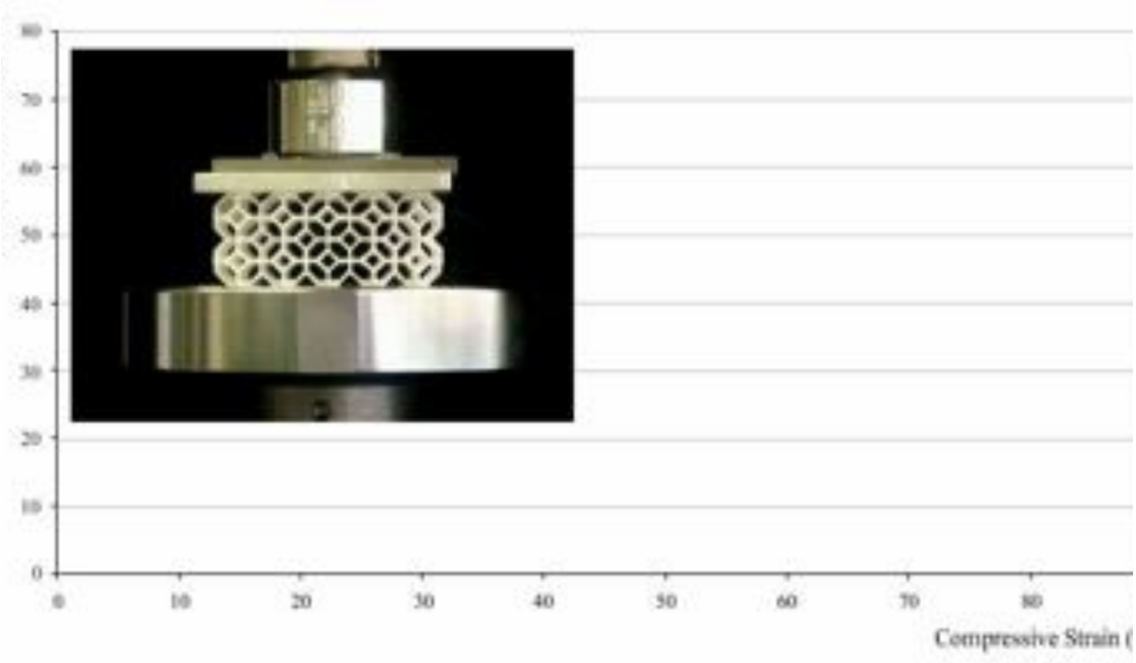

Further Work

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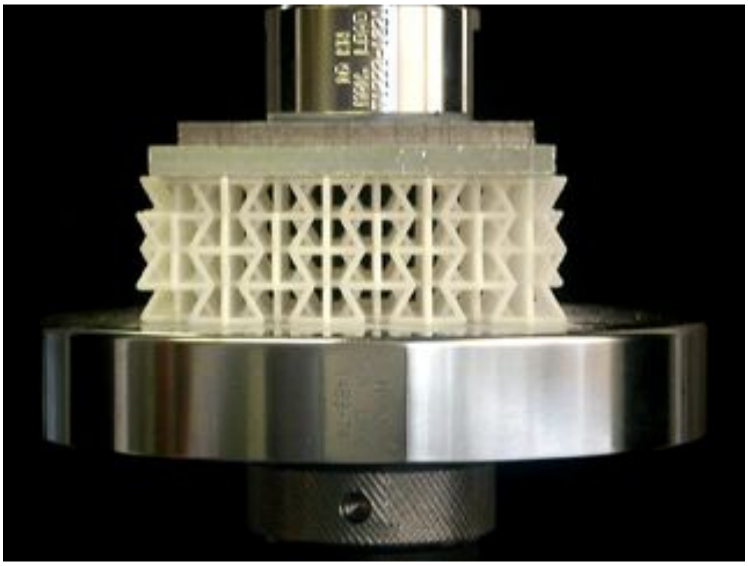
- Auxetic IARMS



Lattice generation: Computational difficulties

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- Conventional modelling techniques (e.g. CAD) are inefficient at generating lattice structures
- Software is being developed that generates lattice structures that conform to a volume

Input volume

Conformal structure

Lattice Generation

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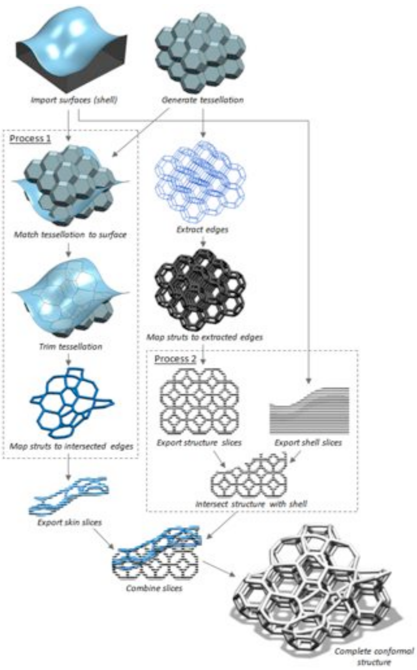

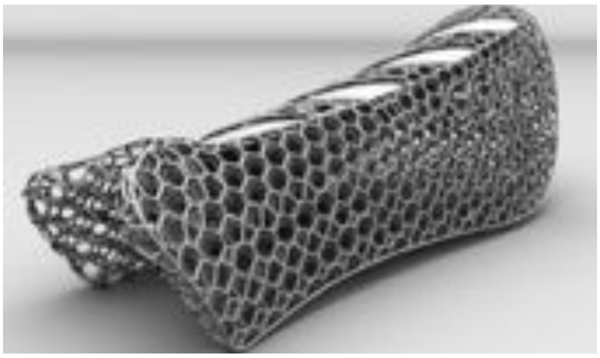

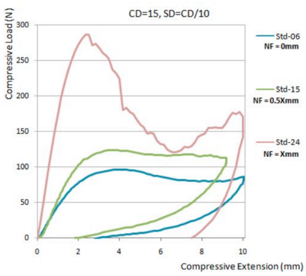

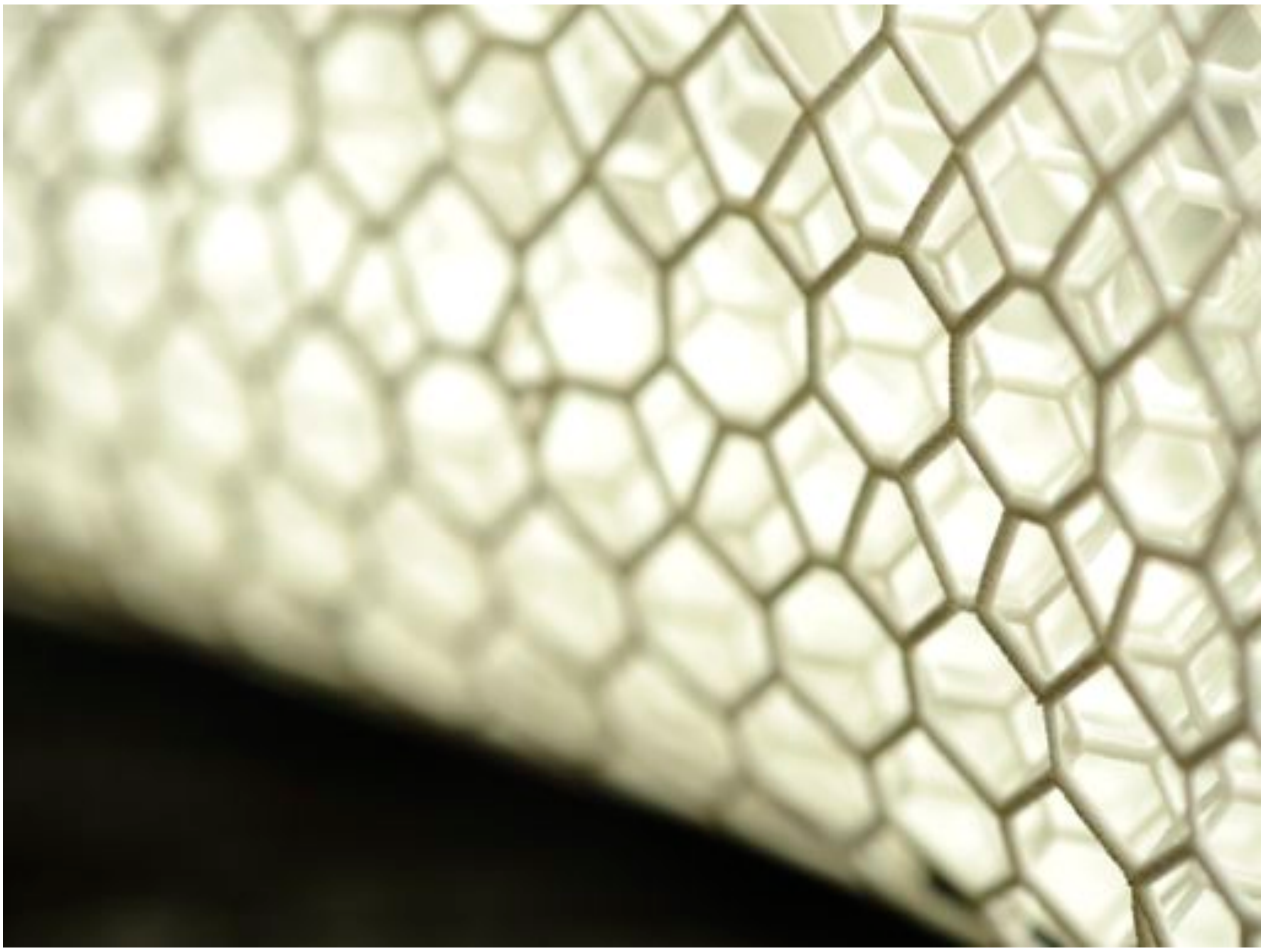

Lattices: Research into efficient generation and optimisation

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Bracket example

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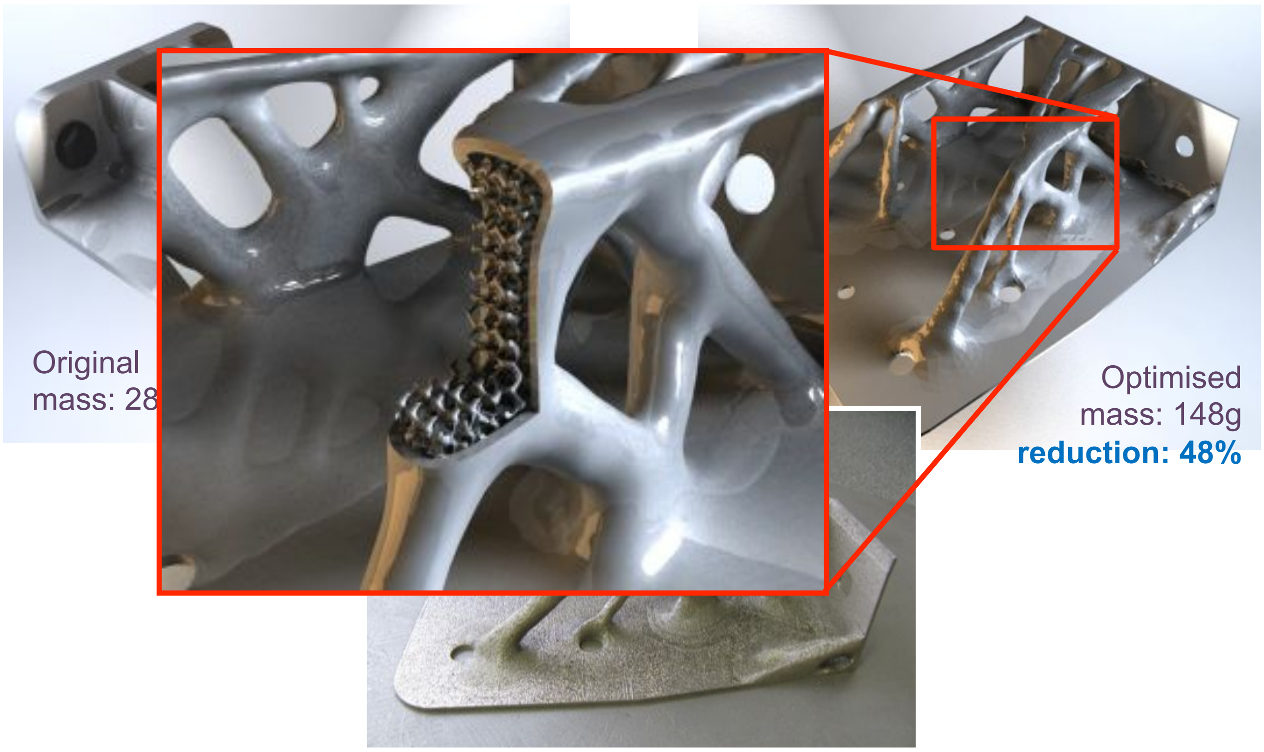

Lattices

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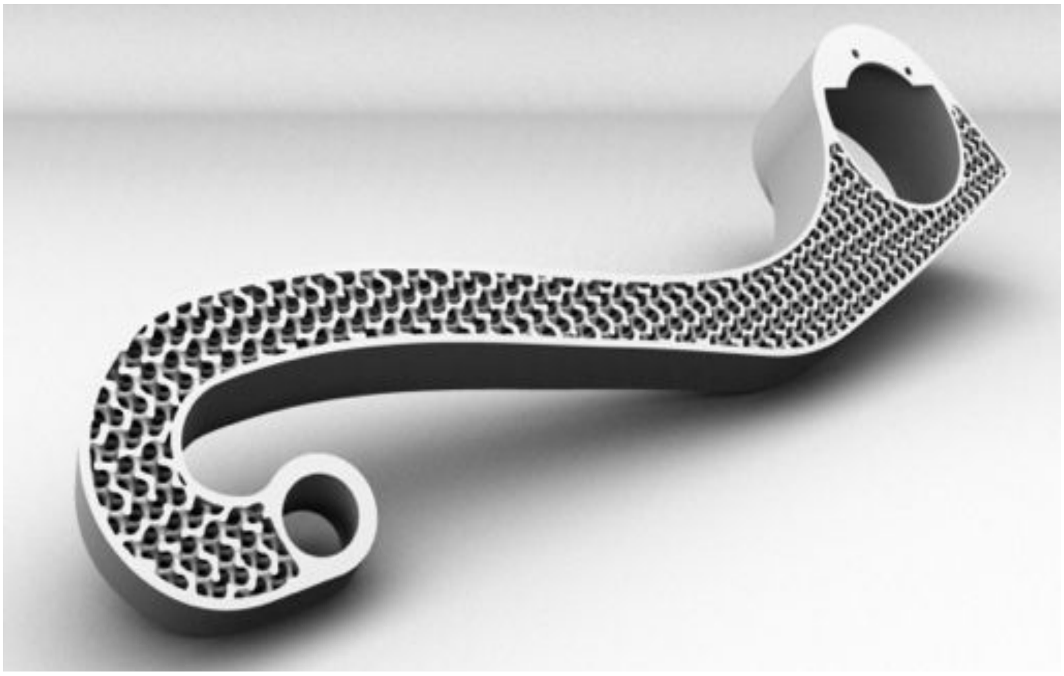

Lattices

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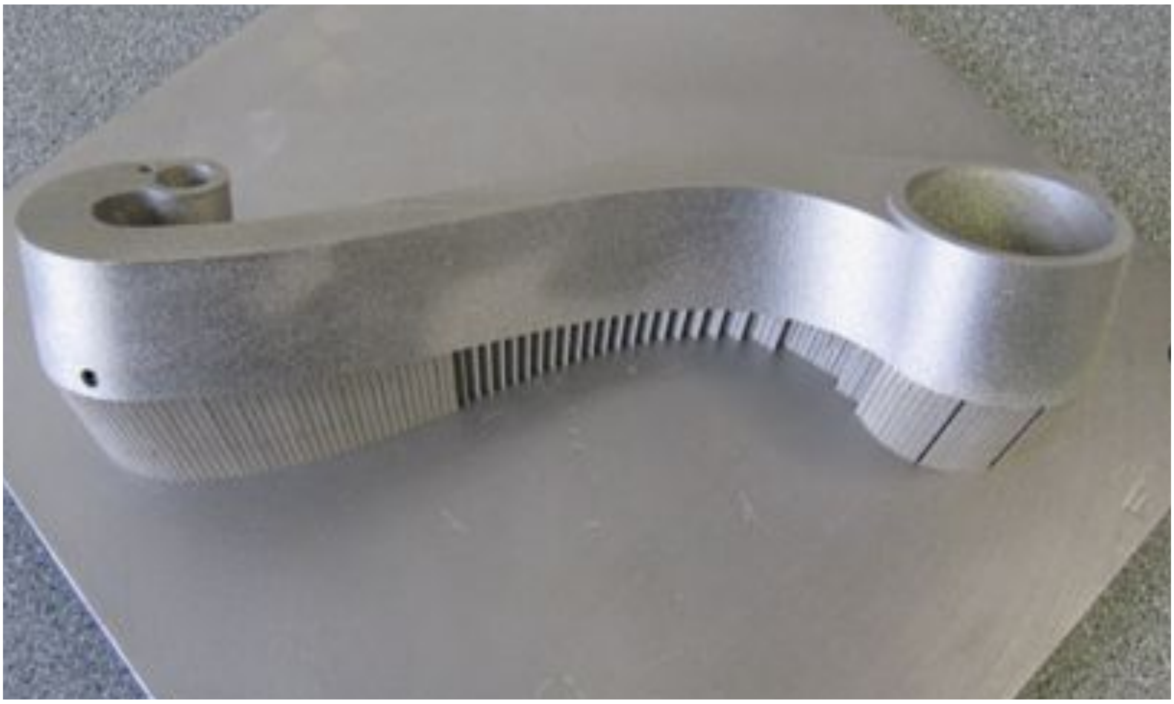

Example – Heat dissipation surfaces

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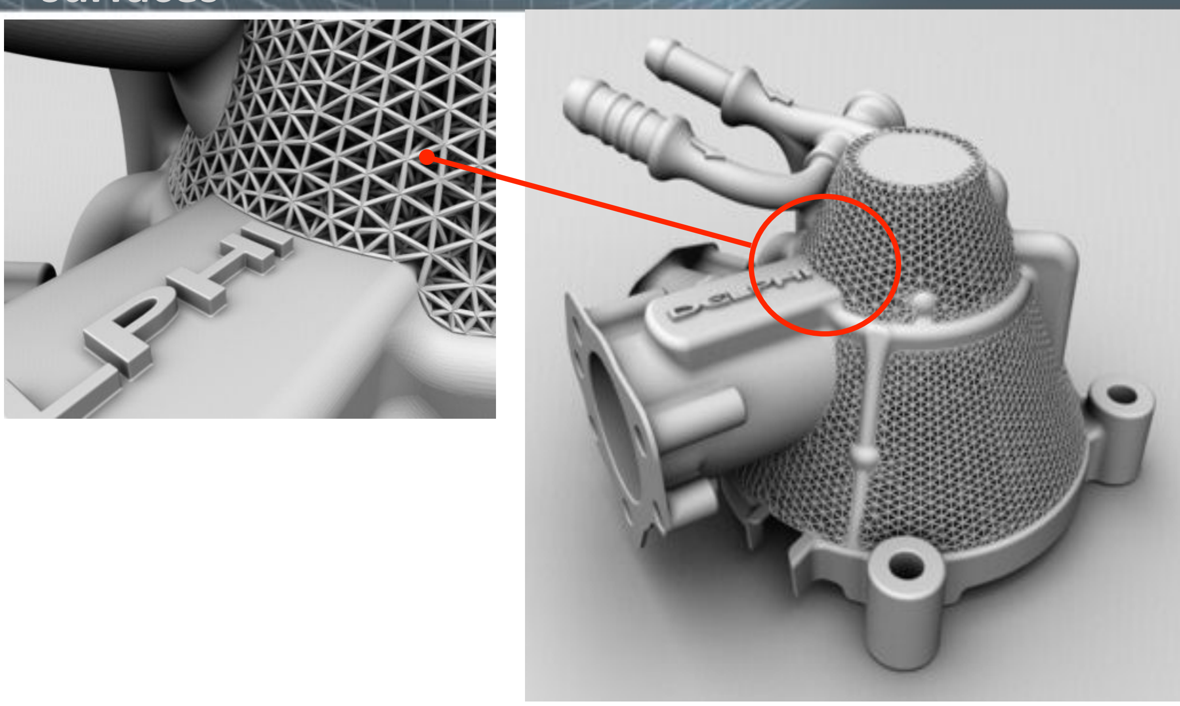

Example – Energy absorbtion

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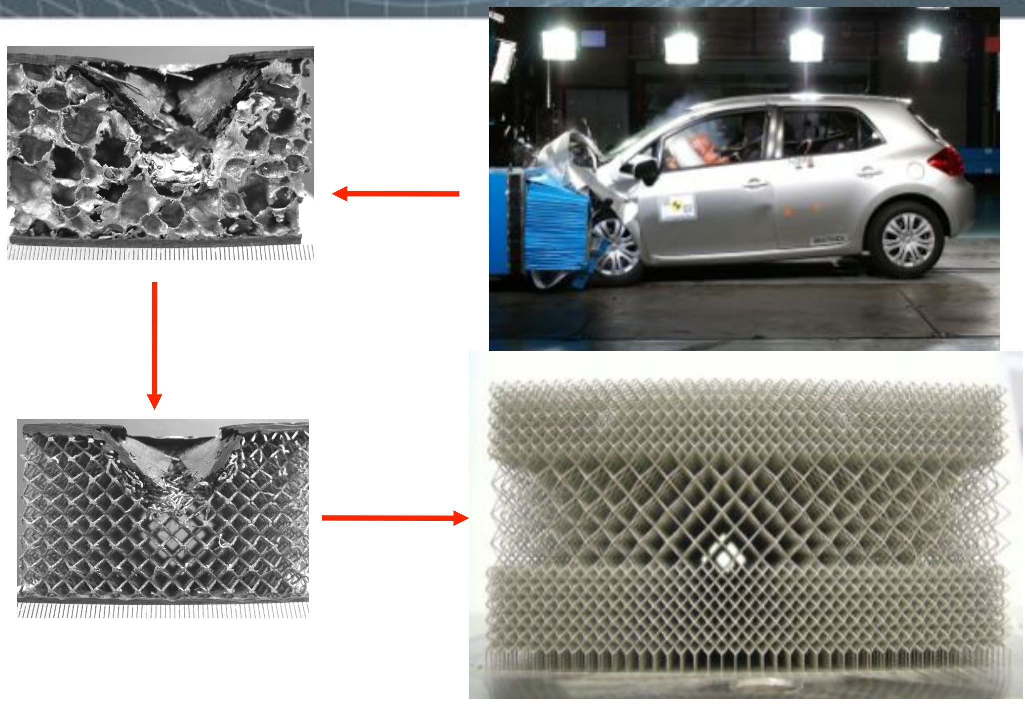

5. Life cycle sustainability

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- Product lifecycle improvements in economic and environmental sustainability
  - Reduced raw material consumption
  - Efficient supply chains
  - Optimised product efficiency
  - Lighter weights components
  - Reduced lifecycle burden

Environmental benefit over product lifecycle

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- Example based on 90M km (Long haul) application

Process	Raw Materials CO_2	Manufacture CO_2	Distribution CO_2	Usage CO_2	Life cycle Kg CO_2
Machining	100Kg	2 Kg	5 Kg	43,779 Kg	43,886
SLM lattice	16 Kg	5 Kg	1 Kg	16,238 Kg	16,260
SLM optimal	18 Kg	7 kg	2 Kg	20,339 Kg	20,366

So how do our lifecycle CO_2 compare

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Scenario 1 – Machined from solid (100%)

Scenario 2 – Selective Laser melted lattice (37%)

Scenario 3 – Selective Laser melted optimised design (46%)

Applied Topology Optimisation: Approx. Weight Savings

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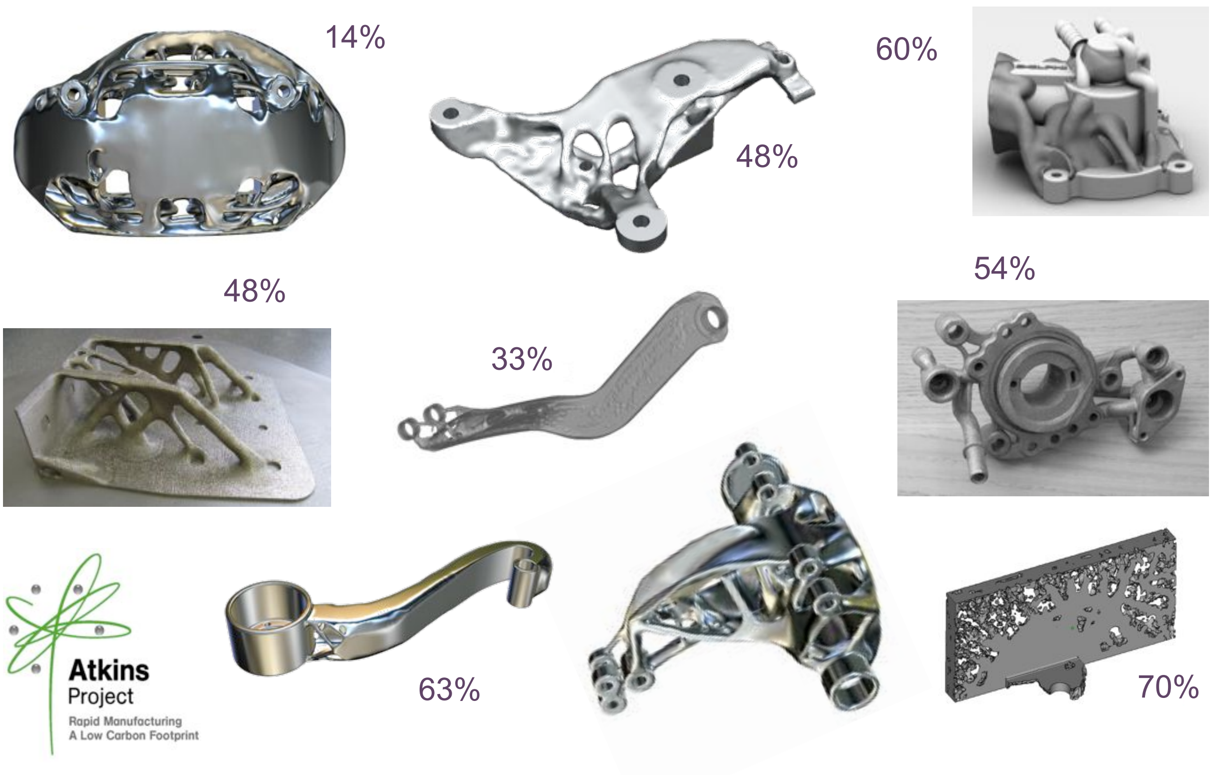

Why does 3D Printing change the way we think?

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- We can tailor parts to consumers
- We can save materials
- We can set-up new businesses that are as cost effective in the west as the east
- AM makes manufacturing attractive, funky and topical in a digitally connected world

So where is 3DP / Additive Manufacturing going?

Larger machines with higher throughput

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Consistent and improved mechanical properties

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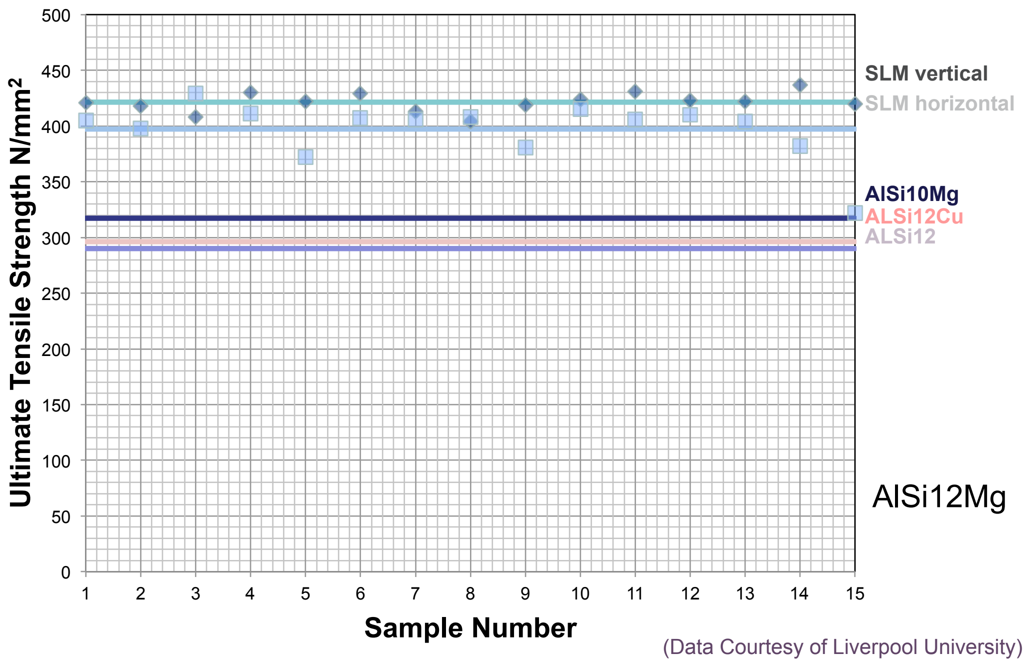

(Data Courtesy of Liverpool University)

Home Printing: MakerBot – the 'market leader'

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- Less than 3-years old
- Business based on open source
- 6700 machines sold in 2011
- $1,749 per machine
- $10M VC investment Q4/2011
- Loyal customer base of Beta Testers – V3 m

MakerBot are not alone

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LE BigRep
SUMPOD
Cubify
shapercube
MakerBot INDUSTRIES
kide
Solidoodle
BOTMILL
BITS FROM BYTES
FABLICATOR
Makergear
FAB@HOME
origo
Create It Real "from vision to reality"
Ultimaker
RepRap

Start-up — Growing — Established

Printing systems could get very complex……..

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What will the future look like?

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This is the future….

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EPSRC Centres for Innovative Manufacturing

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- Liquid Metal Engineering - Brunel (Birmingham, Oxford)
- Industrial Sustainability - Cranfield (Cambridge, Loughborough, Imperial)
- Ultra Precision - Cranfield (Cambridge, NPL)
- Through-life Engineering Services - Cranfield (Durham)
- Regenerative Medicine - Loughborough (Nottingham, Keele)
- Intelligent Automation - Loughborough (Cranfield)
- Additive Manufacturing - Nottingham, Loughborough
- Emergent Macromolecular Therapies - UCL (Imperial, LS Pharmacy)
- Advanced Metrology - Huddersfield
- Composites - Nottingham (Bristol, Cranfield, Manchester)
- Photonics - Southampton
- Continuous Manufacturing & Crystallisation - Strathclyde (Bath, Glasgow, Herriot Watt Loughborough, Edinburgh, Cambridge)

Multifunctional 3D Printing

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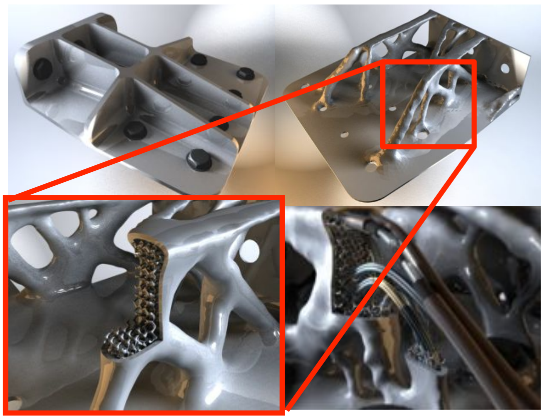
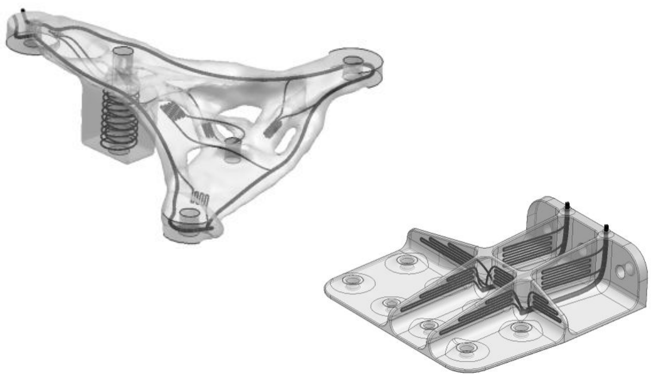
- Centre Vision:
  - To take AM beyond geometry and single materials to the “print” of multifunctional, multi-material components / devices / systems in one operation
- Ultimate exploitation of design freedom
  - Move from “passive” AM to multifunctional “active” AM





Our Partners

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BOEING
AWE
3T
SOLIDICA
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OBJET
econolyst taking a closer look
PEL Printed Electronics Ltd
SMART FIBRES SENSE THE FUTURE
NPL National Physical Laboratory
RENISHAW apply innovation™
BAE SYSTEMS
eos e-Manufacturing Solutions
DELPHI Driving Tomorrow's Technology

Challenges

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- Based on existing AM philosophy, but not on existing equipment
  - Much process and material development
  - Underpinning design systems
- Ultimate exploitation of design freedom
  - Move from “passive” AM to multifunctional “active” AM
- Has a remit to also act as a National Centre
  - Outreach, coordination, dissemination



Someone else's summary……

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Summary

Additive Manufacturing (AM) is viable.

GE is transitioning AM into production.

Much work needs to be done, both internal to GE and external to the supply chain.

Collaboration and leveraging are necessary to move the technology forward .

AM is the future of manufacturing…

imagination at work

(Images Courtesy of GE Aviation)

Someone else's summary……

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Additive Manufacturing at GE
Loughborough 2011
July 12, 2011

(Images Courtesy of GE Aviation)

'…in our lifetime, at least 50% of the engine will be made with additive technologies…'
-Robert McEwan, General Manager, Airfoils and Manufacturing Technologies, GE Aviation, 2011.

imagination at work

Marcel’s metaljet

Canon océ

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