3D ADITIVE MANUFACTURING SYMPOSIUM & WORKSHOP

HOSTED BY 3M BUCKLEY INNOVATION CENTRE. UNIVERSITY OF HUDDERSFIELD. MARCH 17TH 2015

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INTRODUCTION:

The IMI /3M BIC 3D Additive Manufacturing Symposium and Workshop was hosted by 3M Buckley Innovation Centre on March 17th 2015.

The event was attended by the major players in precision engineering, 3D additive design and manufacturing: Representatives from EOS, Renishaw, HK 3D Printing IMI Plc Senior Management team, design engineers, programmers and academics from the University of Huddersfield School of Art Design & Architecture, 3M Buckley centre 3D printing management and designers shared their experiences and latest solutions to expand the potential of innovation and professional enterprise for design, prototyping and manufacturing.

This publication showcases the keynote innovation presentations given at the IMI/3M BIC 3D Additive Manufacturing symposium. The main themes included focus on research, design, concept actualisation, prototyping, and engineering solutions. This is a unique visual documentary of the evolutions in additive manufacturing and provides a snapshot of latest 3D technology solutions in 2015.

Innovation presentations are contributed by:

- **3M Buckley Innovation Centre Manager**: Introduction to 3M BIC & IMI Group Workshop on Additive Manufacture

- **School of Art and Design and Architecture academics**: 3D Printing our Future: NOW in Art, Design & Architecture

- **EOS (Electro Optical Systems)**: New tools for tomorrow’s challenges

- **Renishaw AMPD**: Metals Additive Manufacturing Design for Process

- **HK 3D Printing**: Boom – Do it with 3D Printing - the links between the designer and the engineer

- **3M Buckley 3D Design team**: Design into reality, the links between the designer and the engineer
3D PRINTING OUR FUTURE: NOW

Andrew Taylor & Dr Ertu Unver
School of Art, Design & Architecture, University of Huddersfield

3M: IMI Workshop
In collaboration with EOS, Renishaw & HK 3D Printing

Hosted by 3M Buckley Innovation Centre, University of Huddersfield. 17th March 2015
OVERVIEW:

This *3D Printing our Future:Now* talk and visual presentation was given to delegates at the IMI 3D Workshop held at 3M Buckley Innovation Centre on 17th March 2015.

The event was hosted by 3Mbuckley Innovation Centre for IMI plc a global engineering company, 3M, and leading 3D additive manufacturing technology providers: EOS, Renishaw and HK 3D printing to disseminate and share their experience on the latest 3D additive design and manufacturing technologies available to the engineering and product industries.

The *3D Printing our Future:Now* talk and visual presentation provided an overview of art, design & architecture research, creative practice, and enterprise & innovation specifically using 3D additive technologies within the School of Art, Design & Architecture and research groups at the University of Huddersfield.

The talk focused on introducing the importance of creative design research practice and how 3D printing has evolved as an increasingly essential and highly versatile tool in the creative process particularly for concept, physical visualisation, prototyping, tooling and manufacture.

Nine research cases were shown to the 3M/IMI delegates to highlight the range of 3D art, concept design, prototyping, and manufacturing projects supported by University of Huddersfield 3D printing technology facilities at Queen Street Studios.
Research Centres at School of Art, Design & Architecture situates academics professional research and postgraduate student projects from seven research centres. IDL is a new interdisciplinary research centre/laboratory at the University of Huddersfield. The lab conducts theory-based and applied research generally into product design, and especially in the built environment, pushing the impact of design thinking and practice to new areas. It cuts across the areas of architectural design, construction management, interior design, new product development, engineering, social sciences and healthcare. Our research focuses on solving real world problems through design innovation, mobilising the underlying theories as well as the enabling processes and technologies needed to deliver value to users and the society at large. Research is developed closely with diverse public and private sector organisations to propose novel solutions to design challenges and project-based problems. We offer Undergraduate, Masters and PhD programmes that are future-focused and informed by the state of the art in research and practice.
4D Printing:
Queen Street Studios and 3D Digital Design
School of Art, Design & Architecture
University of Huddersfield

Four rapid prototyping machines are available for students, academics and researchers to accurately produce three dimensional models in a range of materials. Students are advised by the technical team on which machine is best suited for their work, and also the cost of printing the files once the design is complete.

Technical team operate the printers, and oversee any post processing work that each printer may require. Students are responsible for any fine surface finishing, or painting that is required to finish the printed part with technician support.

3D prototyping machines are located in the Queen Street Studios:

- Projet 5500X - Multi Material Printer
- Zbuilder
- Zcorp 650
- Stratasys FDM

Dean worked with 3D prototyping techniques laser sintering as a designer-in-residence on PhD at the University of Huddersfield with Dr. Ertu Unver and Dr. Paul Atkinson.

Working with rapid prototyping techniques like laser sintering as a designer-in-residence, Dean realized that these methods were fully capable of producing high-quality objects fit for the consumer market. Inspired by work being done on applying organic metaphors to architecture, he created the project FutureFactories and began designing his objects as parametric systems. A model has parametric constraints set by the designer, using randomness and evolutionary algorithms to produce a range of unique results from the same template. Coupled with the use of rapid prototyping, the result is a rapid manufacturing process that creates one-off design objects.
Future Factories project pushed the boundaries of the functional object categories all industrial design adheres (a lamp is a lamp, a chair is a chair.) creepers.mgx is a good example.

It's a modular LED-based lighting system, where stems of flower-like shapes clip on to cables running from floor to ceiling.

It references the way creeper vines infiltrate their surroundings. And like real plants, all the Creepers are unique in shape. 3D Printing for product design applications.

Biomimicry lighting concepts and Bespoke jewellery printed in titanium, aluminium, and gold.
AutoMAKE project combines generative systems with craft knowledge and digital production technologies to create a new way of designing and making objects that blurs the boundaries between maker and consumer, craft and industrial production. AutoMAKE was developed with researchers from University of Huddersfield, Falmouth University, and Sheffield Hallam University as a collaborative research project that aimed to investigate the potentials of using generative systems to digitally design unique one-off works and produce them using a range of rapid prototyping/manufacturing technologies and CNC equipment.
University funded practice led research by Andrew Taylor in collaboration with Surface Design students and academics. The project initiated 3D workshops to introduce 3D concept modelling and 3D printing for the first time to BA Surface Design Final year students. 3D printed prototypes were exhibited at the Surface Design Show and EcoBuild, London.

Images show developmental 3D modeling phases and final printed prototypes. BA Surface Design students Vicky Kelly, & Shereen Ahmed. 2011.

Student project blog: http://extraordinary-3d-materials.blogspot.co.uk
Extraordinary 3D Surface Materials: A practice led research exhibition with Surface Design final year students.

Fluid dynamics experiments for generating lighting concepts.
Exhibited in 2011 at Euromold, Frankfurt, Germany. Dr. Ertu Unver, University of Huddersfield.

3D Biomimicry lighting concept modelling experiments.

www.shapeways.com/shops/danhughesmcgrail-digitalsculpture
By Lewis, Chara, Mojsiewicz, Kristin and Pettican, Anneké (2008), *Skyscraping*. [Show/Exhibition] Brass Art. Anneké Pettican is an artist, Senior Lecturer and co-director of Brass Art (1999 -) with Chara Lewis and Kristin Mojsiewicz. Their collaborative practice explores the uncanny, including aspects of doubling and the limen – the in-between spaces of the physical world and the realms of the imagination.
“We’ve changed the whole way we draw architecture; everything’s changed from hand-drawing to 3-D drawings. And if you draw everything 3-D, then it’s time to change the whole construction process”

Ebner; UCLA Professor & 3M Architect.

Students from the University of California in Los Angeles, University of Huddersfield, Munich Technical University and the Center for Entrepreneurship and University of Applied Sciences, collaborated on the full-scale mobile prototype of urban living accommodation in 2014.
3D printed bogie parts (chassis bearers, brake calipers, brake disc) printed on Projet 5500X Multi Material Printer, at Queen Street Studios, School of Art, Design & Architecture. The train bogie prototype was commissioned by the Institute of Railway, (Dr. Phil Shackleton, Senior Research Fellow, IRR) at University of Huddersfield and funded under the EU FP7 Project Spectrum.
Enterprise activities between the University of Huddersfield and Paxman Coolers Ltd.
3D design modelling, prototype development and tooling manufacturing for Paxman cap cooling
3D PRINTING OUR FUTURE: NOW3D PRINTING OUR FUTURE: NOW3D PRINTING OUR FUTURE: NOW3D PRINTING OUR FUTURE: NOW3D PRINTING OUR FUTURE: NOW3D PRINTING OUR FUTURE: NOW3D PRINTING OUR FUTURE: NOW3D PRINTING OUR FUTURE: NOW3D PRINTING OUR FUTURE: NOW3D PRINTING OUR FUTURE: NOW

SLIDE SOURCES:

1. Research Centres at School of Art, Design & Architecture, University of Huddersfield. 2015.

2. 3D printing: Queen Street Studios, School of Art, Design & Architecture labs and research. University of Huddersfield. 2015


11. 3D printed apartment by Peter Ebner; [http://www.3ders.org/articles/20140407-students-build-3d-printed-mobile-mini-house.html](http://www.3ders.org/articles/20140407-students-build-3d-printed-mobile-mini-house.html)

12. 3D printed chassis bearers, brake calipers and bogie for Institute of Railway Research (IRR) printed in SADA 3D printing lab at University of Huddersfield. Images courtesy of Dr. Phillip Shackleton Senior Research Fellow Institute of Railway Research.


IDEATION CONSULTATION

DESIGN

3D

CAD DEVELOPMENT

3D PRINT CHECKING

3D PRINTING
IDEATION CONSULTATION

DESIGN

3D CAD DEVELOPMENT

3D PRINT CHECKING

3D PRINTING
PRODUCING A 2D ANIMATION OF THE CLIENTS PRODUCT TO SHOWCASE FUNCTION AND SITUATIONAL ENVIRONMENTS
VR VIS

THE ABILITY TO SHOWCASE
A CLIENTS PRODUCT IN THE REAL
WORLD BY TRANSPONDING A 3D MODEL
ONTO A REFERENCE PLANE
The ability to showcase a client's product in 3D by way of using stereoscopic conversion.
MAIN BENEFITS TO 3D PRINTING
MAIN BENEFITS TO 3D PRINTING

Streamlined work flow from CAD to testing

VAVE analysis of parts and assemblies can be assessed more rapidly and re-designed
MAIN BENEFITS TO 3D PRINTING

Parts can be produced for direct application

Tooling costs for test components negated therefore costs for final product reduced
For more information: [http://www.3mbic.com/](http://www.3mbic.com/)
EOS (Electro Optical Systems): New tools for tomorrow's challenges
Electro Optical Systems

New tools for tomorrows challenges
Agenda

- EOS Company
- Benefits of Additive Manufacture.
- Materials
- Practical Applications
- Tooling

Lifestyle-Products: Face Mask (Source: Joshua Harker)
EOS is world market leader for laser sintering systems

EOS – Basic facts

Electro Optical Systems

- **1989 foundation** of Electro Optical Systems GmbH
- **Portfolio**: Laser-sintering systems for plastics, metal.
- **Application fields**:
  - High-end rapid prototyping
  - Rapid tooling
  - e-Manufacturing™ systems

Source: EOS
EOS: A Success Story

Source: EOS. Figures for EOS Group, for financial years ending 30 September. Number of Employees: Headcounts.
Tools: EOS Polymer Laser Sintering Systems

**FORMIGA P 110**: Compact system for RP applications and small series

- **Usable build size**
  - Width 200 mm
  - Depth 250 mm
  - Height 330 mm

- **Laser**
  - CO₂ laser
  - Nominal power 30 W
  - Wave length 10.6 µm
  - Laser spot size ~0.4 mm

- **Layer thickness**
  - 0.12 mm
  - 0.10 mm
  - 0.06 mm

**EOS P 396**: Productive, modular polymer laser sintering system

- **Usable build size**
  - Width 340 mm
  - Depth 340 mm
  - Height 600 mm

- **Laser**
  - CO₂ laser
  - Nominal power 70 W
  - Wave length 10.6 µm

- **Layer thickness**
  - PA 2200: 0.06 mm; 0.10 mm; 0.12 mm; 0.15 mm; 0.18 mm
  - All other materials according to compatibility matrix

**EOSINT P 760**: With greatest built volume for plastic parts

- **Usable build size**
  - Width 700 mm
  - Depth 380 mm
  - Height 580 mm

- **Laser**
  - 2 CO₂ lasers
  - Total nominal power: 100 W
  - Wave length 10.6 µm

- **Layer thickness**
  - PA 2200: 0.06 mm; 0.10 mm; 0.12 mm; 0.15 mm; 0.18 mm
  - All other materials according to compatibility matrix

**EOSINT P 800**: For high-performance plastic components

- **Usable build size**
  - Width 700 mm
  - Depth 380 mm
  - Height 560 mm

- **Laser**
  - 2 CO₂ lasers
  - Total nominal power: 100 W
  - Wave length 10.6 µm

- **Layer thickness**
  - Standard: 0.12 mm
Tools: EOS Direct Metal Laser Sintering Systems

**EOSINT M 280:** Leading-edge DMLS system for the Additive Manufacturing of metal parts

- **Build size**
  - Width 250 mm
  - Depth 250 mm
  - Height 320 mm

- **Laser**
  - Yb-fibre laser
  - 200 W or 400 W

- **Technical data**
  - Precision optics: F-theta-lens, high-speed scanner
  - Scan speed: up to 7.0 m/s

**EOSINT M 270 Dental:** High-performance DMLS for production of dental copings and bridges

- **Build size**
  - Width 250 mm
  - Depth 250 mm
  - Height 215 mm

- **Laser**
  - Yb-fibre laser
  - 200 W

- **Technical data**
  - Precision optics: F-theta-lens, high-speed scanner
  - Scan speed: up to 7.0 m/s

**EOS M 400:** System for the Industrial Production of High-Quality Large Metal Parts

- **Build size**
  - Width 400 mm
  - Depth 400 mm
  - Height 400 mm

- **Laser**
  - Yb-fibre laser
  - 1,000 W

- **Technical data**
  - Precision optics: F-theta-lens
  - Scan speed: up to 7.0 m/s
Laser sintering offers various advantages compared to traditional manufacturing processes.

Key differentiation criteria for laser sintering

- **Freedom of design**
  - Lightweight
    - Static: weight of parts
    - Dynamic: moving, accelerated parts
  - Complex components
    - E.g. alternative structures of heat exchangers

- **Cost advantage**
  - Integrated functionality
    - Embedded functionality without assembly

- **Customization**
  - Individualized parts
    - Customer specific adaptations
    - Cost efficient small series up to 'lot size one'

- **Time to market**
  - Rapid prototyping
    - Fast feasibility feedback of virtual models
    - Haptic feedback

Source: EOS
Materials

EOS MaragingSteel MS1 - high performance steel for series tooling and other applications

Characteristics, applications, status

- Key characteristics
  - 18 Maraging 300 type steel (1.2709, X3NiCoMoTi18-9-5)
  - fully melted to full density for high strength
  - easily machinable as-built
  - age hardenable up to approx. 54 HRC
  - good thermal conductivity and polishability

MS1 – 1.2709

- Mechanical properties as built
  - UTS: 1100 MPa
  - yield strength: 1000 MPa
  - hardness: 33 - 37 HRC

- Mechanical properties after age hardening (6 hours at 490°C)
  - UTS: > 1950 MPa
  - yield strength: > 1900 MPa
  - hardness: 50 - 54 HRC

- Physical properties
  - relative density as built: approx. 100 %

Other alloys-steel

- Tool steel with improved anti-corrosion properties
- Alloy with improved heat conductivity *
EOS Titanium Ti64 produces fully dense parts with dendritic, martensitic grain structure

**Metallurgy**

- Typically martensitic structure with grains growing from layer to layer
  - Preferential Z orientation
  - Grain size → Layer thickness

Optical micrographs of EOS Titanium Ti64, showing fully dense martensitic structure with acicular crystals

Source: EOS, EADS
An innovative drive shaft design resulted in more than 70% weight reduction.

Example **Lightweight**

![Innovative drive shaft](image)

**Innovative drive shaft**

**Application**
- Drive shaft for formula student race cars
- Laser sintered twin walled end fittings
- No failure for entire race season

**Product details**
- Weight: 350g
- Length: 50 cm
- Material: Carbon fibre & titanium

**Advantages**
- Massive **weight savings by 73%** compared to steel drive shaft (1,300g)

Source: University of Warwick, EOS
Even simple brackets can be designed in a bionic way and thus help to save weight

Example **Lightweight**

**Bionic bracket**

**Application**
- Innovative concave bionic bracket
- Hollow structures
- Material: Aluminium

**Advantages**
- Weight reduced by 40% to a total weight of 33g
- Built in one piece
- Integrated thread and thus less assembly time and parts

Stress test of welded and sintered bracket

Source: P3 digital services, EOS
However, to retrieve the maximum value, the design needs to leverage all possibilities

**Example Integrated Functionality**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conventional manufacturing (13 parts, aluminum)</td>
</tr>
<tr>
<td>2</td>
<td>Additive manufacturing, conventional design (13 parts, PA12)</td>
</tr>
<tr>
<td>3</td>
<td>Additive manufacturing, optimized design (2 parts, PA12, colored)</td>
</tr>
</tbody>
</table>

**Diode clamp**

**Application**
- Diode clamp for illumination purposes in machinery environment
- Hollow and material efficient design, integrated hinges, labeling and series number

**Advantages**
- About 80% reduction of assembly time (from 10 to 2 minutes)
- More than 30% cost advantage
- Lead times reduced by 75%

Source: Kuhn-Stoff, EOS
More than 30 laser sintered parts are mounted in the EOS Formiga P100 System

Example **Integrated Functionality** – Formiga P100 System

- Powder dispenser unit
- Temperature control module
- Lens cleaning module
- Laser adjustment unit
- Frame system

Source: EOS
Some components are highly integrated to fully leverage the laser sintering design options

Example **Integrated Functionality**

- **Mirror deflection unit**
  - Laser sintered device to adjust laser mirror in Y and Z position
  - Material: PA2200
  - Highly integrated functionality
    - Integrated eccentric levers to fix adjustment screws
    - Elastic lip seal to close opening
    - Positioning scale integrated – no labels necessary

Source: EOS
Direct parts minimize tooling cost, lead times and help to handle e.g. regional variants

Example **Integrated Functionality**

**Washing rotor Rotolavit**

**Application**
- Rotor of washing unit
- Traditional design required several tools and 32 single components
- Inox inlet tubes need perfect finishing and lavish deburring

**Advantages**
- High level of integration: 3 components only (2 LS parts, 1 steel ring)
- No tooling and finishing for inlet tubes necessary
- Allows small series (e.g. regional adaptations)

Source: Hettich, EOS
Festo designed a gripper that is produced in ‘one shot’ and ready to operate.

Example **Integrated Functionality**

**Bionic handling assistant**

**Application**
- Bionic gripper, self adapting to objects
- Movements realized by pneumatically operated membranes

**Advantages**
- Safe and gentle handling
- Weight 'reduced to the max'
- Highly flexible due to self adapting gripper fingers
- Cost efficient – entire gripper produced in 'one shot', no post assembly

Source: Festo, Fraunhofer IPA, EOS
This light-weight gripper weights 19g and can handle 12kg parts.

Example **Integrated Functionality**

**Light weight gripper**

**Application**
- Hole gripper for part handling
- Weight of gripper: 19g
- Handles up to 12kg parts
- Integrated pneumatic membrane to apply gripping force

**Advantages**
- About 80% weight reduction compared to conventional gripper
- Printed in one shot - no final assembly
- Geometry fully flexible and scalable
- Tested to >5 mio. cycles

Source: Kuhn-Stoff, EOS
Customization is believed to be a strong future trend for market differentiation

Example **Customization**

**Customization of lamp**

**Application**
- Design lamp
- Customer can adapt the basis design of lamp within given parameters
- Customization 'front-end' available on internet platform

**Advantages**
- 'Mass customization' – combines individualization and manufacturing possibility
- Absence of molds allows for complex geometries to be created without difficulty

Source: Digital Forming, EOS
Example **High Volume, High Value Production**

**Fuel Injection Nozzles**

**Application**
- Turbine Engine Fuel Nozzle
- Joint Venture GE Aviation / Snecma CFM International. LEAP engine.
- 25,000 units per annum estimated

**Advantages**
- Reduced number of components.
- Less risk of errors during multiple welding steps.
- Better service life.

Source: Within, 3T, EOS
We see big OEMs to start setting up production

Example General Electric Aviation

- 19 fuel nozzles to be installed on every CFM LEAP engine (more than 4500 sold)
- 100,000 additive parts will be manufactured by GE Aviation by 2020
- 1.000 lbs potential reduction in weight of a single aircraft engine through additive production
- 300 plus 3D printing machines currently in use across GE

Source: Morris Technologies, General Electric
Typical Superalloy Components Manufacturer
Comparison of conventional design insert with DMLS design insert

Conventional cooling system (left), DMLS cooling channels (right)

Source: BKS; Polymold; EOS
Optimized solution with hybrid design

DMLS tools and hybrid design improve quality and cycle time

Solution

- Optimized conformal cooling channels regarding the cooling requirements
- Hybrid structure
  - lower part CNC milled
  - Upper part built on EOS M 270
- Material: EOS Maraging Steel MS1
- Building time:
  - CNC milling: 5 h
  - Direct metal laser sintering: 25 h
  - Post processing: 5 h

Source: BBE Engineering; Prodintec
Optimized solution with hybrid design

DMLS tools and hybrid design improve quality and cycle time

Benefits:
- less warpage and better mechanical properties
- Higher surface quality
- Cooling time down from 56 to 35 s → 37 % faster
- Cooling temperature reduce from 102°C to 82°C
- Temperature gradient lowered from 80°C to 30 °C
- Production rate increased from 1 part per minute to 2 parts per minute
Better injection moulding process with DMLS

DMLS tools and hybrid design improve part quality and cycle time

Benefits

- Cooling time reduction from 24s to 7.5s => 68 % faster cooling time
- Average ejection temperature from 95°C to 68°C
- Temperature gradient from 12°C to 4°C
- Reduction of scrape rate: from 60% to 0%
- Improvement of productivity up to 3 parts/min

4 cavities inserts
A Renishaw perspective on Additive Manufacturing

Stephen Crownshaw
AM Business Development Manager, UK & Ireland
• What is additive manufacturing?

• Applications

• Design for process

• Challenges

• The future for Renishaw
Subtractive manufacturing

- Wasted material
- Long lead times on material supply
- Complex, multi-stage processes
- Expensive tooling and fixtures
- High capital investment – centralised manufacturing
- Component complexity limited by process capability
Additive manufacturing

- No wasted material
- Powder supply by the kg
- One stage process
- No tooling or fixtures
- Relatively low capital investment – localised manufacturing
- Almost no limit to component complexity
- Component weight minimised
What is AM?

Laser melting is an additive metal manufacturing process that uses 3D CAD data as a digital source.

It produces dense metal parts direct from the CAD using industry standard file formats such as stl.

Layers of fine gas atomised metal powder are deposited and a high power fibre laser melts the powder together to form the finished part.
Q. Why have Renishaw chosen to get involved in the Additive Manufacturing industry?
A. It's an emerging manufacturing technology in sectors where Renishaw are already leaders in their field.

Q. Why Additive Metal?
A. The scope for complex metal objects is vast – the machine tool industry has revenues of around $68 Billion per year.

Q. Why now?
A. AM systems are in their infancy, comparatively speaking and require a step change to be accepted in large scale manufacturing.
Renishaw AM systems
AM – Inert atmosphere generation

AMPD machines are Unique in the way this is achieved and all systems are suitable for building reactive materials.

• At the start of the process we create a vacuum
• This removes air and any humidity from the entire system
• Once complete the chamber is filled with ~400 litres of high purity Argon.
• While the process is running the atmosphere is always maintained at below 1000ppm (0.1%) oxygen and can be set to run below 100ppm (0.01%) for Titanium.
• Gas consumption is typically between 5 and 30 litres/Hr and laser fire is achieved approx 10 minutes after cycle start.

Vacuum preparation and chamber cleansing leads to better atmosphere control and improved material properties
Market potential for AM

- **Automotive**
  - Passenger
  - Commercial
  - Motor sport

- **Aeronautical**
  - Civil aero
  - Space

- **Production**
  - Machine parts
  - Assembly aids

- **Defence**
  - Land
  - Air
  - Marine

- **Power & Comm’s**
  - Sonar body
  - Housings
  - Fuel cells

- **Medical**
  - Implants
  - Bone scaffolds
  - Hearing aids
  - Dental aligners
  - Caps & bridges
  - Surgical guides

- **Consumer**
  - Fashion
  - Jewellery
  - lighting
  - Furniture
  - entertainment
Where AM works best
Small bespoke series components - dental crowns & bridges, implants etc.
Complex geometries & structures - heat transfer, medical implants, transition to composite structures, aerospace and motorsport applications
Hidden internal features – conformal cooling, valve bodies etc.
Materials & alloys – materials that are difficult to machine & hazardous to process via other methods.

All benefit from component design that accounts for the ‘design for process constraints’ imposed by layer manufacture.
Design for process – key principles

Identify & position key features

Create a structurally optimised design

Consider part/process orientation demands

LMC0591 Agitation housing

Original Design (Design for machining)

Fundamental Design (Constraints) + Minimised material to join Constraints =
Design for process

Old way

New way

CAD not complete
Design for process

Original DFP3 pump front plate part

Aim

• Weight Removal
• Part consolidation
• Reduction in manufacture and assembly time
Design for process

Improved flow path smoothness through CFD simulation of fuel flow velocity

a) original flow paths
b) redesigned flow paths
Design for process

- Pressure test = 2mm wall section
- 5 non-value added assembly operations eliminated
- Built on Renishaw AM250 in Ti6Al4V
- 21% reduction in overall packaging area
- 54% reduction in volume
Design for additive manufacturing - challenges

- Design for manufacture crucial to the business case
- Not enough people are trained yet in designing for AM
- Software tools need more development – mathematical design optimisation
- AM could mean significant changes to distribution and ‘conventional’ business models.
- AM technologies remain too expensive and too slow – machine marketplace is still immature.
- International standards and practices for performance measurement and monitoring must be developed. This means collaboration and partnerships between competitors – both users and system manufacturers.
Investment – AM production – Cardiff, Wales

Cardiff site at Miskin

190 acre site

490,000 Sq ft (Approx 50,000M²)

65,000 Sq ft refurbishment program, (over 3x current AMPD manufacturing facility in Stone)

Over £ 20M now spent on refurbishment with more to come.
Investment – AM production – Cardiff, Wales

AM production area at the Cardiff site at Miskin

All AM systems now covered by full Work Instructions – allowing production scale up to be rapidly executed.

All Renishaw AM systems are now produced in our state of the art Cardiff plant. Renishaw is investing in staff, equipment and facilities to grow AM products
Room to grow – AM Development AMPD Stone Staffs.

Now production of machines is in the Cardiff facility the Renishaw AMPD development team will continue to strengthen.

New product development has expanded into the vacated space at AMPD Stone Staffordshire close to air, road and rail links, covering disciplines from design, product development, process development and applications.

Further expertise is being developed in major Renishaw locations around the world and within our Group Engineering function.

In total around 80 to 100 members of staff throughout the organization are working on the AM product line in all disciplines.
Thank you
For more information please visit www.renishaw.com
3M Innovation Briefing

Monday, 16 March 2015

Presented by Ken Whild
3D Overview
HK 3D Printing

Boom
Do it with 3D Printing
HK 3D Printing Customers

- Aston Martin
- AQUALISA
- Bentley
- Clear Aligner™
- Vent-Axia
- BAE Systems
- Underground
Guns
HK 3D Printing
Media Perception
HK 3D Printing
History of 3D Print

Section 1
30 years of change

1. **3D SYSTEMS**
   Stereolithography

2. **STRATASYS**
   Fused Deposition Modelling

3. **REALIZER**
   Selective Laser Melting

4. **OBJECT**
   Polyjet Matrix

5. **EOS**
   Selective Laser Sintering

6. **ARCAM**
   Electro Beam Manufacturing

7. **MANY...**
   Fused Filament Fabrication

Timeline:
- 1986: 3D Systems
- 1989: Stratasys
- 1995: Realizer
- 1998: Object
- 2001: EOS
- 2002: Arcam
- 2008: MANY...

HK 3D Printing
Printing in 3D

Phase 01
The designer uses a CAD program to create a 3D model.

Phase 02
The 3D model is sliced into several layers – each layer represents a picture of a cross section of the 3D model. The pictures are then uploaded to the printer.

Phase 03
The printer spreads plastic powder in a thin layer across the build chamber. The thermal printhead starts to move, and heat from the printhead melts the picture of one cross section into the plastic powder layer.

Phase 04
The 3D printer prepares new layers of plastic powder, and the thermal printhead continues to apply heat onto layers of powder. Eventually the 3D model is made in the build chamber surrounded by unmelted powder.
Stereolithography (SLA)
Fused Filament Fabrication (FFF)

The extruder uses torque and a pinch system to feed and retract the filament precise amounts.

A heater block melts the filament to a useable temperature.

The heated filament is forced out the heated nozzle at a smaller diameter

The print head and/or bed is moved to the correct X/Y/Z position for placing the material

The extruded material is laid down on the model where it is needed.
Fused Deposition Modelling (FDM)
Polyjet Matrix

The Objet PolyJet Process
So can we use 3D Print

Section 3
Typical Design Cycle

Prototype

Concept Design

Engineering

Tooling

Production

Detail Design

Design Change

Design Change

Design Change

Design Change
Creating Product Designs

Print in 3D

- Fit and form
- Focus group
- Design validation
Creating Product Designs

Print in 3D

- Tool design validation
- Short run samples in actual materials
Injection Moulding
Jigs and Fixtures / Assembly Aids

Complex Shapes Machined from CAD
Metal Forming

Rubber Pad Press

Hydro Forming

Stamping

Stretch Forming
Composite Tooling

Material Limits:

ABS – 80C  ULTEM – 150C  PPSF – 175C
Vacuum Forming
End use parts

High Complex parts that are traditionally HARD to produce
Who are HK 3D Printing?

Section 4
Who are HK 3D Printing?

- Origins from Hahn and Kolb Germany 1850
- Hahn and Kolb (GB) Limited 1963
- Representative of the World’s leading technologies and global brands
- Growing to over 200 employees
- Providing local supply support and services
- HK Holdings 2002
- MBO of H&K GB
- HK RPD division 1999
- EOS UK Agent
- Objet 1st World Partner
- Arcam 1st World Partner
- Realizer 1st European Partner
- HK RPD renamed HK 3D Printing (2013)
The Pexion Group
An integral part of your success

Who we are
We are dedicated in pursuing the very best and most innovative solutions for our customers.

What we do
We manufacture products and provide solutions for the Aerospace, Oil & Gas, Defence, Marine, construction and Power Generation markets.

Where we work
We are a focused on providing engineering solutions globally.

Heritage
Founded in 1876.
HK 3D Partners

- Worlds largest RPD Vendor
- Incorporated 1989
- Merger of Stratsys and Objet
- Over 17000 customers worldwide
- 20,000 printers installed
- Recent acquisition of Makerbot

- Founded in 1990
- Dr. Matthias Fockele and Dr. Dieter Schwarze pioneers of RPD
- 1999 Delivered 1st 3D Metal Printer
- Introduction of multiple metals
Any Questions?
**Idea Series**
The Stratasys Idea Series levels the playing field by bringing professional 3D printers to individuals and small teams, accelerating creativity.

Making the leap to world-class 3D printing at such a low cost is a revolution on its own.

**Design Series**
If you’ve ever taken a 3D prototype for a test spin before production, you already know its impact.

Cut turnaround time and increase quality by building prototypes right under your own roof with Stratasys Design Series 3D printers.

**Production Series**
Rethink the factory from the floor up.

The Stratasys Production Series is built to streamline manufacturing while maximizing your possibilities — handling the largest prototypes and accurate low-volume parts with agility.
**SLM50**
With the SLM 50, Realizer delivers the globally first SLM™ desktop machine for manufacturing components made of metal. This machine has a 100 mm-high build volume with a build area of 70 by 40 mm.

**SLM100**
The ReaLizer SLM-100™ is designed specifically for the production of "smaller" components, whereby high precision and surface quality are of utmost importance. This machine has a 100 mm-high build volume with a build area of 125 by 125 mm.

**SLM300**
The ReaLizer SLM-300™ was designed for all-round use – it is suited for laboratories as well as the industrial production of components. The build volume is 300 x 300mm with 300 mm height.
3M Buckley Innovation Centre
IMI Group Workshop on Additive Manufacture
(3D Printing)
17th March 2015
3M Buckley Innovation Centre, Huddersfield
Innovation Avenue
• £12 million flagship project

• 100% subsidiary of the University

• All sizes of company – large corporate, SME and start-up

• Support for high-growth, high-technology businesses

• Not sector or technology focused to foster innovation
3M BIC is here to:

- Attract high growth and high tech companies as tenants and network members by
- Offering access to facilities for tenants – Accommodation, Events space and Technology
- Offer access and advice to business matters, markets and finance
- Facilitate joint projects with businesses and other partners (including the University) and signposting businesses where appropriate
An incremental network

- Experience
- Relevance
- Facilities
- Expertise
- Technology
- Business acumen
FURTHER INFORMATION: WWW.3MBIC.COM/
IMI Event  Photographs