University of Huddersfield Repository

Unver, Ertu and Taylor, Andrew

3D Additive Manufacturing Symposium & Workshop

Original Citation

Unver, Ertu and Taylor, Andrew (2015) 3D Additive Manufacturing Symposium & Workshop. University of Huddersfield, Huddersfield, UK.

This version is available at http://eprints.hud.ac.uk/id/eprint/25753/

The University Repository is a digital collection of the research output of the University, available on Open Access. Copyright and Moral Rights for the items on this site are retained by the individual author and/or other copyright owners. Users may access full items free of charge; copies of full text items generally can be reproduced, displayed or performed and given to third parties in any format or medium for personal research or study, educational or not-for-profit purposes without prior permission or charge, provided:

- The authors, title and full bibliographic details is credited in any copy;
- A hyperlink and/or URL is included for the original metadata page; and
- The content is not changed in any way.

For more information, including our policy and submission procedure, please contact the Repository Team at: E.mailbox@hud.ac.uk.

http://eprints.hud.ac.uk/

3M BUCKLEY INNOVATION CENTRE

IMI

3D ADDITIVE MANUFACTURING

SYMPOSIUM & WORKSHOP

HOSTED BY 3M BUCKLEY INNOVATION CENTRE. UNIVERSITY OF HUDDERSFIELD.

MARCH 17TH 2015

eos

e-Manufacturing Solutions

EDITED BY DR.ERTU UNVER & ANDREW TAYLOR.
SCHOOL OF ART, DESIGN & ARCHITECTURE. UNIVERSITY OF HUDDERSFIELD

HK 3D SOLUTIONS

RENISHAW

apply innovation

CONTENTS:

Chapter 1:
School of Art and Design and Architecture academics:
3D Printing *our* Future: *NOW* in Art Design & Architecture,
Andrew Taylor & Dr. Ertu Unver — 4 – 19

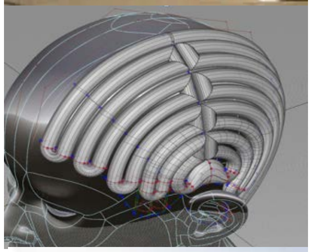
Chapter 2:
3M Buckley 3D Design: Design into reality, the links between the designer and the engineer. Paul Tallon — 20 - 40

Chapter 3:
EOS (Electro Optical Systems): New tools for tomorrows challenges. Garth Stevenson — 41 - 67

Chapter 4:
***A* Renishaw Perspective:** Additive Manufacturing Design for Process. Stephen Crownshaw — 68 - 87

Chapter 5:
HK 3D Printing: Boom – Do it with 3D Printing - links between the designer and the engineer*.* Ken Whild &Tom Smith — 88 – 118

Chapter 6:
3M Buckley Innovation Centre Manager:
Summary of the Symposium:3M BIC Facilities and Research
Dr. Michael Wilson — 119 – 128



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 snaphsot 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 tomorrows 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.

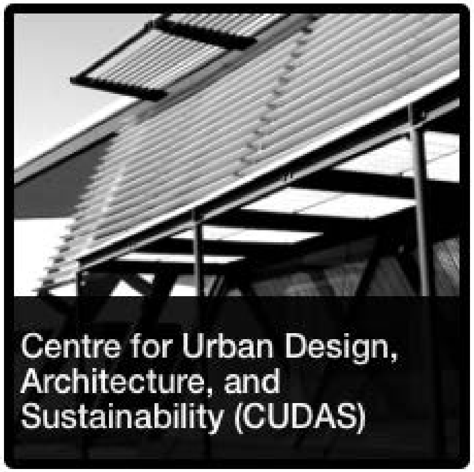
The talk focused on introducing the importance of creative design research practice and how 3D printing has evolved as an increasingly essential and highly versatile tool in the creative process particularly for concept, physical visualisation, prototyping , tooling and manufacture.

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.

***3D PRINTING OUR FUTURE**: NOW*

RESEARCH CENTRES // ART. DESIGN. ARCHITECTURE

Research Centres at School of Art, Design & Architecture situates academics professional research and postgraduate student projects


Centre for Urban Design, Architecture, and Sustainability (CUDAS)


Fashion Thinking

G


Global Disaster Resilience Centre


Innovative Design Lab


Sculptural Thinking


Textile Thinking

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

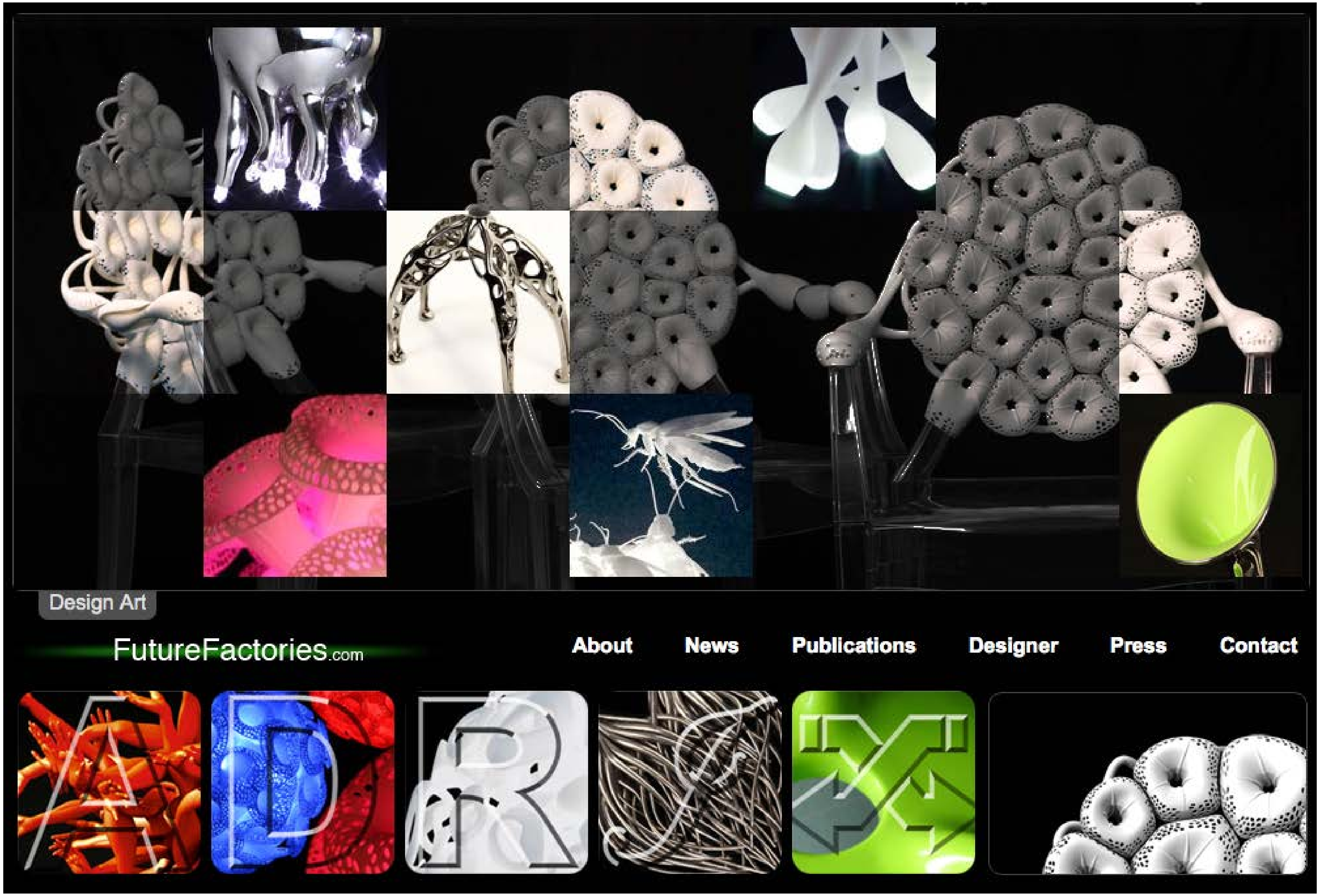
3D Printing:
Queen Street Studios and 3D Digital Design
School of Art, Design & Architecture
University of Huddersfield

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



Futurefactories (2003-2009) : The Application of Random Mutation to Three- Dimensional Design. Lionel T. Dean

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.

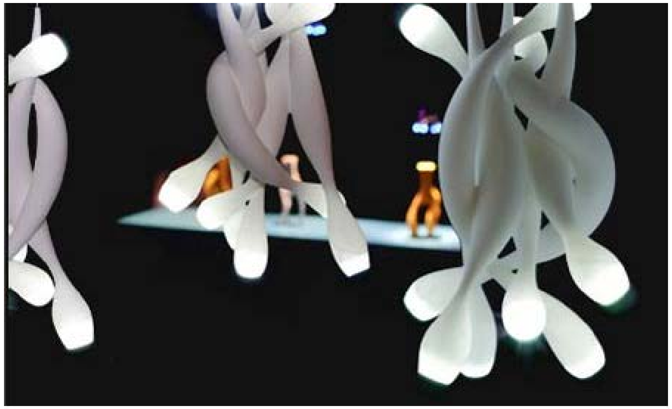


Figure 215
MMP Polished Stainless Steel Icon

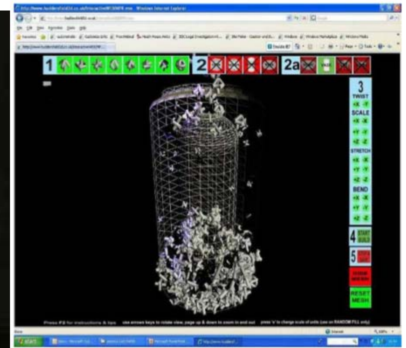
Design „Icon“: Lionel T. Dean, Future Factories; Material: 18-carat yellow gold (Source: CPM)

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.

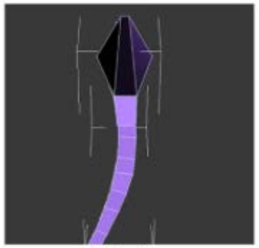


Selection of bangles and necklaces generated using automake software.
Image 4 of 11

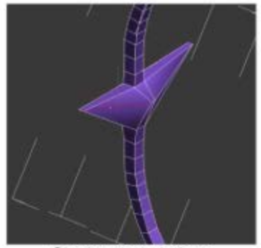
AutoMAKE: Generative systems, digital manufacture and craft production. Generative Art Conference, 11th -14th December 2007, Milan, Italy.
Ertu Unver, Justin Marshall, and Paul Atkinson.

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.

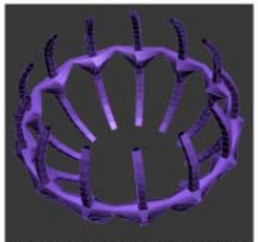
Center piece and bottom rib



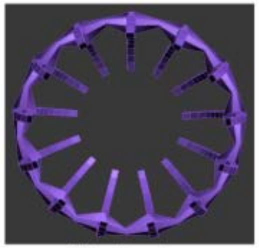
Side view



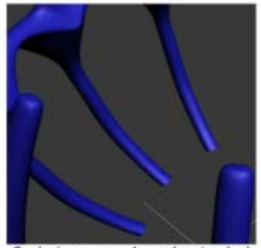
Single created piece



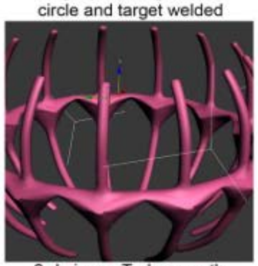
1st Single piece aligned to form circle and target welded



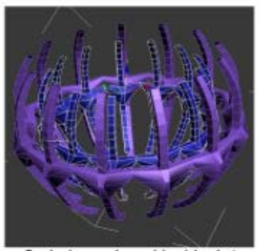
View from top



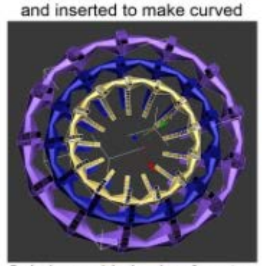
2nd piece - each end extruded and inserted to make curved



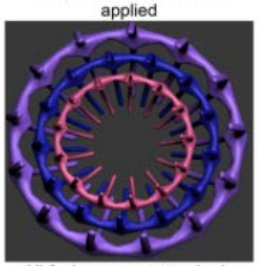
3rd piece - Turbosmooth applied



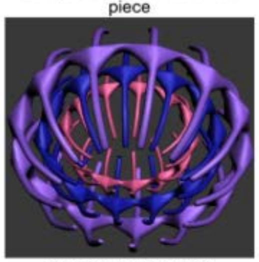
2nd piece placed inside 1st piece



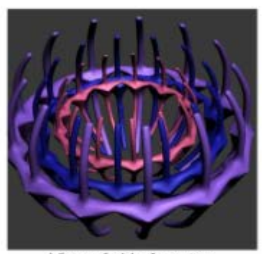
3rd piece added - view from top



All 3 pieces - not attached - turbosmooth applied



View from underneath



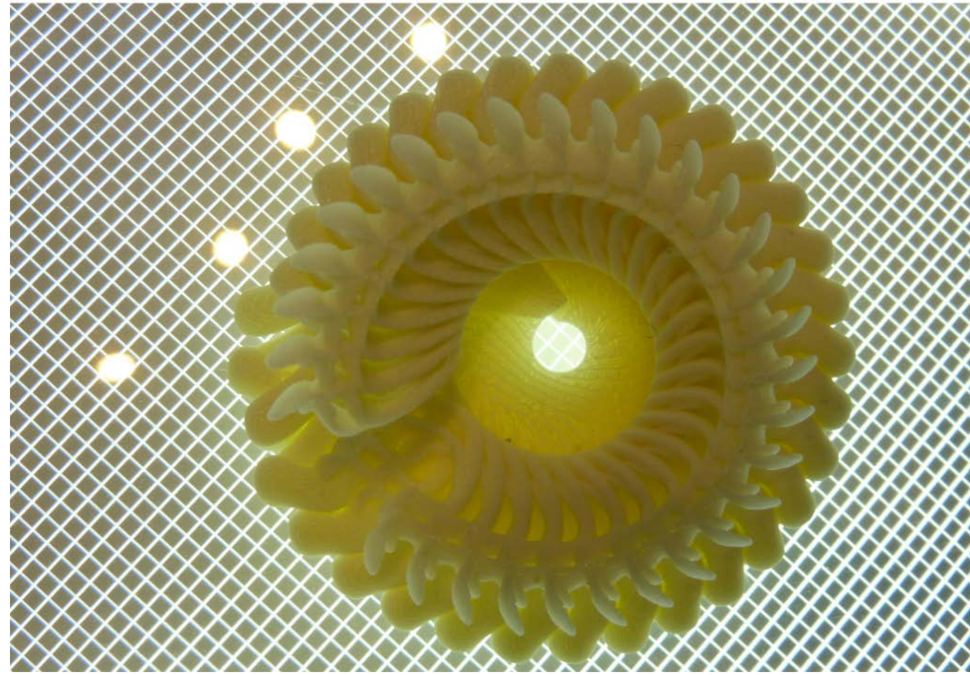
View of side from top

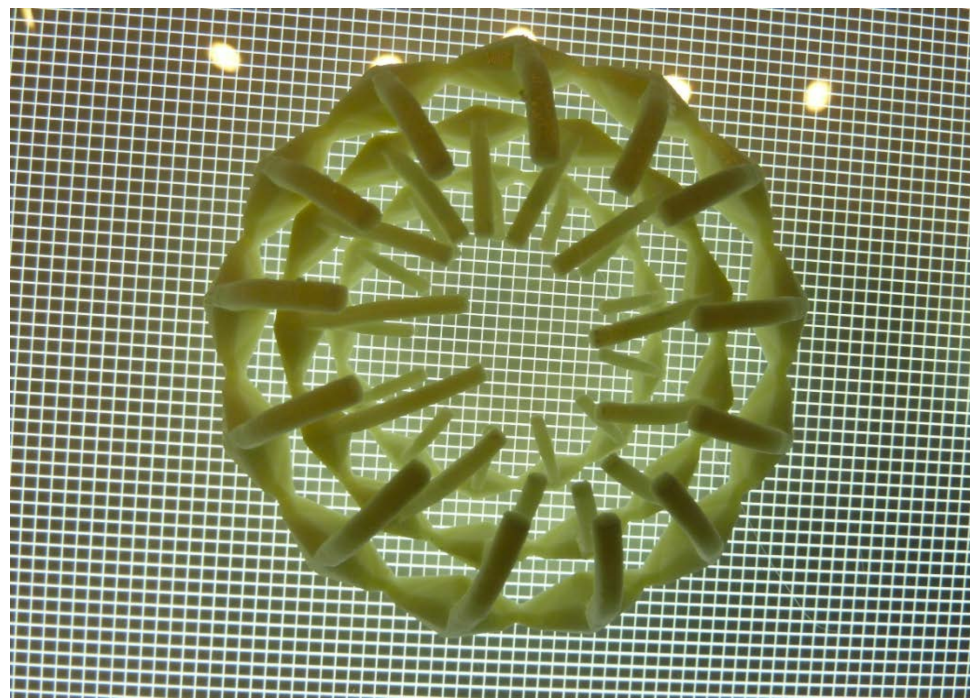
University funded practice led research by Andrew Taylor in collaboration with Surface Design students and academics. The project initiated 3D workshops to introduce 3D concept modelling and 3D printing for the first time to BA Surface Design Final year students. 3D printed prototypes were exhibited at the Surface Design Show and EcoBuilld, London.

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

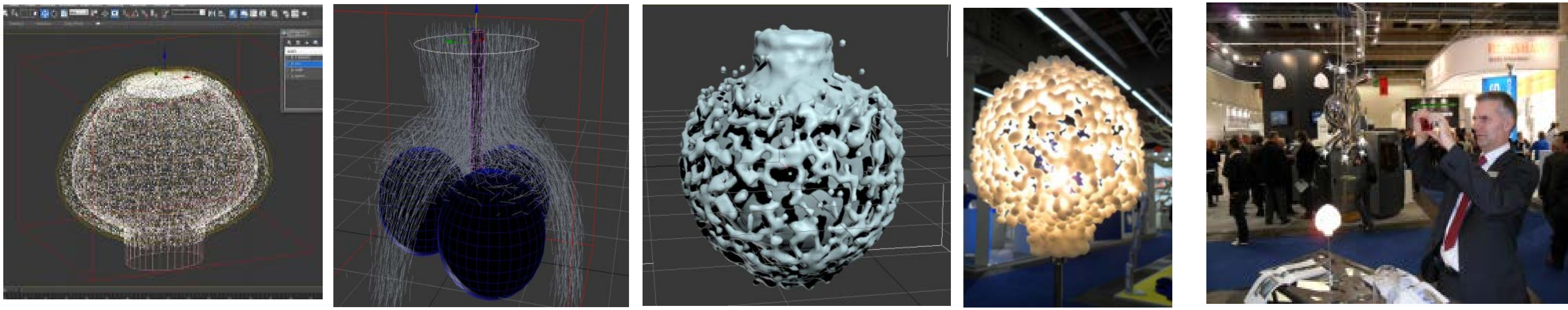
Student project blog: http://extraordinary-3d-materials.blogspot.co.uk

Shereen Ahmed: BA(Hons) Surface Design with Fashion & Interiors graduate 2011.
3D printed concept development for lighting product design: Exhibited at Surface Design show, Business Design Centre, London. February 2011.
http://www.surfacedesignshow.com/   http://shereenahmed.wix.com/mainpage

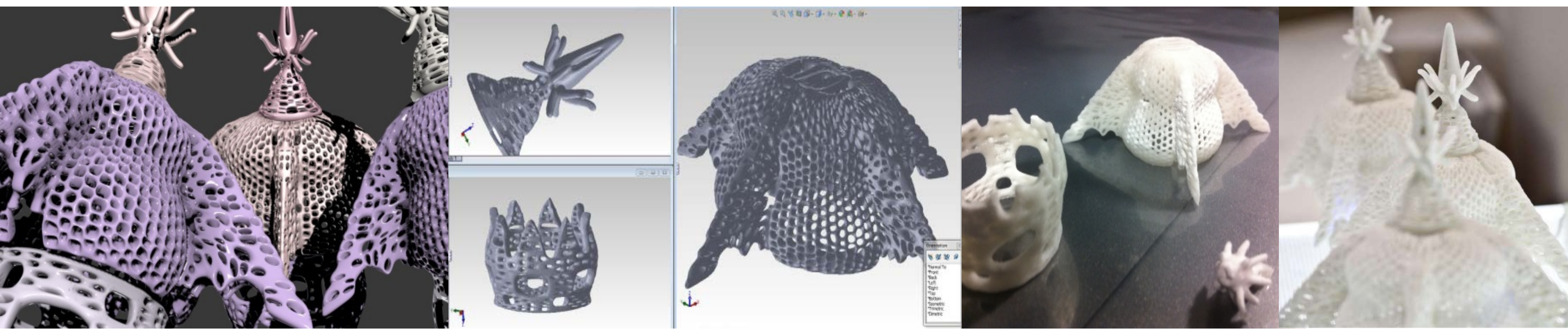




Extraordinary 3D Surface Materials: A practice led research exhibition with Surface Design final year students.
3D modeling concept methods and 3D printed prototypes. Exhibited at the Surface Design Show, Business Design Centre, Islington, London, 2011.



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.
Exhibited in 2012 at Ecobuild, London, UK. Andrew Taylor, University of Huddersfield.

Patrick Stewart OBE with the Portrait

3D print of the sculpted bust of Sir Patrick Stewart
by MA 3D Digital Design graduate Daniel Hughes-McGrail – Solaesthetic.
Sourced from Shapeways.

www.shapeways.com/shops/danhughesmcgrail-digitalsculpture

Moments of Death and Revival, 2008, installation detail, Version 1: 3D printed objects in acrylic polymer, dimensions from 19cm-25cm, train, track, lights. Photo: Brass Art, © the artists

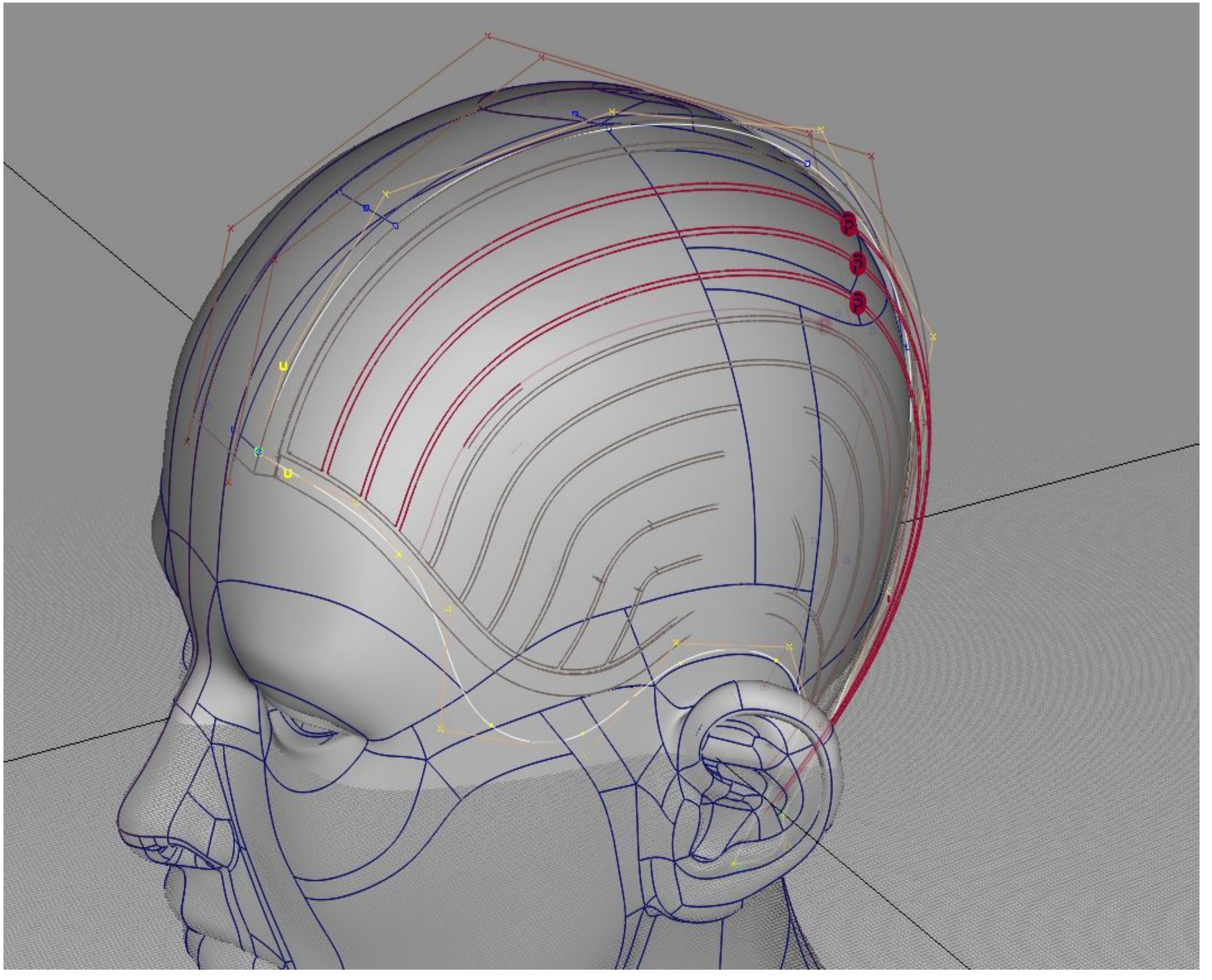
By Lewis, Chara, Mojsiewicz, Kristin and Pettican, Anneké (2008), *Skyscraping*. [Show/Exhibition] Brass Art. Anneké Pettican is an artist, Senior Lecturer and co-director of Brass Art (1999 -) with Chara Lewis and Kristin Mojsiewicz. Their collaborative practice explores the uncanny, including aspects of doubling and the limen – the in-between spaces of the physical world and the realms of the imagination.

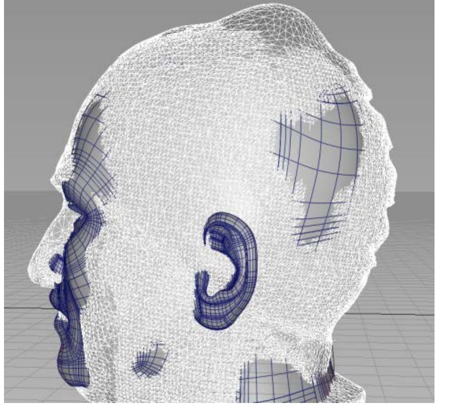
“We’ve changed the whole way we draw architecture; everything’s changed from hand-drawing to 3-D drawings. And if you draw everything 3-D, then it’s time to change the whole construction process”

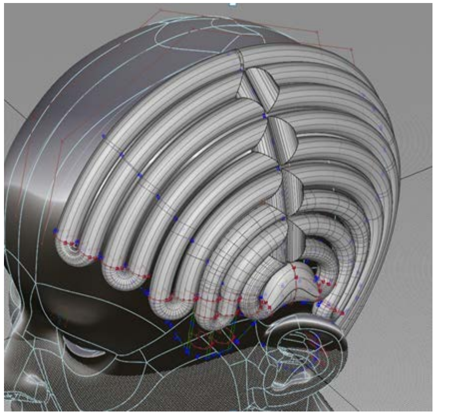
Ebner; UCLA Professor & 3M Architect.

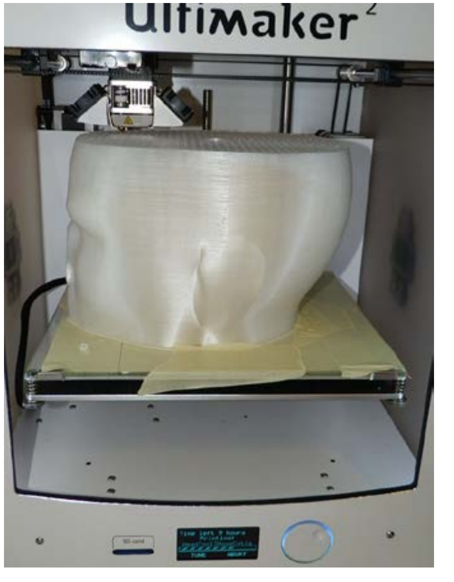
Students from the University of California in Los Angeles, University of Huddersfield, Munich Technical University and the Center for Entrepreneurship and University of Applied Sciences, collaborated on the full-scale mobile prototype of urban living accommodation in 2014.

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

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

3. PhD Lionel Dean, (2009) Futurefactories: the application of random mutation to three- dimensional design. http://eprints.hud.ac.uk/8799/1/ltdeanfinalthesis.pdf

4. Dean, L, Icon Jewellery. http://www.futurefactories.com/

5. Justin Marshall, Ertu Unver, and Paul Atkinson. *AutoMAKE: Generative systems, digital manufacture and craft production.* http://eprints.hud.ac.uk/3386/

6. Phases of 3D modeling and 3D printed Concept**s**, Surface Design Final year students, 2011. http://extraordinary-3d-materials.blogspot.co.uk

7. Taylor, A, 2011 Extraordinary 3D Surface Materials: A practice led exhibition of 3D learning artefacts and prototypes. http://eprints.hud.ac.uk/17246/

8. Unver & Taylor 2011 – 2012. Fluid dynamics experiments for generating lighting concepts. 3D Biomimicry for lighting concept design. http://eprints.hud.ac.uk/12760/

9. Daniel Hughes-McGrail. 3D Patrick Stewart bust, Sourced from Shapeways. www.shapeways.com/shops/danhughesmcgrail-digitalsculpture

10. Brass Art. Lewis, Chara, Mojsiewicz, Kristin and Pettican, Anneké (2008) *Skyscraping.* [Show/Exhibition] http://eprints.hud.ac.uk/3554/

11. 3D printed apartment by Peter Ebner; 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.

13. Unver, Ertu, Howard, Chris and Swann, David (2013) *Design & Development of Scalp Cooling Cap.* In: Smart Scalp Cooling Symposium, 3M Buckley Innovation Centre , Huddersfield, UK. http://eprints.hud.ac.uk/17743/ http://www.paxman-coolers.co.uk/news

14. Automake/FutureFactories (2008) E Unver, J Marshall, LT Dean, P Atkinson, Hub: National Centre for Craft & Design

15. Unver, E (2013) *Design and Development of a new Scalp Cooling Cap - Stage 1 : Confidential Design and Development Report* Confidential Report Submitted to Paxman Coolers ltd.

3M BUCKLEY INNOVATION CENTRE

PAUL TALLON

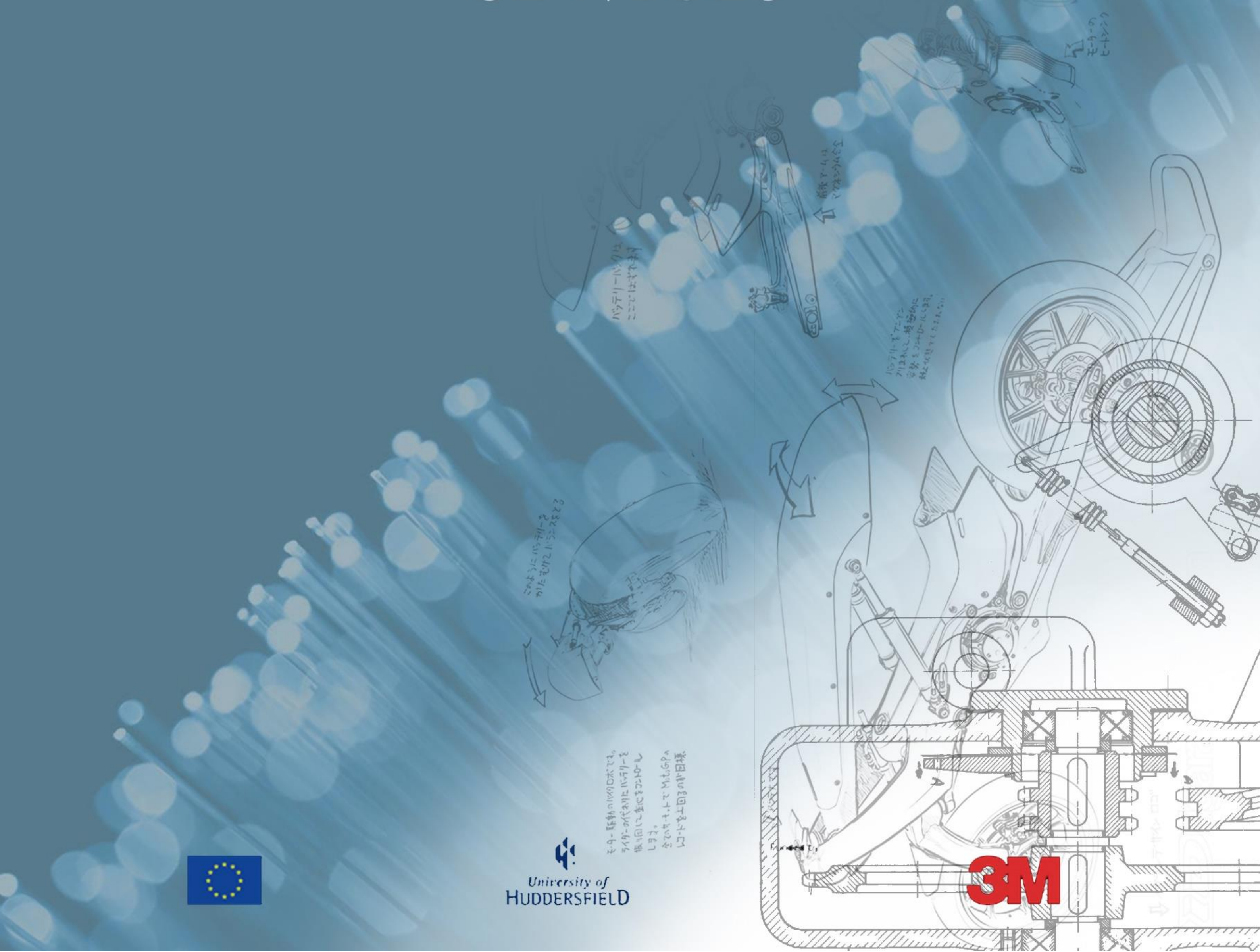
LEAD DESIGNER

University of HUDDERSFIELD

3M

3M BUCKLEY INNOVATION CENTRE

DESIGN & PROTOTYPING SERVICES



CONSULTATION PROCESS

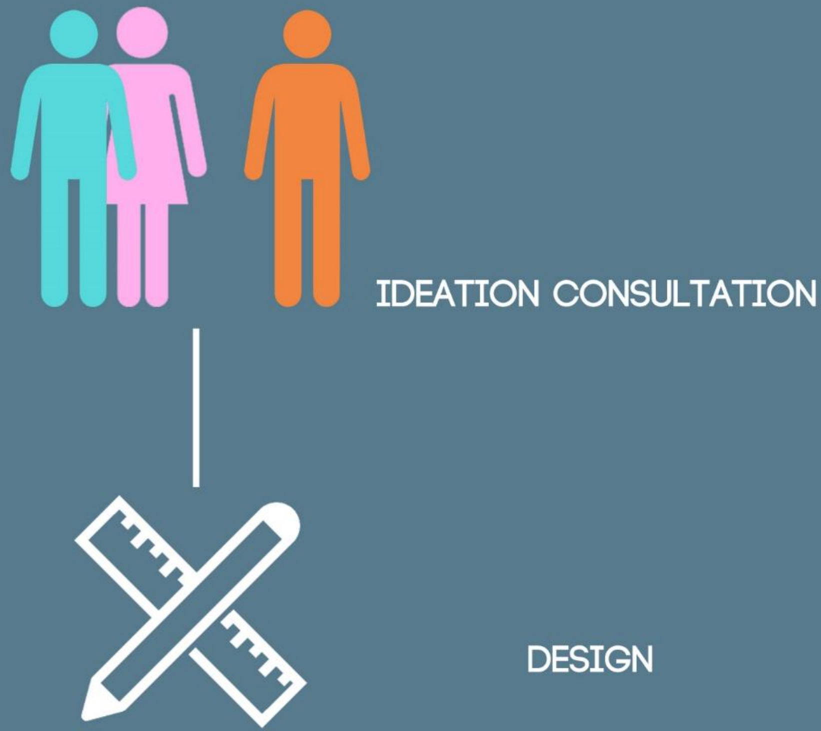
University of HUDDERSFIELD

Funded by

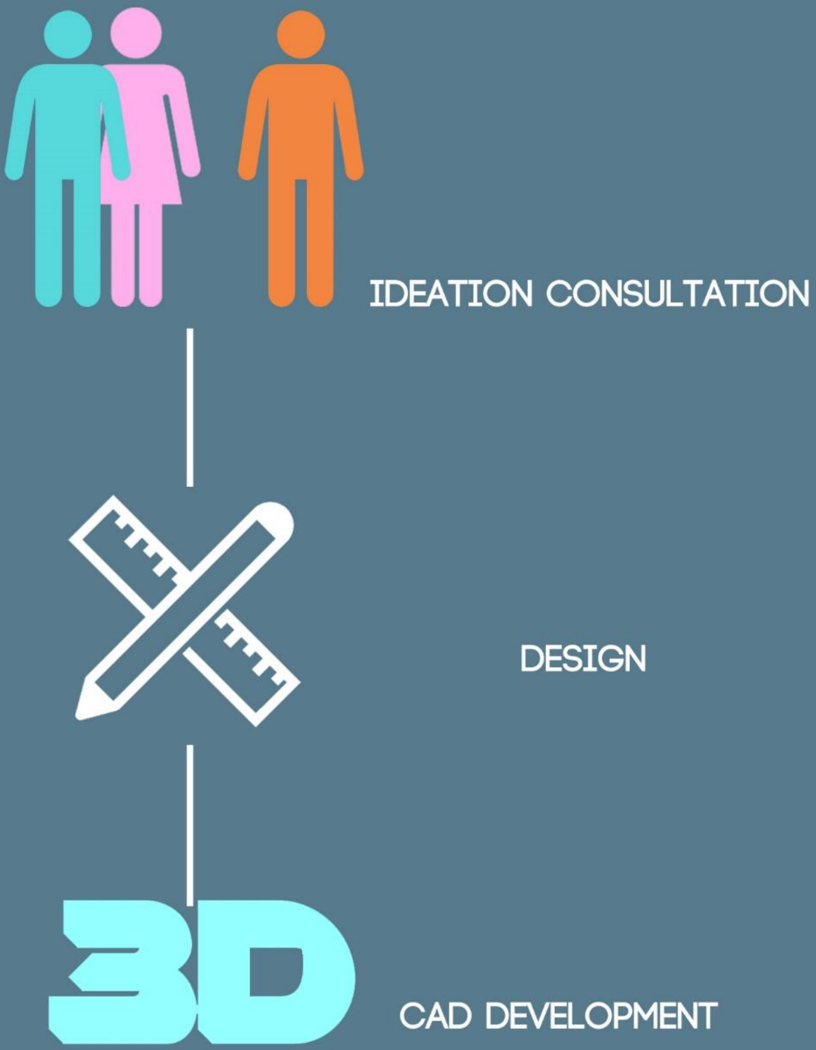
3M

IDEATION CONSULTATION

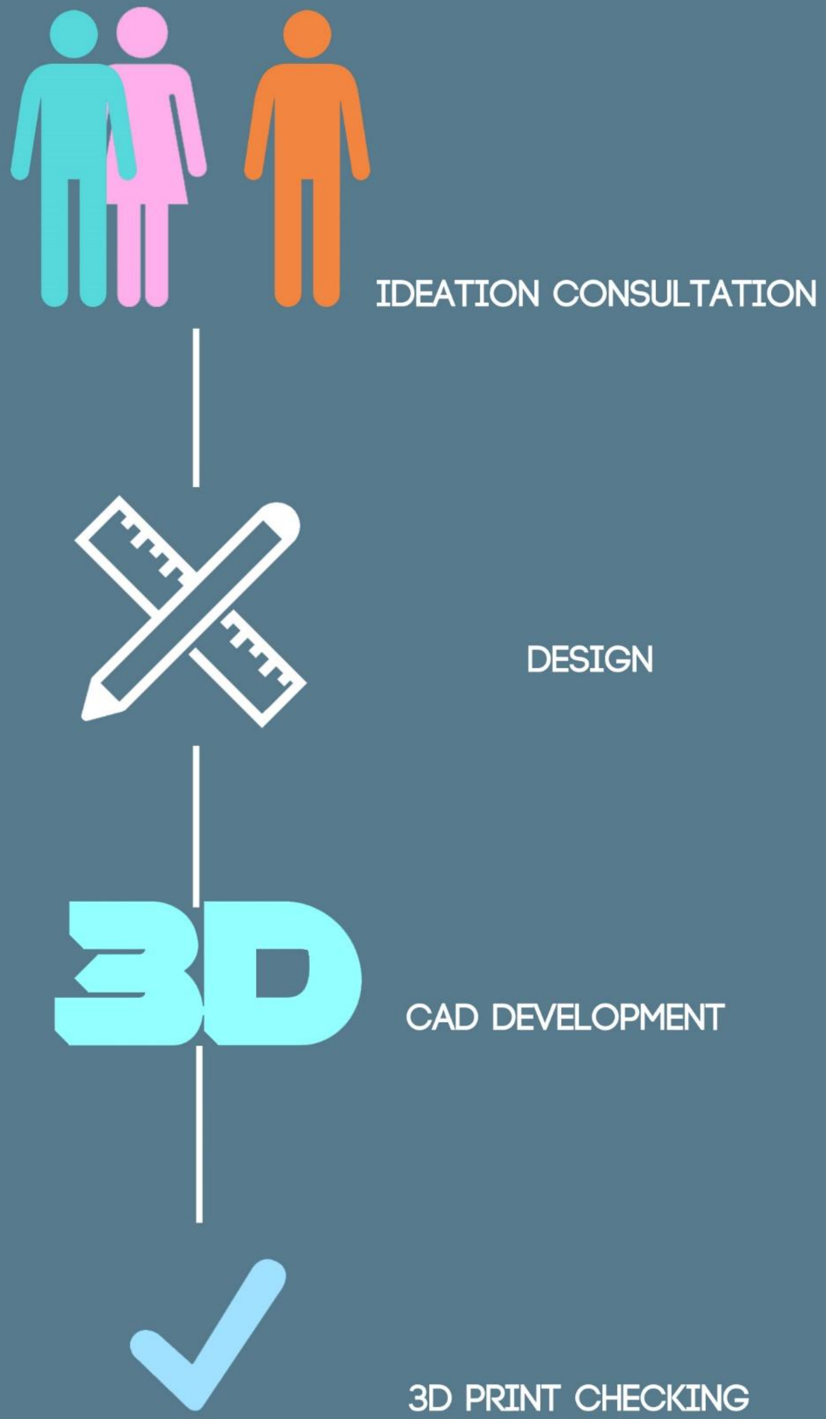
University of HUDDERSFIELD
Funded by
3M

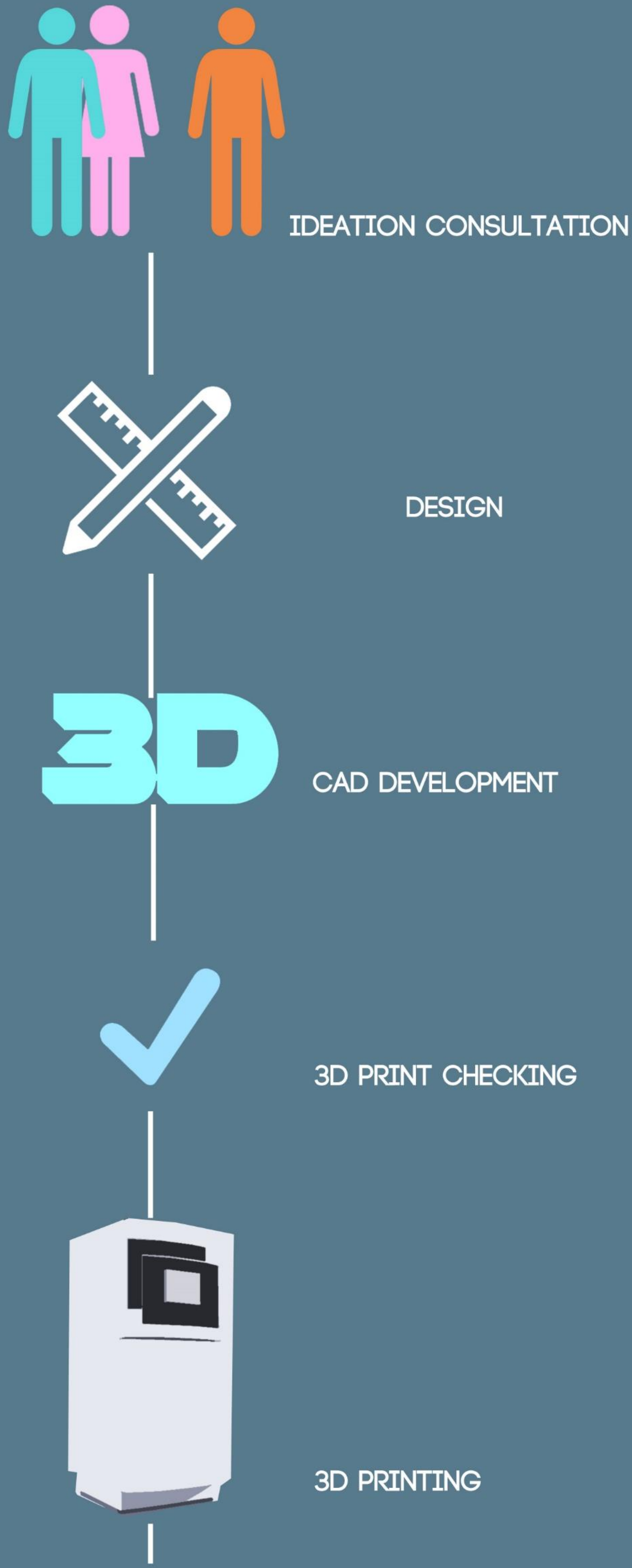


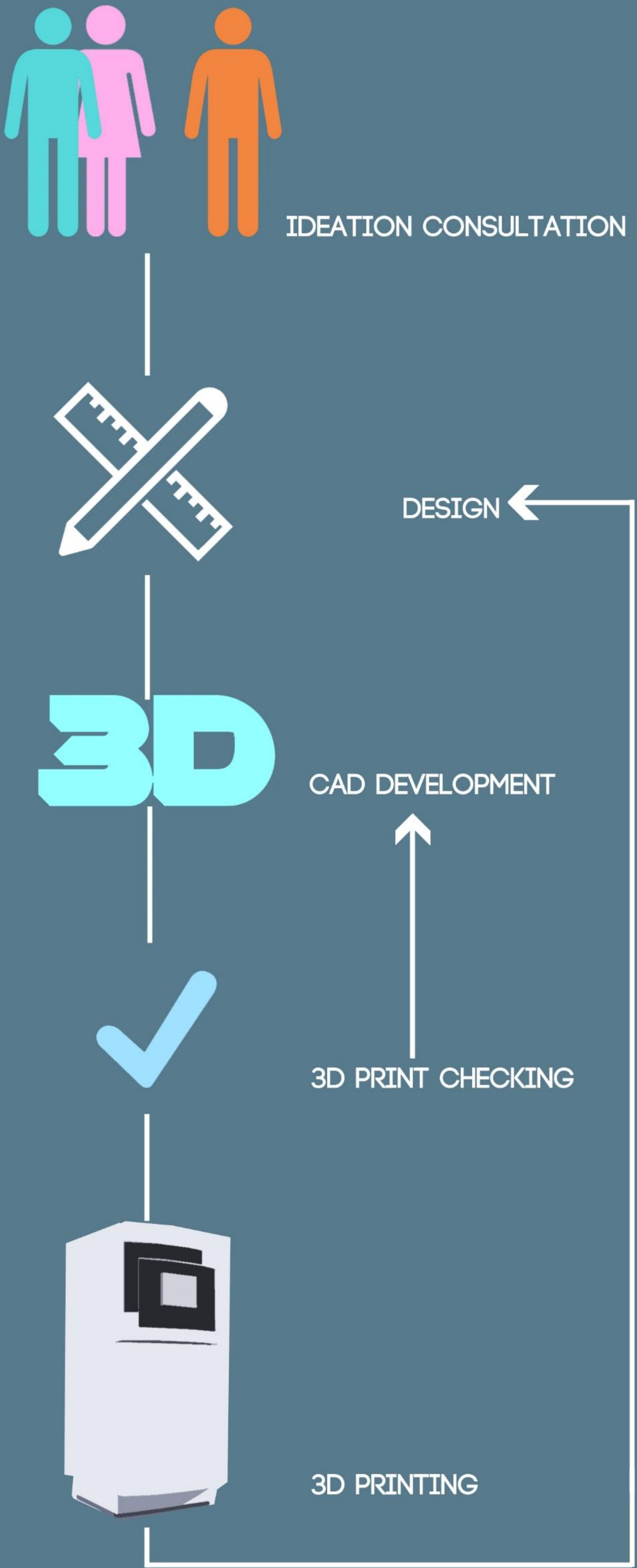
University of HUDDERSFIELD
Funded by
3M



Funded by
University of Huddersfield
3M

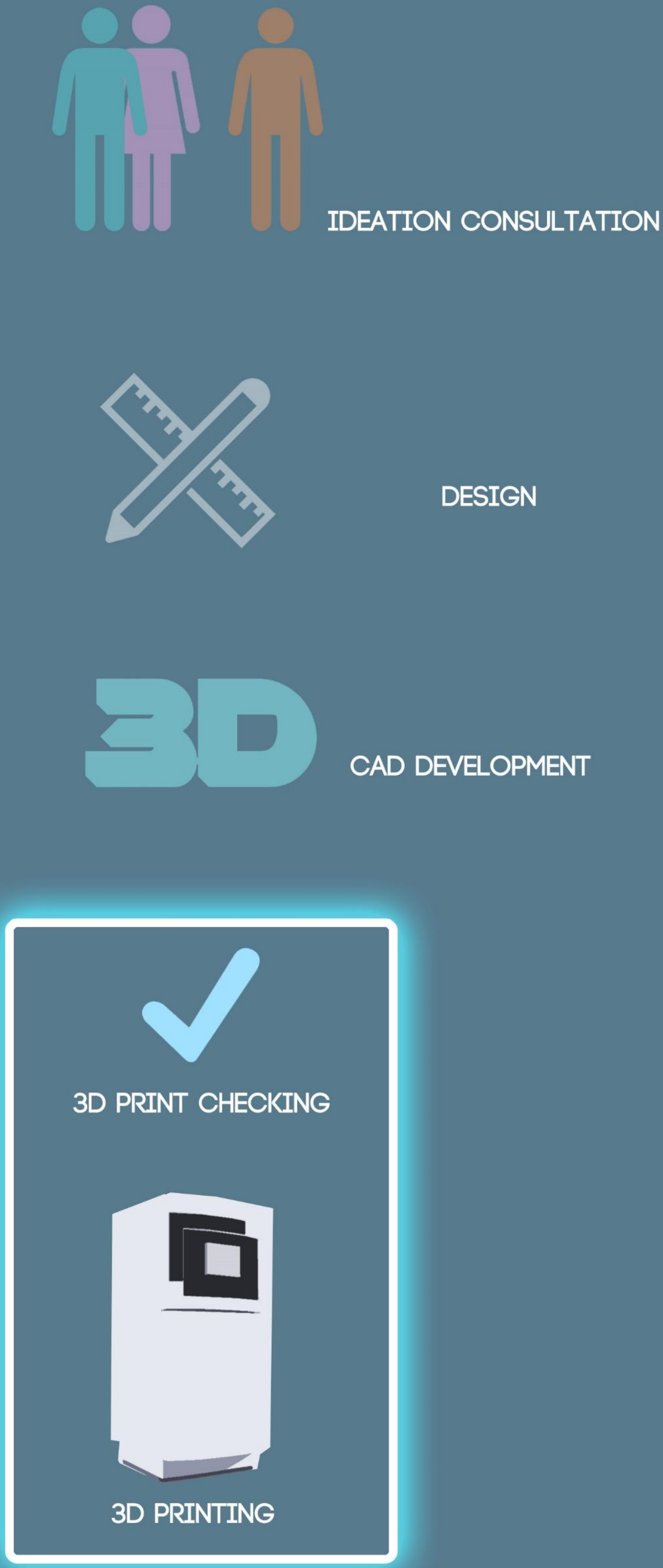

IDEATION CONSULTATION
DESIGN
3D
CAD DEVELOPMENT
3D PRINT CHECKING

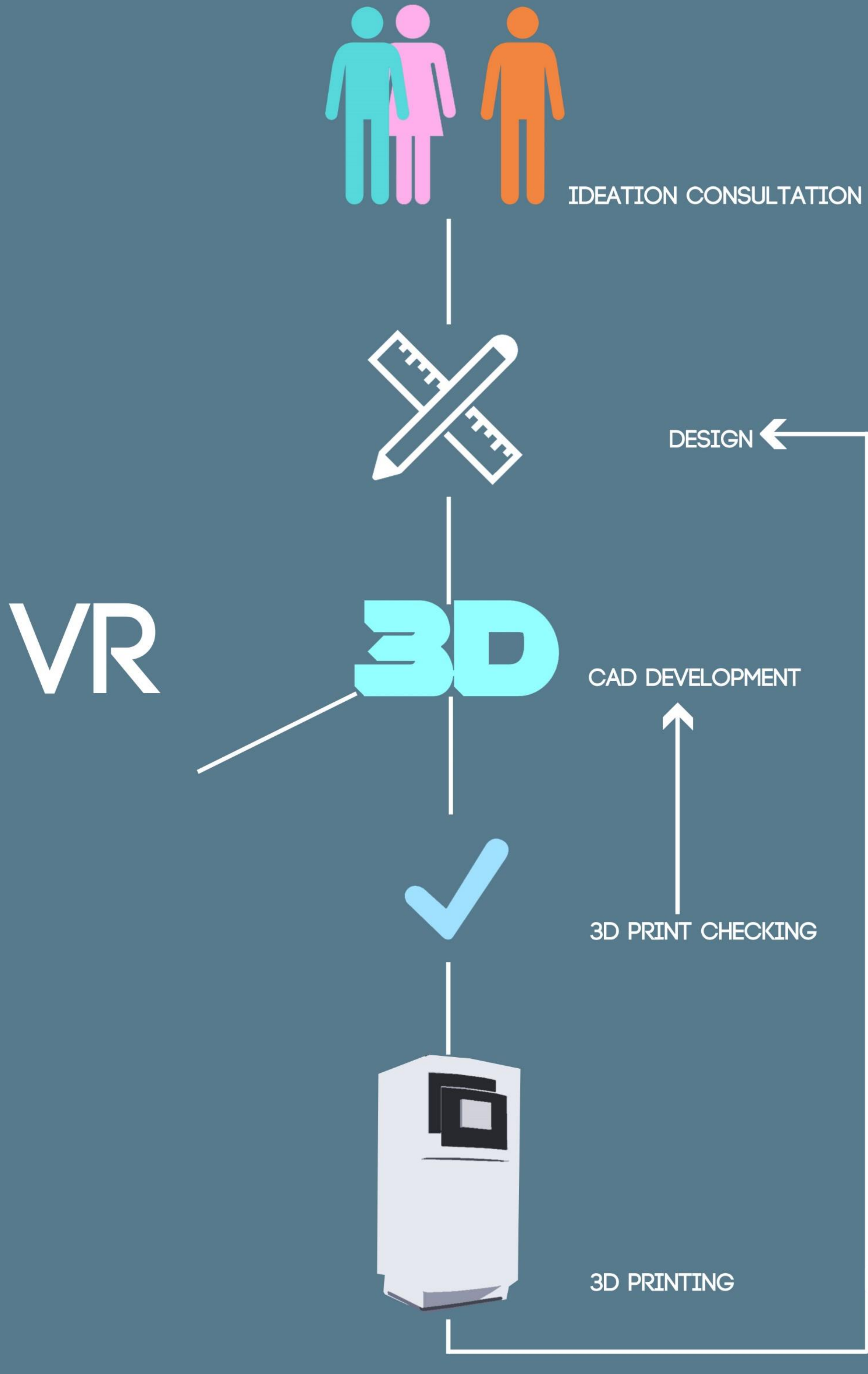

IDEATION CONSULTATION
DESIGN
3D
CAD DEVELOPMENT
3D PRINT CHECKING
3D PRINTING



University of HUDDERSFIELD

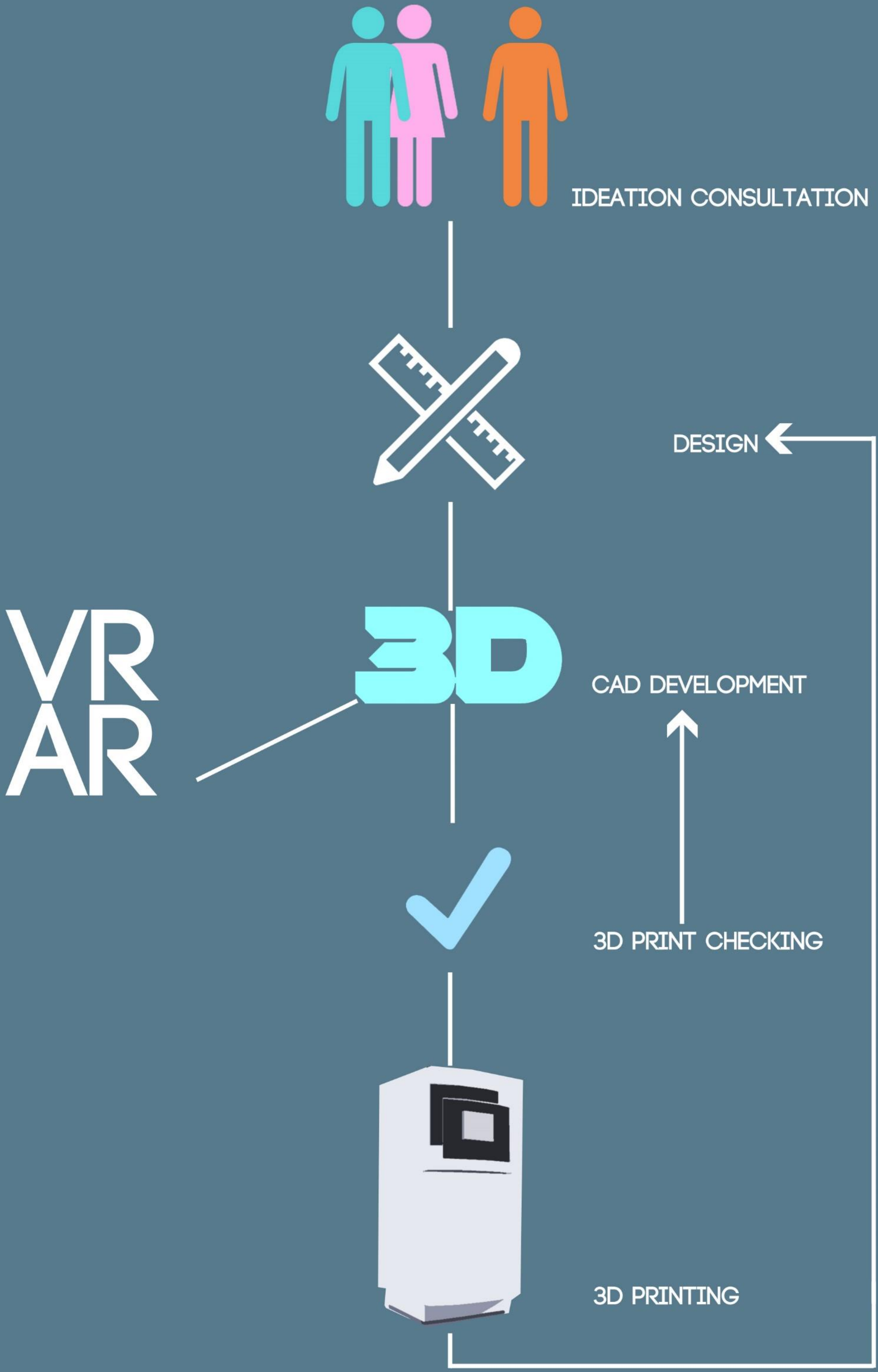
3M


IDEATION CONSULTATION
DESIGN
3D
CAD DEVELOPMENT
3D PRINT CHECKING
3D PRINTING

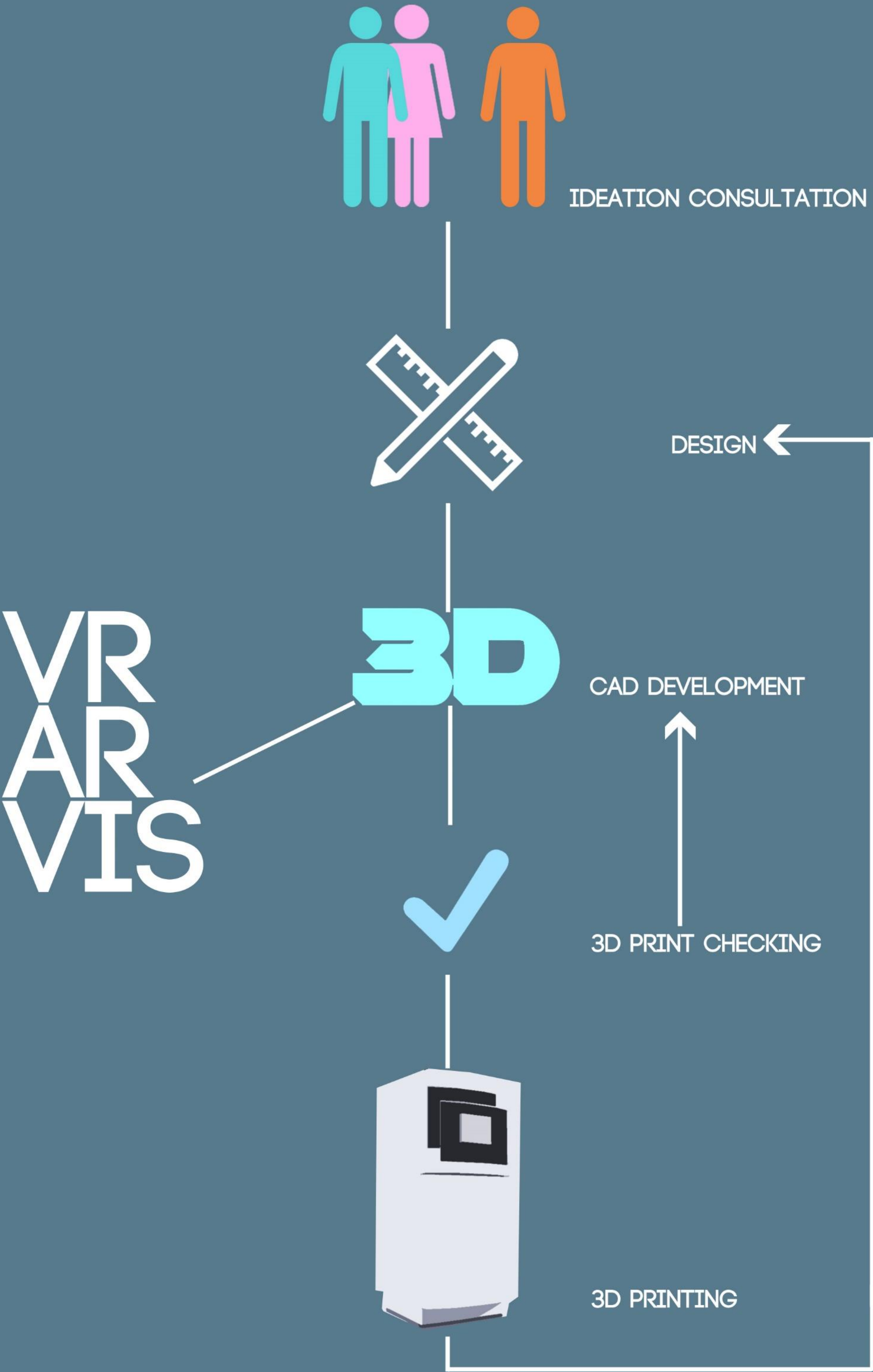


University of
HUDDERSFIELD

3M



IDEATION CONSULTATION
DESIGN
VR
AR
3D
CAD DEVELOPMENT
3D PRINT CHECKING
3D PRINTING



University of HUDDERSFIELD

VR
AR
VIS

VR
AR

VIS

PRODUCING A 2D ANIMATION OF THE CLIENTS PRODUCT TO SHOWCASE FUNCTION AND SITUATIONAL ENVIRONMENTS

VR

VIS

AR

THE ABILITY TO SHOWCASE
A CLIENTS PRODUCT IN THE REAL
WORLD BY TRANSPOSING A 3D MODEL
ONTO A REFERENCE PLANE

AR
VIS

VR

THE ABILITY TO SHOWCASE
A CLIENTS PRODUCT IN 3D
BY WAY OF USING STEROSCOPIC
CONVERSION

Main Benefits to 3D Printing

MAIN BENEFITS TO 3D PRINTING

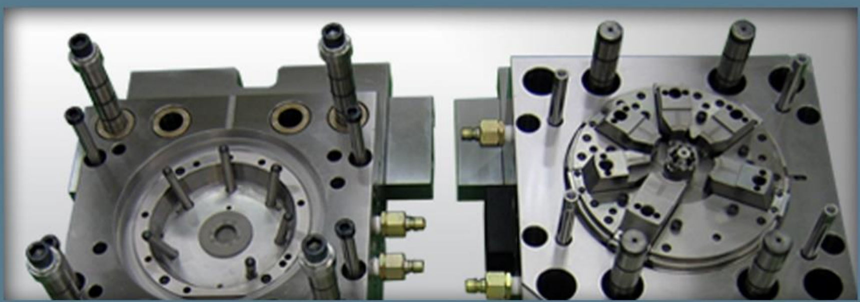
Streamlined work flow from CAD to testing

VAVE analysis of parts and asemblies can be assesed more rapidly and re-designed

MAIN BENEFITS TO 3D PRINTING

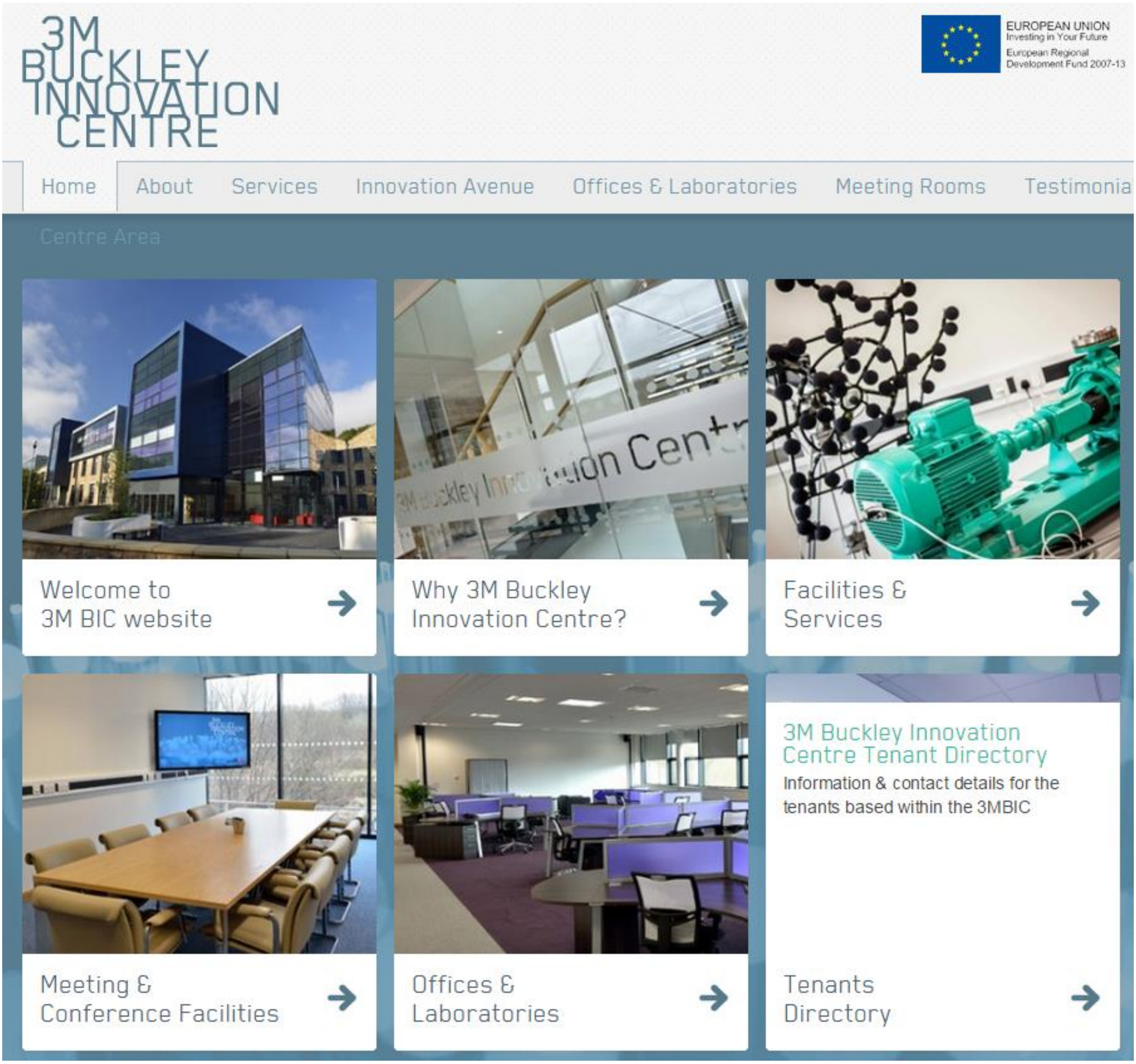
Parts can be produced for direct application

Tooling costs for test components negated therefore costs for final product reduced



For more information: http://www.3mbic.com/

EUROPEAN UNION
Investing in Your Future
European Regional Development Fund 2007-13
University of HUDDERSFIELD
Funded by Kirklees COUNCIL
3M



EOS (Electro Optical Systems): New tools for tomorrows challenges

IMI March 2015

e-Manufacturing Solutions

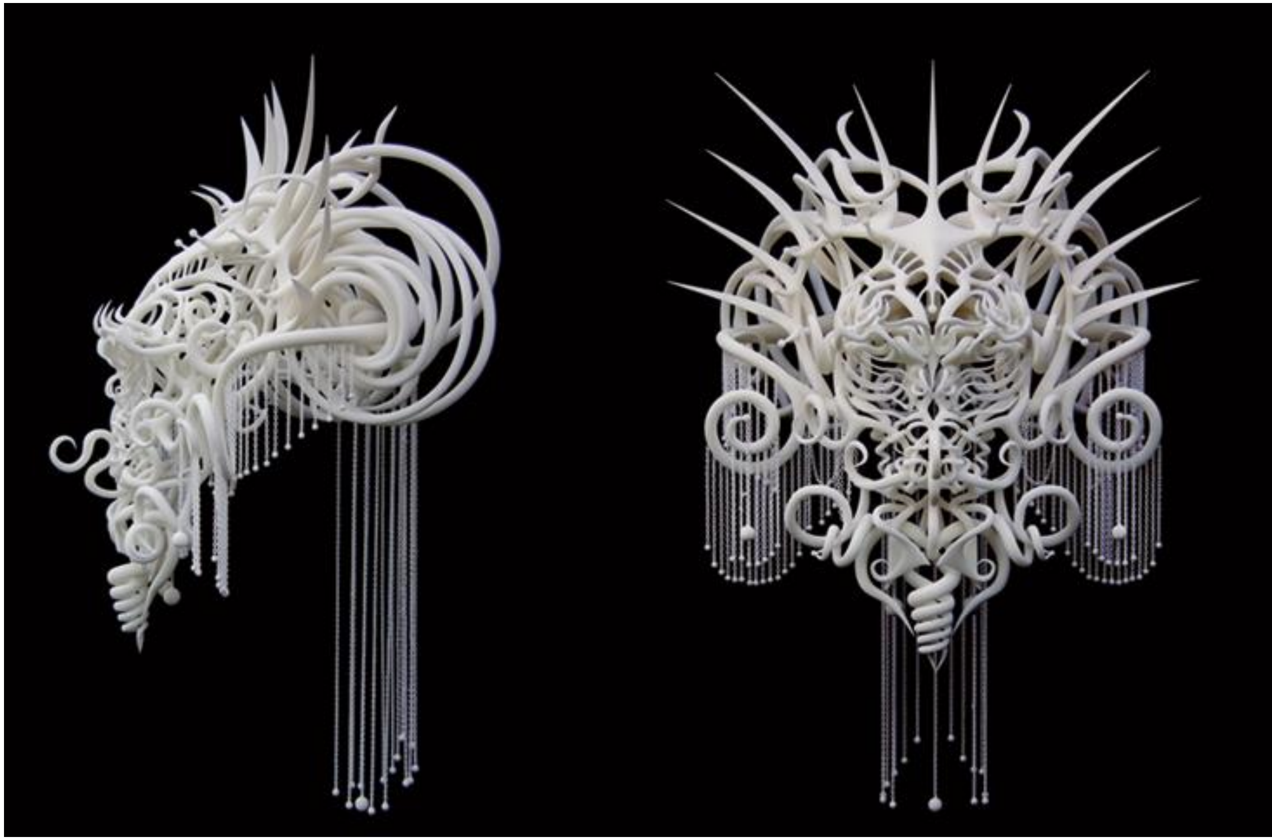
Electro Optical Systems

New tools for tomorrows challenges

This presentation may contain confidential and/or privileged information.
Any unauthorized copying, disclosure or distribution of the material in this document is strictly forbidden.

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

e-Manufacturing Solutions

EOS – Basic facts

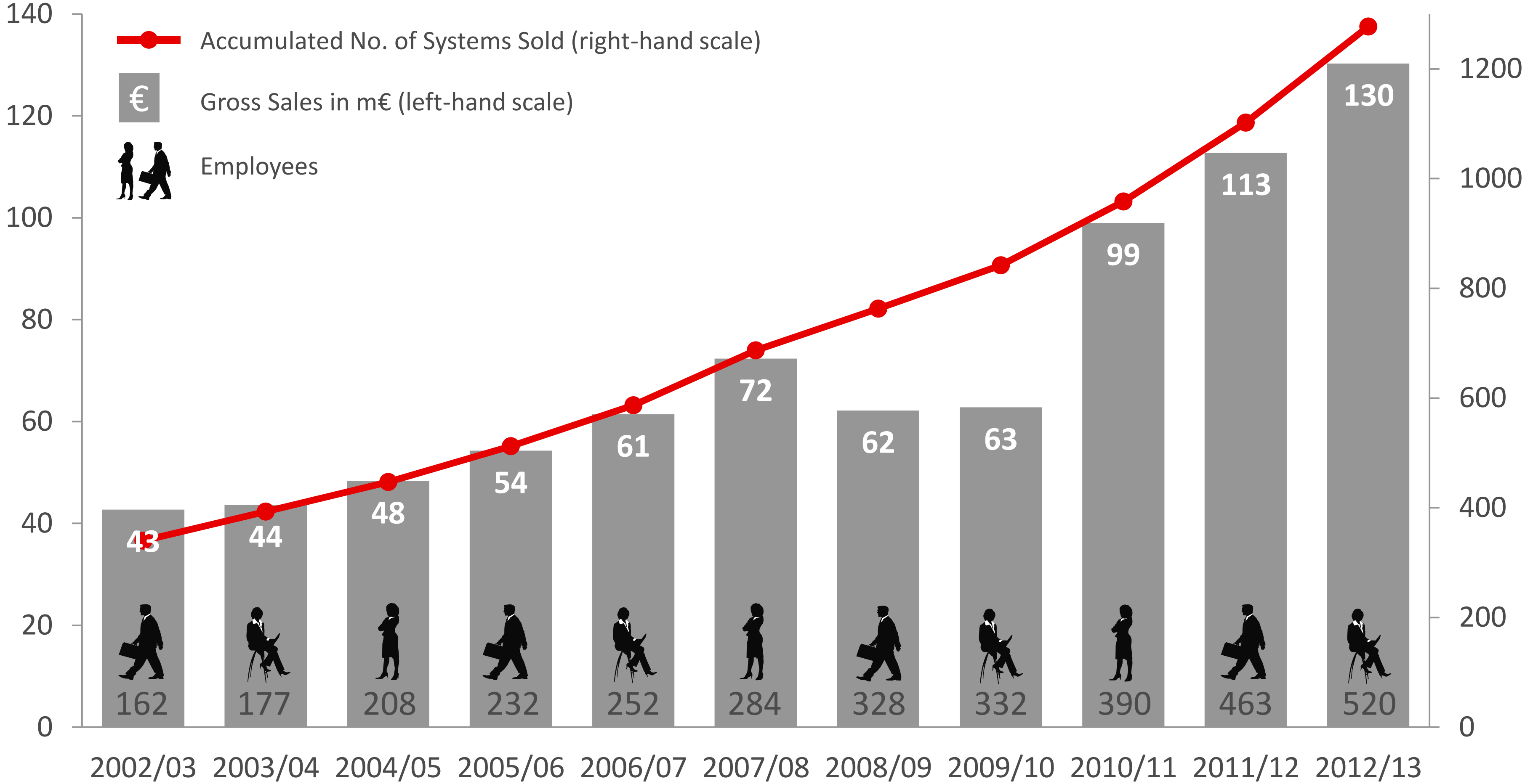
Electro Optical Systems

- **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

e-Manufacturing Solutions

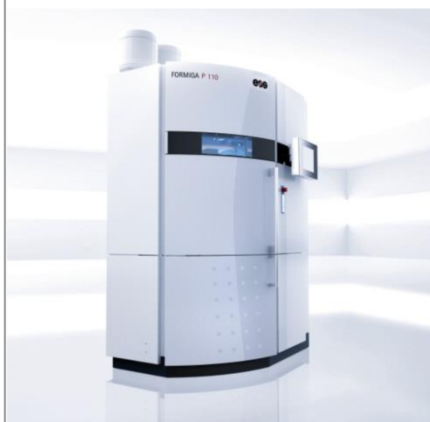


Source: EOS. Figures for EOS Group, for financial years ending 30 September. Number of Employees: Headcounts.

Tools: EOS Polymer Laser Sintering Systems

e-Manufacturing Solutions

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



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

Laser
- CO_2 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
- CO_2 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 CO_2 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 CO_2 lasers
- Total nominal power: 100 W
- Wave length 10.6 µm

Layer thickness
- Standard: 0.12 mm

Tools: EOS Direct Metal Laser Sintering Systems

e-Manufacturing Solutions

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

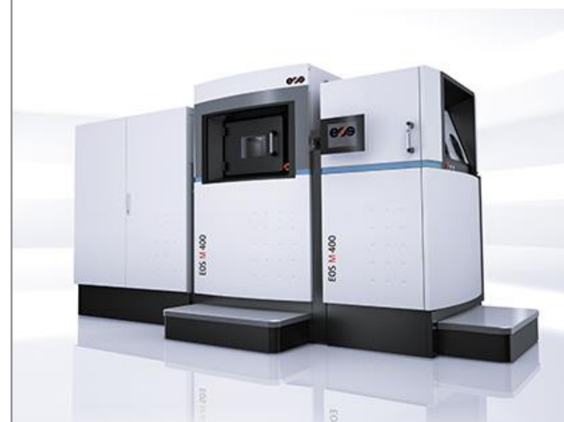
EOSINT M 270 Dental: High-performance DMLS for production of dental copings and bridges

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

e-Manufacturing Solutions

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

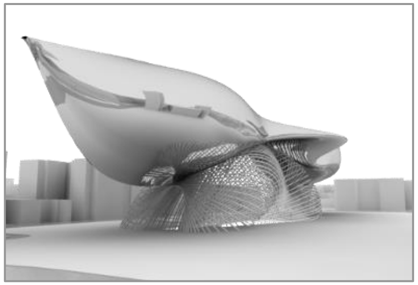
Individualized parts

- 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

e-Manufacturing Solutions

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 *

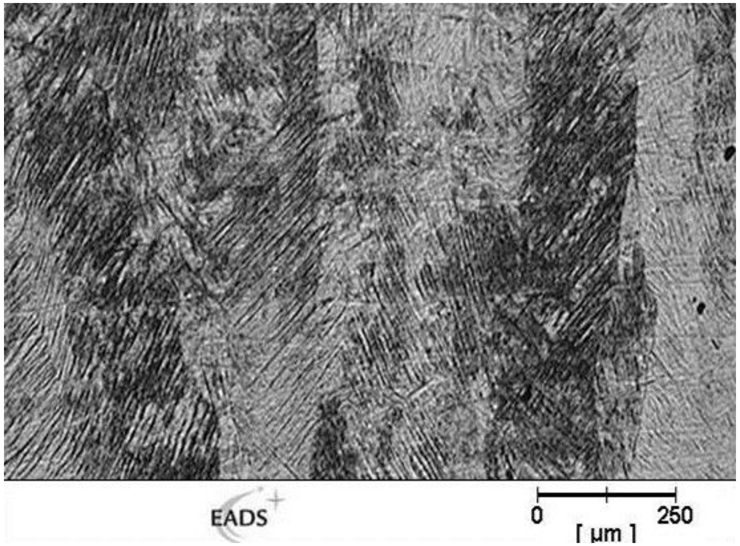
EOS Titanium Ti64 produces fully dense parts with dendritic, martensitic grain structure

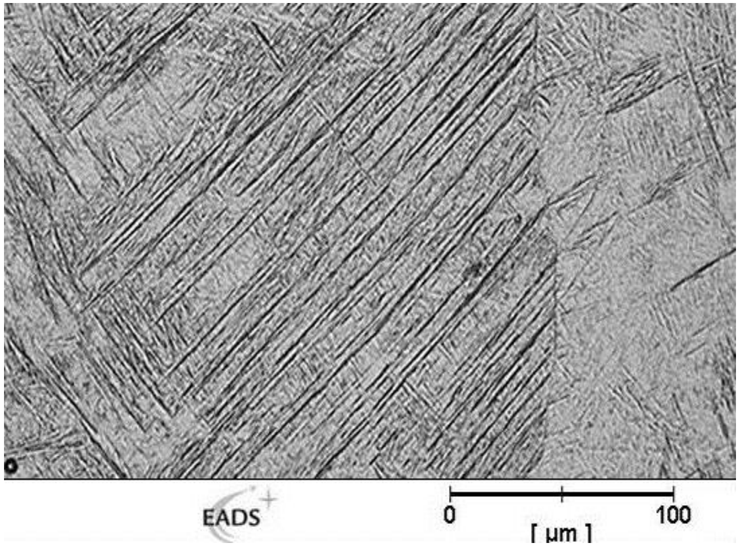
e-Manufacturing Solutions

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

e-Manufacturing Solutions

Example **Lightweight**

Steel (left) and
carbon-titan shift (right)

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)

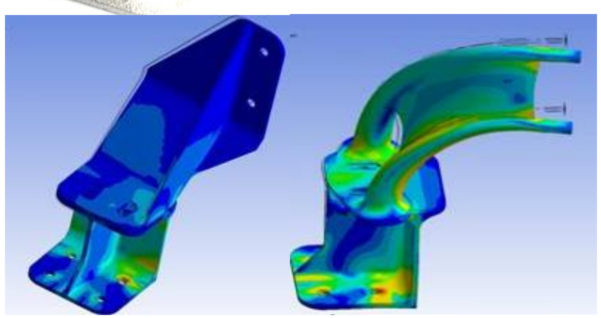
Source: University of Warwick, EOS

Even simple brackets can be designed in a bionic way and thus help to save weight

e-Manufacturing Solutions

Example Lightweight

Stress test
of welded and
sintered bracket



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

Source: P3 digital services, EOS

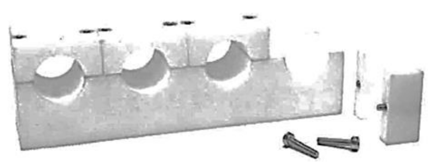
However, to retrieve the maximum value, the design needs to leverage all possibilities

e-Manufacturing Solutions

Example Integrated Functionality

1 Conventional manufacturing (13 parts, aluminum)

2 Additive manufacturing, conventional design (13 parts, PA12)



3 Additive manufacturing, optimized design (2 parts, PA12, colored)

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

e-Manufacturing Solutions

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

e-Manufacturing Solutions

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

e-Manufacturing Solutions

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 compo-nents 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

e-Manufacturing Solutions

Example Integrated Functionality

Bionic handling assistant

Application

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

Advantages

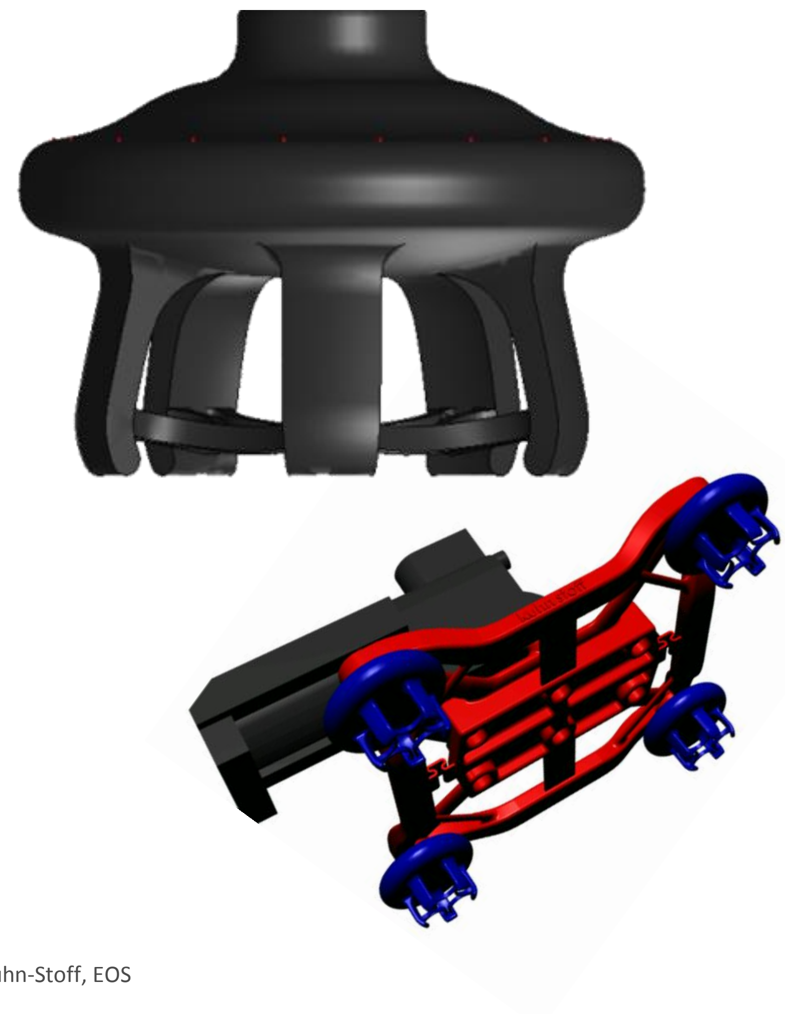
- Safe and gentle handling
- Weight 'reduced to the max'
- Highly flexible due to self adapting gripper fingers
- Cost efficient – entire gripper produced in 'one shot', no post assembly

Source: Festo, Fraunhofer IPA, EOS

This light-weight gripper weights 19g and can handle 12kg parts

e-Manufacturing Solutions

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

e-Manufacturing Solutions

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

Not Just Low Volume Additive Manufacturing

e-Manufacturing Solutions

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

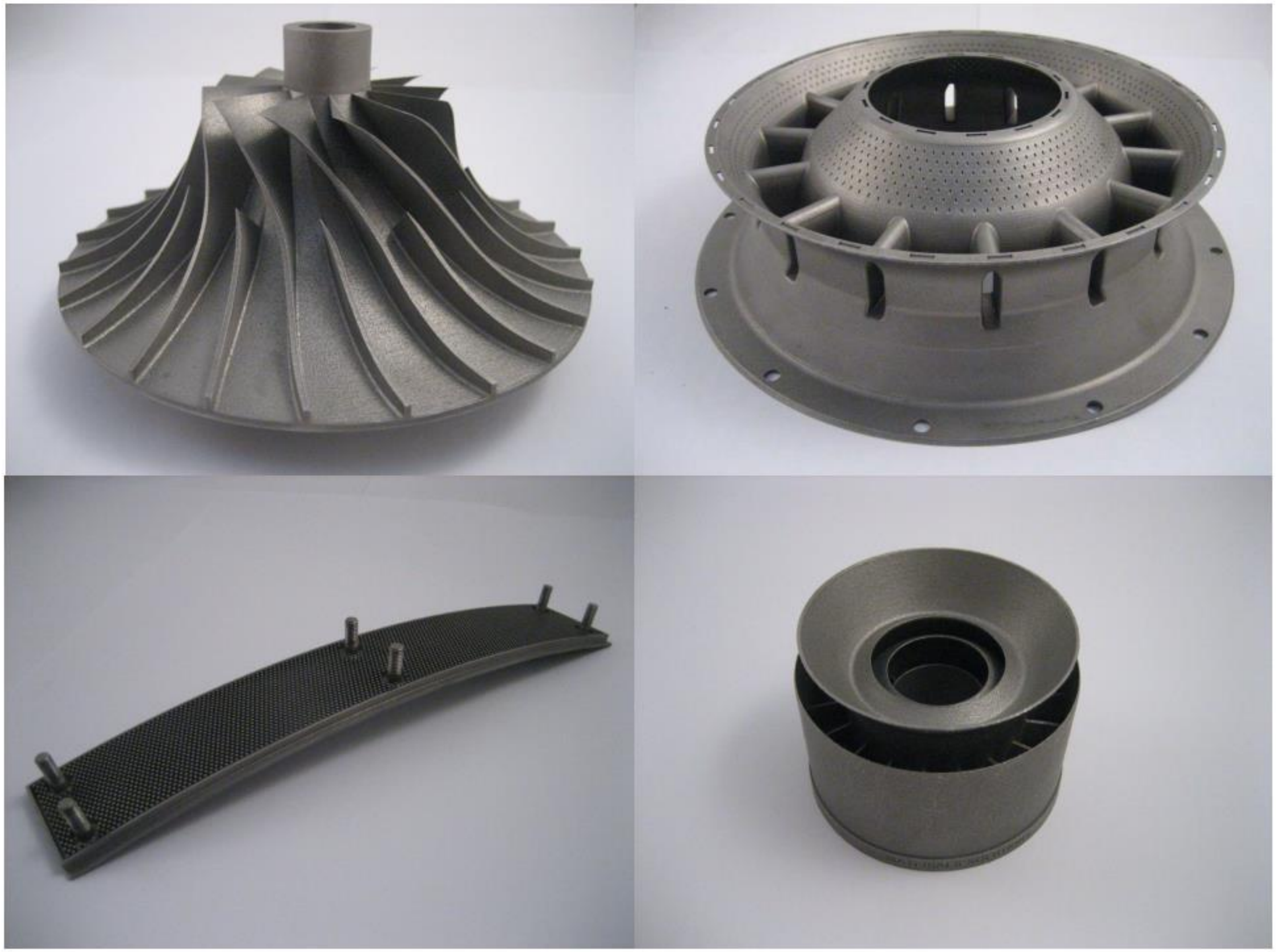
Example General Electric Aviation

- 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

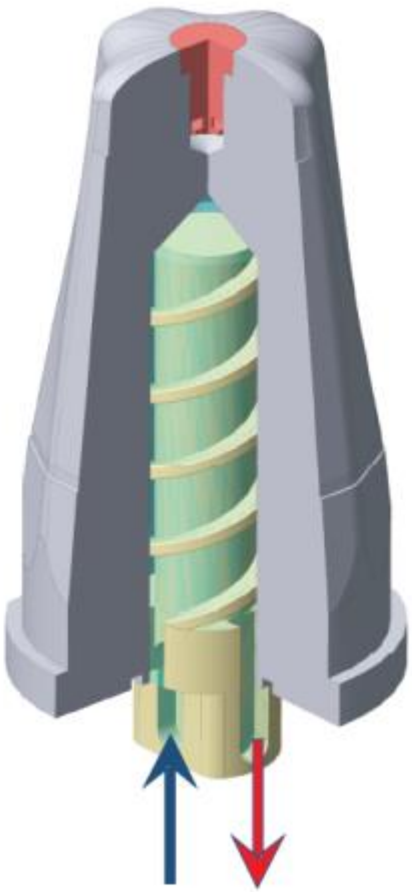
Source: Morris Technologies, General Electric

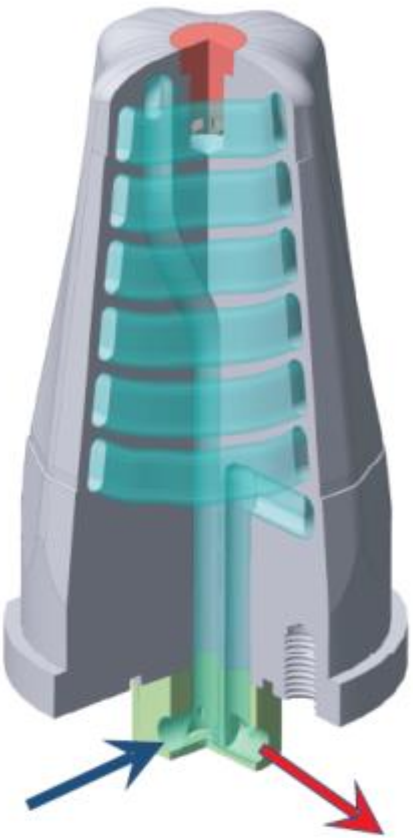
Typical Superalloy Components Manufacturer



Materials Solutions
Rapid development to meet environmental challenges

Comparison of conventional design insert with DMLS design insert





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

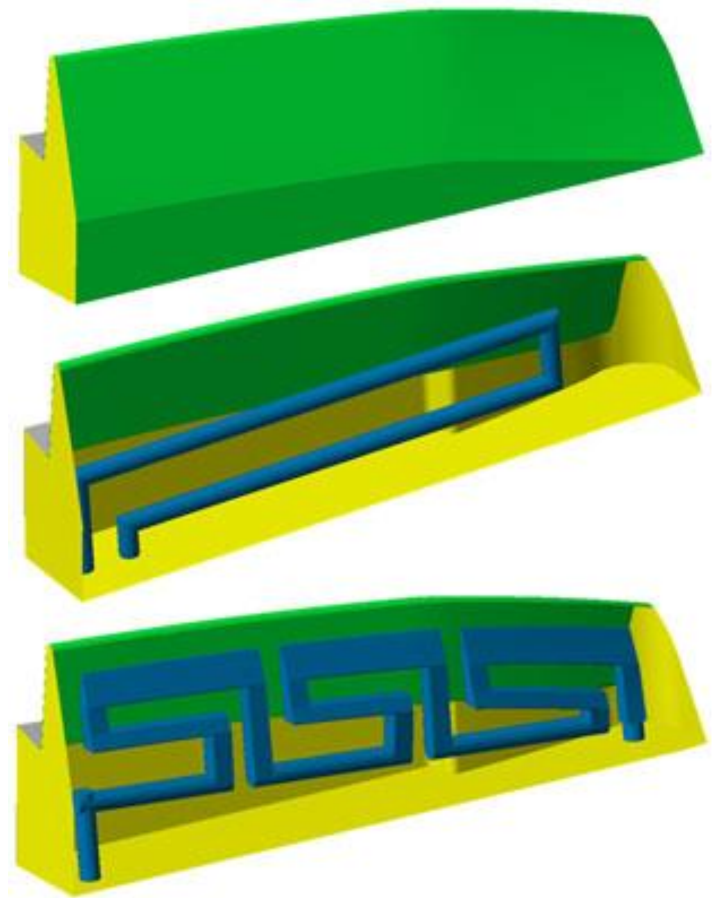
Source: BKS; Polymold; EOS

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



up: external surface; middle: conventional cooling; down: conformal cooling

Source: BBE Engineering; Prodintec

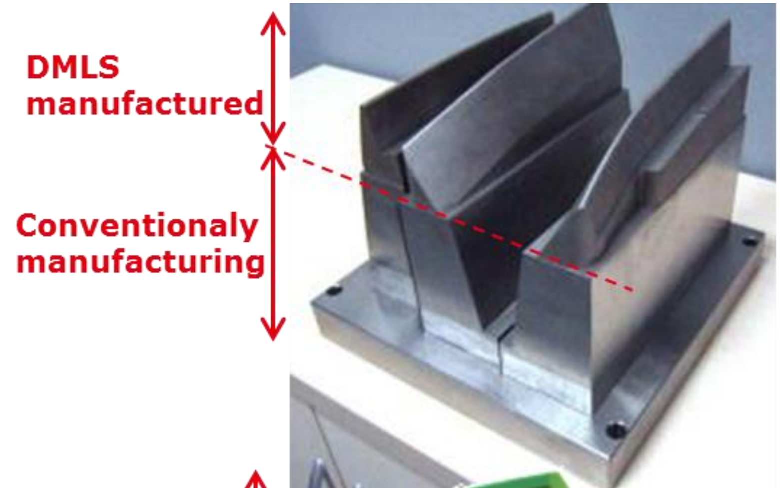
Optimized solution with hybrid design

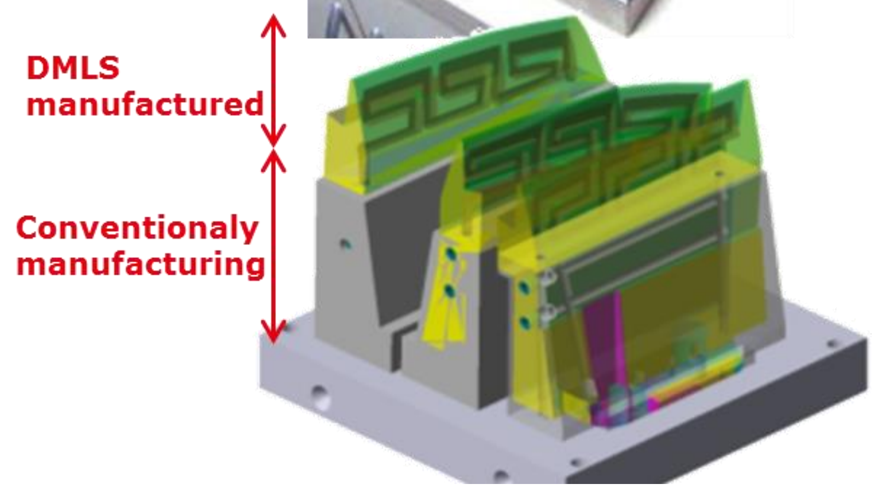
DMLS tools and hybrid design improve quality and cycle time

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

Hybrid tool design: upper part DMLS; lower part conventional





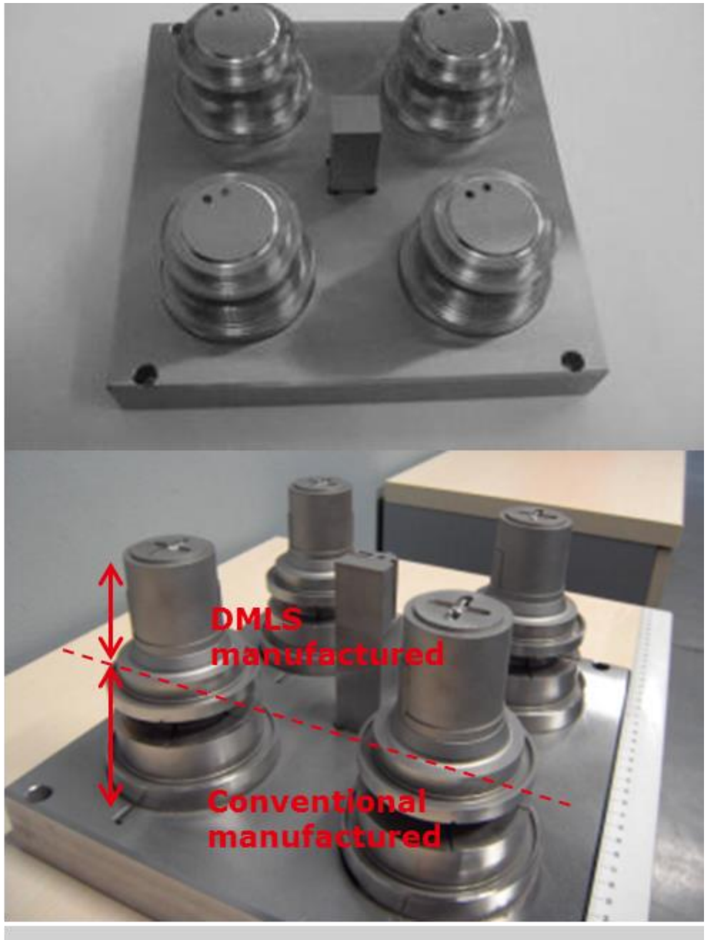
Better injection moulding process with DMLS

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 95ºC to 68ºC
- Temperature gradient from 12ºC to 4ºC
- Reduction of scrape rate: from 60% to 0%
- Improvement of productivity up to 3 parts/min

4 cavities inserts



e-Manufacturing Solutions

www.eos.info

This presentation may contain confidential and/or privileged information.
Any unauthorized copying, disclosure or distribution of the material in this document is strictly forbidden.

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

RENISHAW
apply innovation™

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**

RENISHAW
apply innovation™

Additive manufacturing

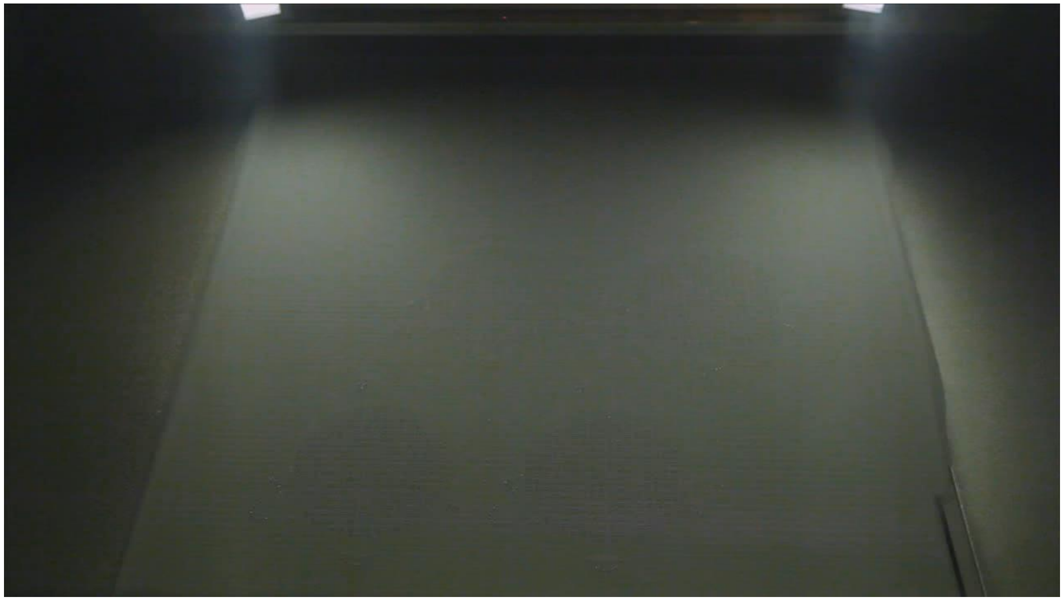
+

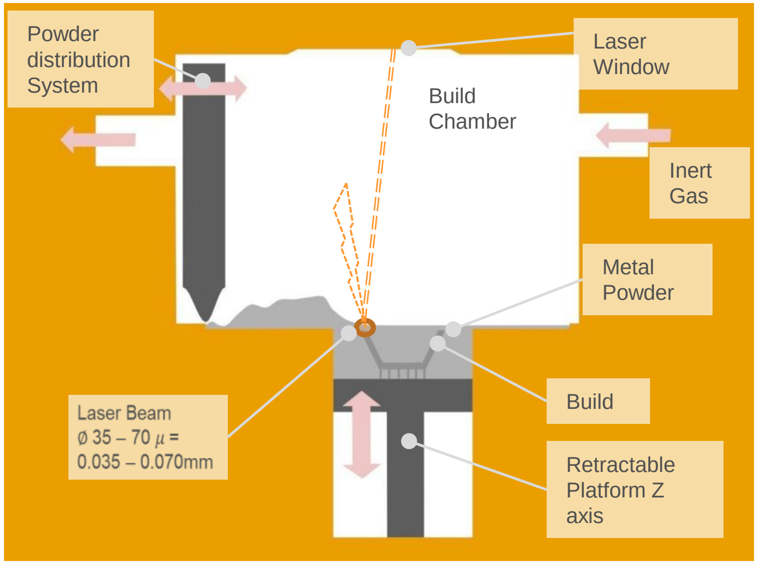
=

- 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

RENISHAW
apply innovation™

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.

RENISHAW
apply innovation™

Why AM for Renishaw?

Q. Why have Renishaw chosen to get involved in the Additive Manufacturing industry?

A. Its 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

RENISHAW
apply innovation™

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

Start

VACUUM

ARGON

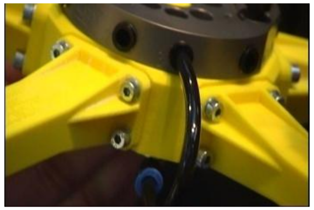
<0.1% O^2

<30 L/Hr

Market potential for AM

- Automotive
  - Passenger
  - Commercial
  - Motor sport
- Aeronautical
  - Civil aero
  - Space
- Production
  - Machine parts
  - Assembly aids
- Defence
  - Land
  - Air
  - Marine
- Medical
  - Implants
  - Bone scaffolds
  - Hearing aids
  - Dental aligners
  - Caps & bridges
  - Surgical guides
- Power & Comm’s
  - Sonar body
  - Housings
  - Fuel cells
- Consumer
  - Fashion
  - Jewellery
  - lighting
  - Furniture
  - entertainment





Suitable applications

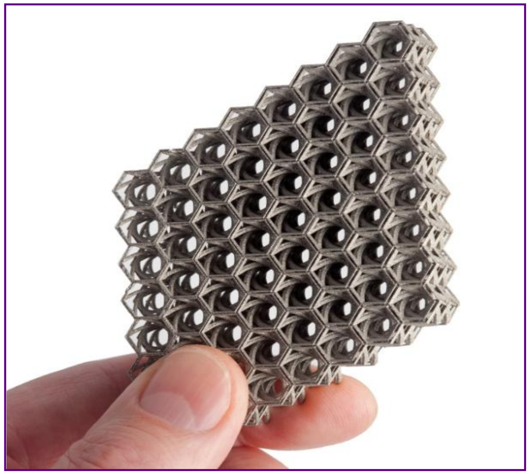
Where AM works best

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.



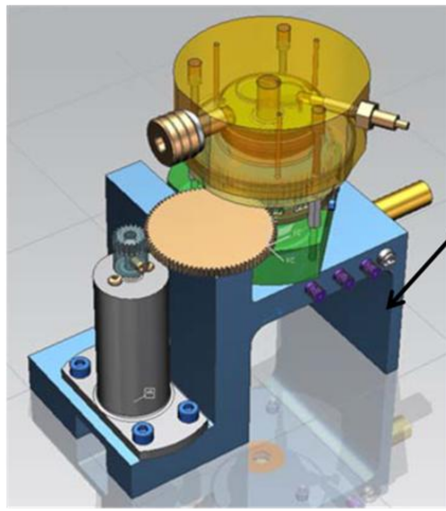
All benefit from component design that accounts for the 'design for process constraints' imposed by layer manufacture.

Design for process – key principles

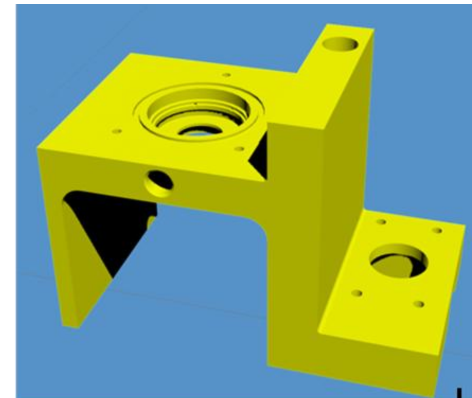
Identify & position key features

Create a structurally optimised design

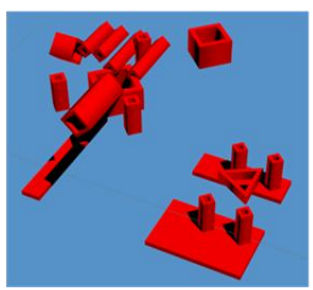
Consider part/process orientation demands



LMC0591
Agitation housing

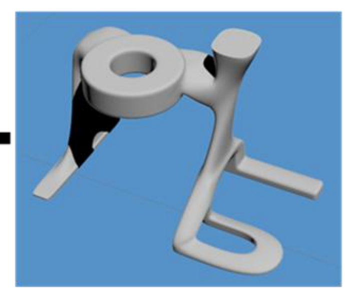


Original Design
(Design for machining)



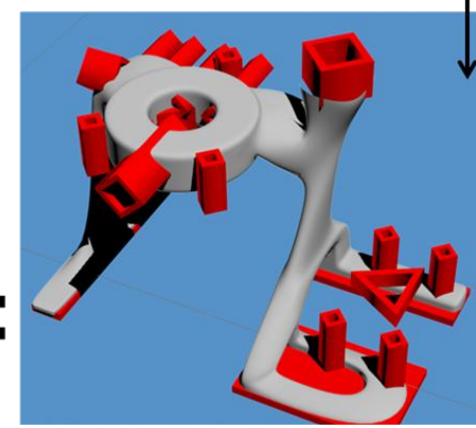
Fundamental Design
(Constraints)

+



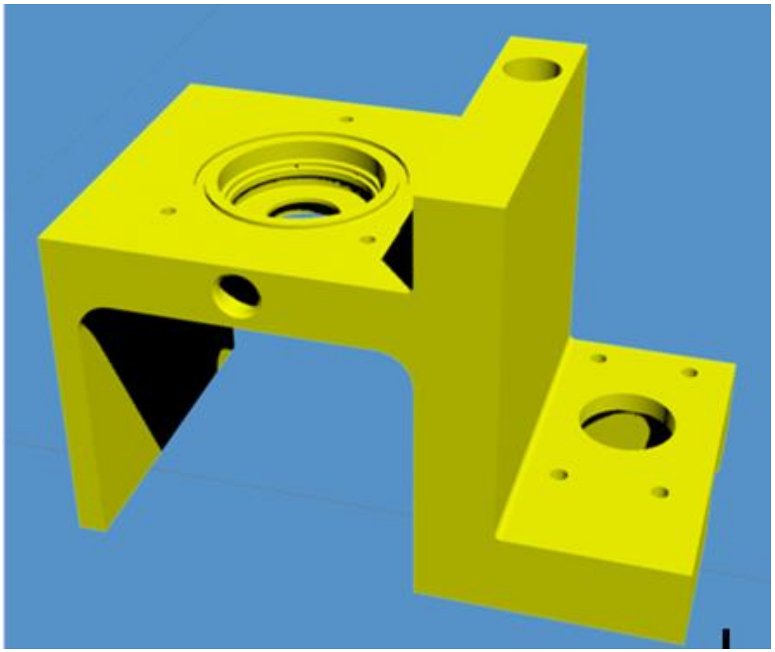
Minimised material to join Constraints

=

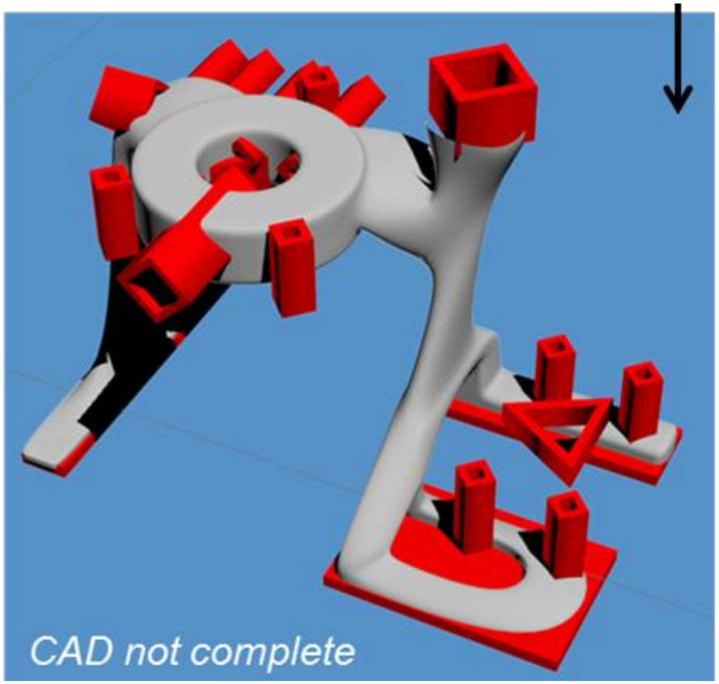


RENISHAW
apply innovation™

Design for process



Old way



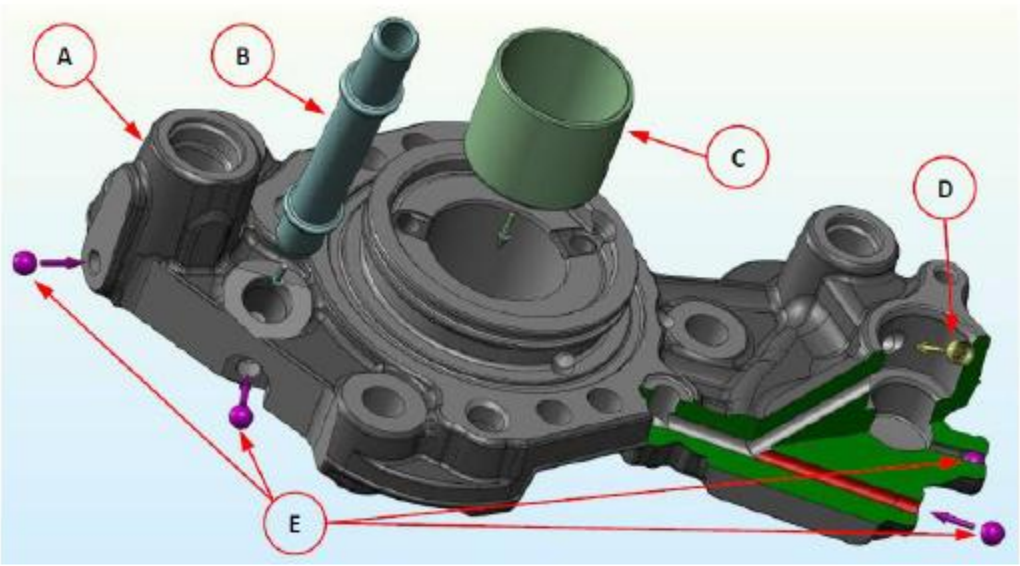
New way

RENISHAW apply innovation™

Design for process

DELPHI

Original DFP3 pump front plate part



	Item
-	*Assembly Front Plate*
A	Front Plate M/C
B	Fuel Inlet Connector (Press-fit)
C	Bearing (PTFE Coated)
D	Orifice Filter
E	Plugging Balls Ø5mm

Aim

- Weight Removal
- Part consolidation
- Reduction in manufacture and assembly time

AMRG Additive Manufacturing Research Group

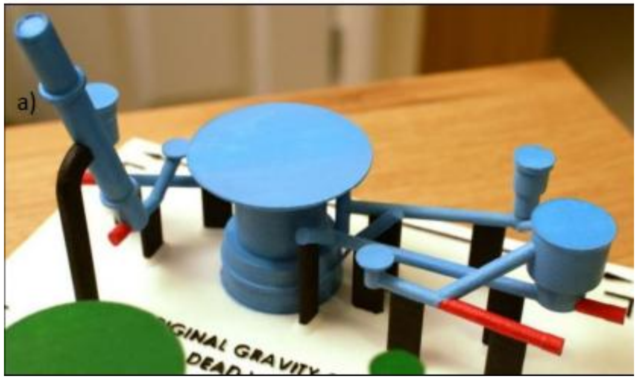
Loughborough University

Atkins Project Rapid Manufacturing A Low Carbon Footprint

RENISHAW
apply innovation™

Design for process

DELPHI



Improved flow path smoothness through CFD simulation of fuel flow velocity

a) original flow paths
b) redesigned flow paths

AMRG Additive Manufacturing Research Group

Loughborough University

Atkins Project
Rapid Manufacturing
A Low Carbon Footprint

RENISHAW
apply innovation™

Design for process

DELPHI

- 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

AMRG Additive Manufacturing Research Group

Loughborough University

Atkins Project
Rapid Manufacturing
A Low Carbon Footprint

RENISHAW
apply innovation™

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.

RENISHAW
apply innovation™

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 through out the organization are working on the AM product line in all disciplines.

RENISHAW
apply innovation™

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

HK 3D Printing Customers

ASTON MARTIN

AQUALISA

Clear Aligner™
C A Laboratories ltd.

Vent-Axia

BAE SYSTEMS

UNDERGROUND

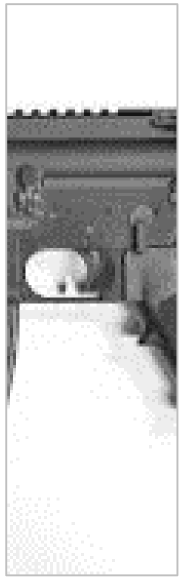
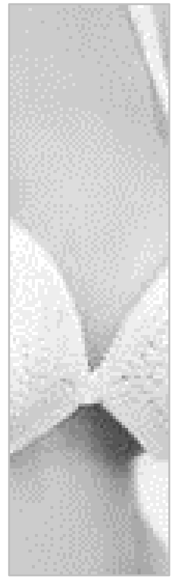
HK
3D Printing

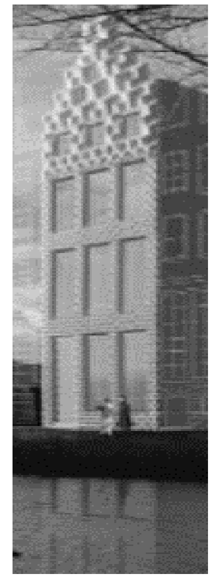
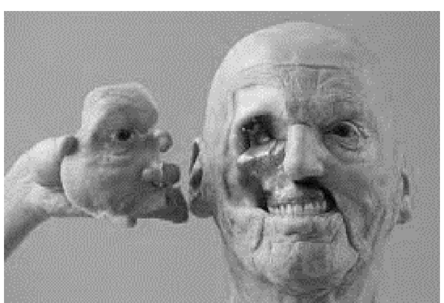
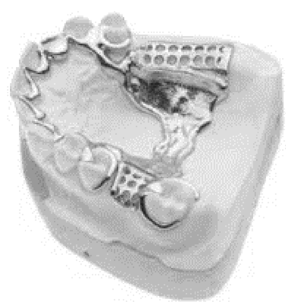
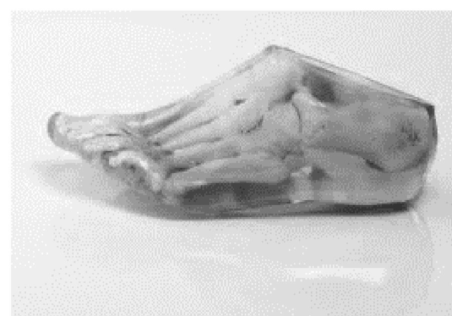
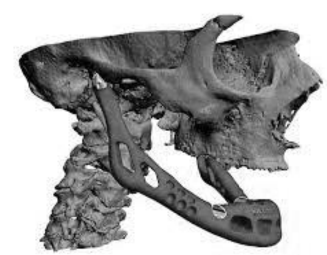
Guns

HK 3D Printing

Media Perception

HK 3D Printing

History of 3D Print

Section 1

30 years of change

1986 — 1989 — 1995 — 1998 — 2001 — 2002 — 2008

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

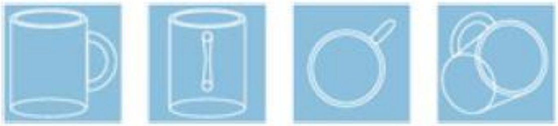
7 **MANY...**
Fused Filament Fabrication

HK 3D Printing

Technology Overview

Section 2

Printing in 3D



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

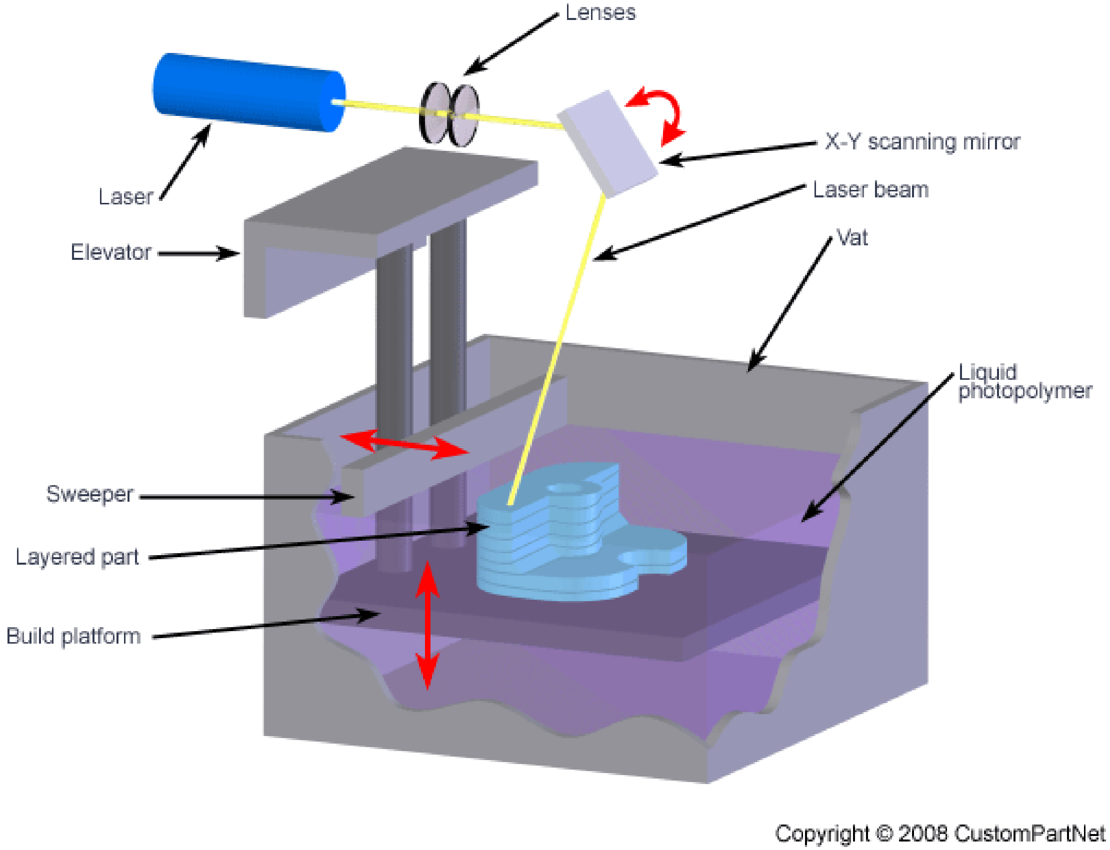
Phase 02
The 3D model is sliced into several layers - each layer represents a picture of a cross section of the 3D model. The pictures are then uploaded to the printer.

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.

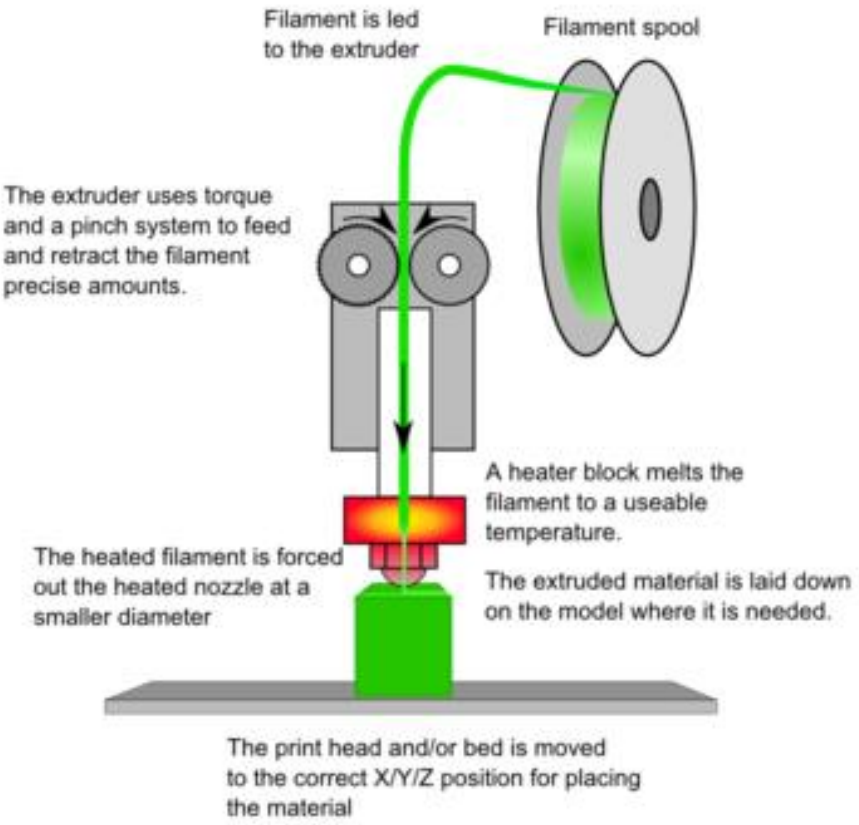
Phase 04
The 3D printer prepares new layers of plastic powder, and the thermal printhead continues to apply heat onto layers of powder. Eventually the 3D model is made in the build chamber - surrounded by unmelted powder.

HK 3D Printing

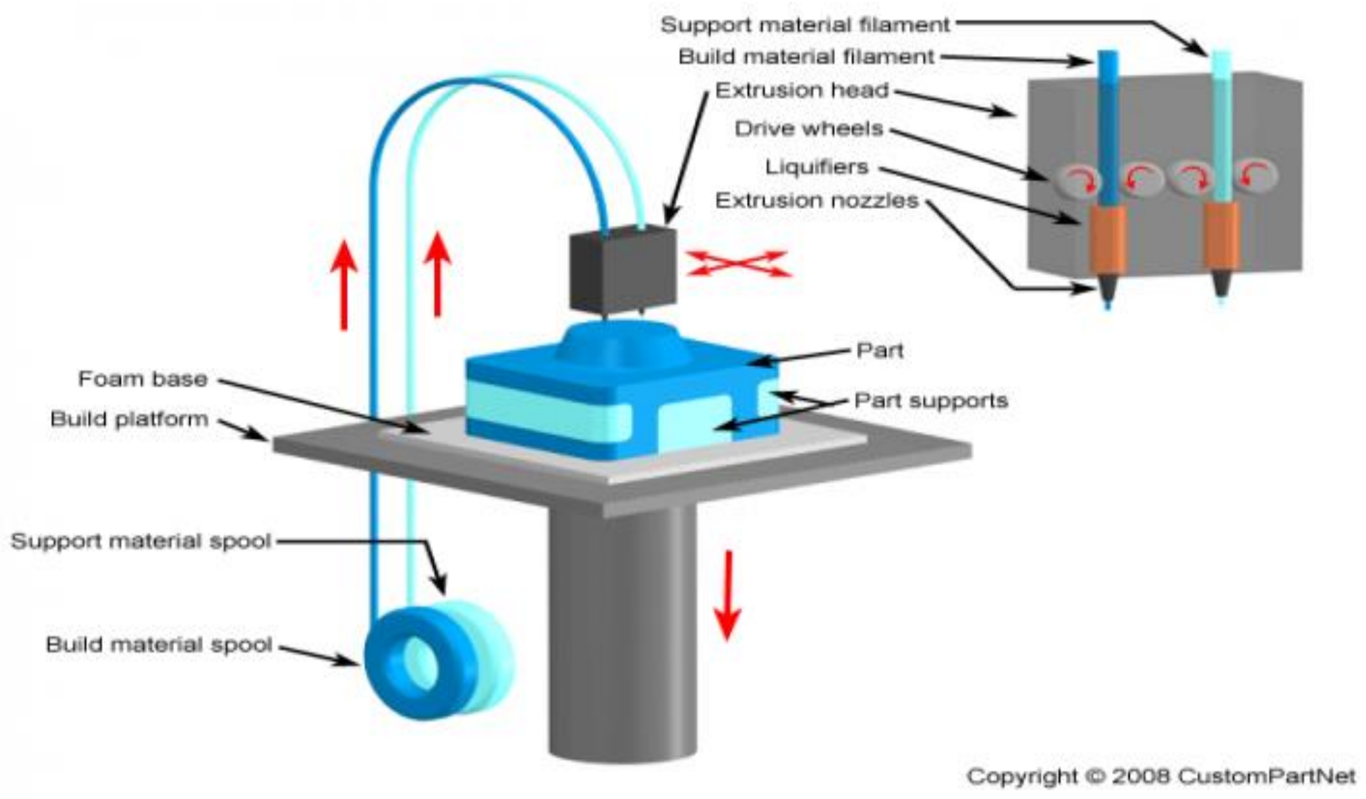
Stereolithography (SLA)



Fused Filament Fabrication (FFF)

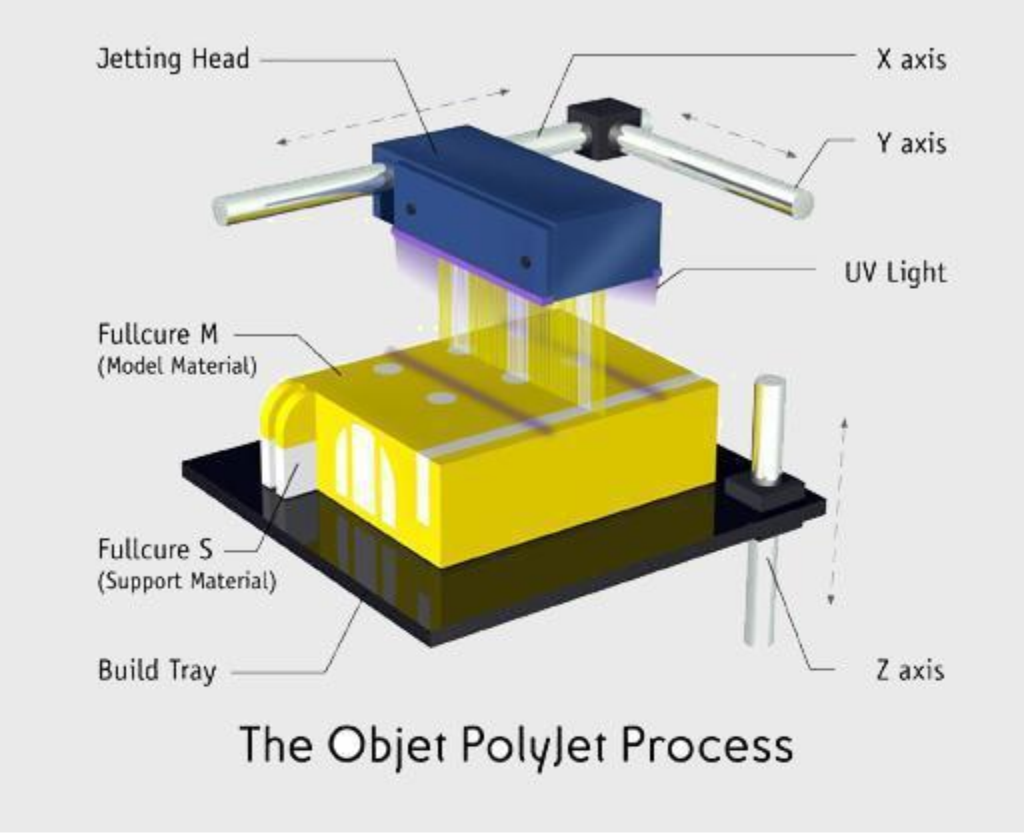


Fused Deposition Modelling (FDM)



HK 3D Printing

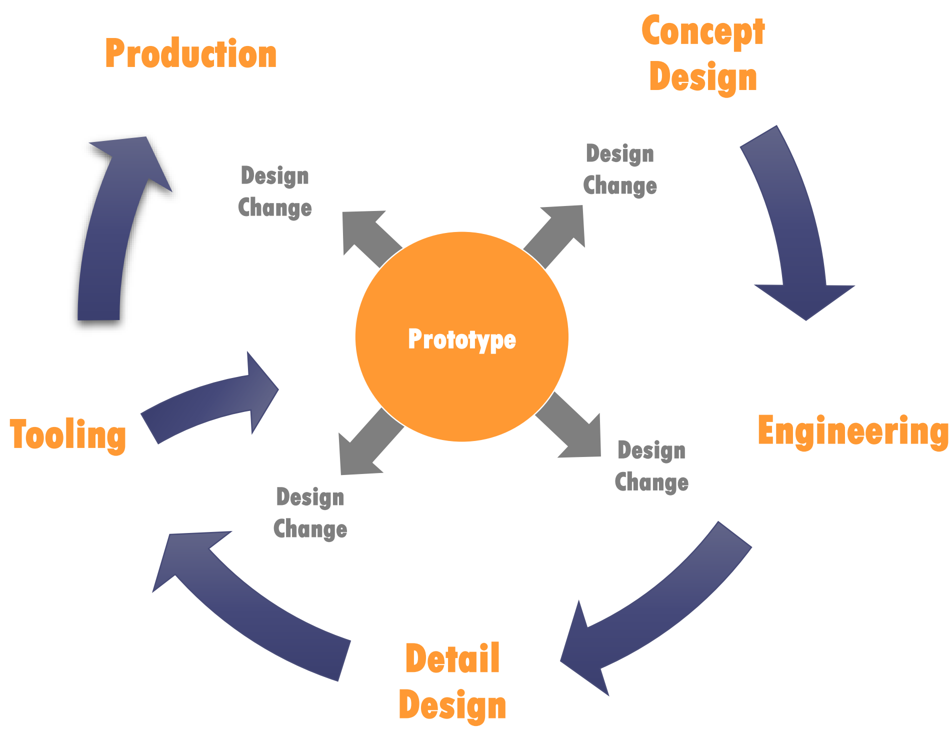
Polyjet Matrix



So can we use 3D Print

Section 3

Typical Design Cycle



Creating Product Designs

Print in 3D

- Fit and form
- Focus group
- Design validation

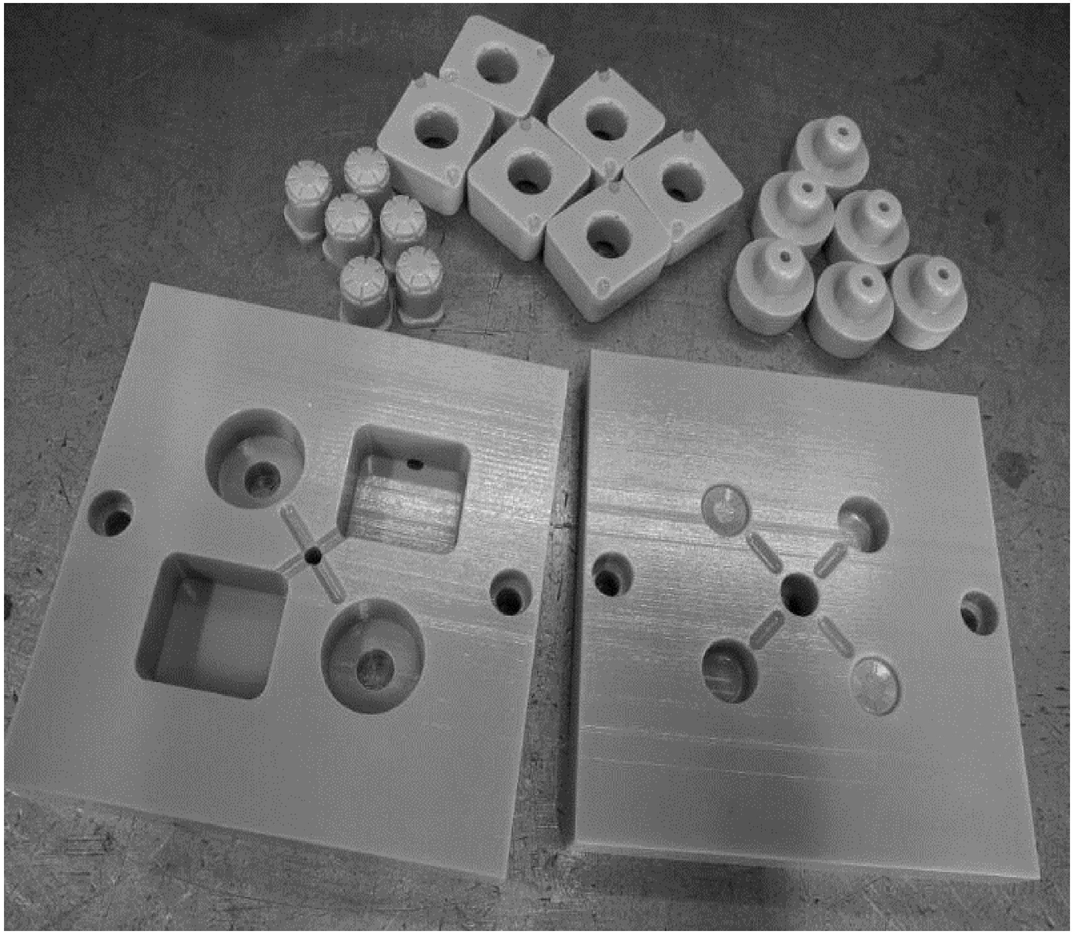
HK 3D Printing

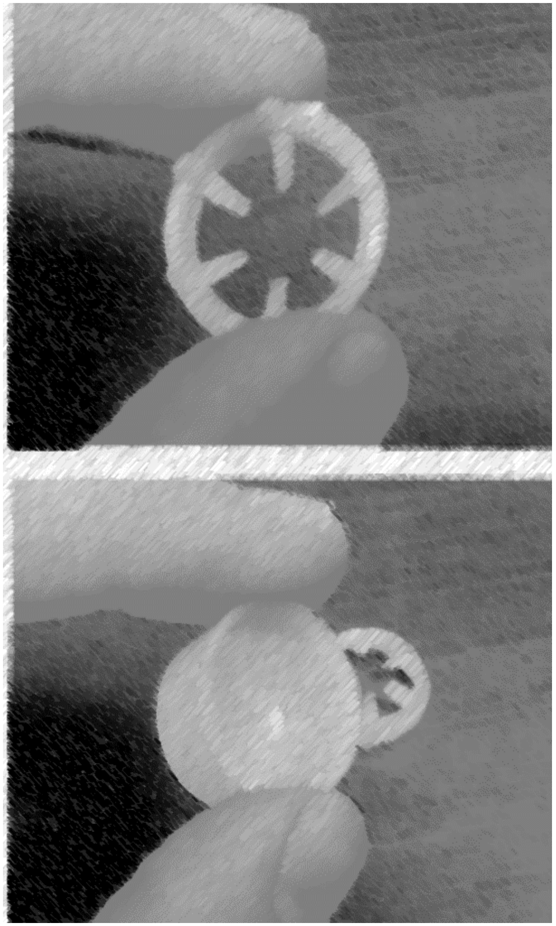
Creating Product Designs

Print in 3D

- Tool design validation
- Short run samples in actual materials

Injection Moulding

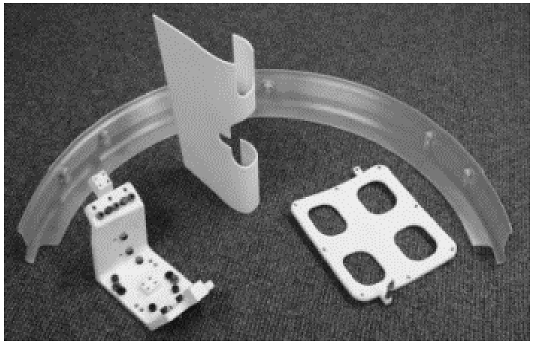
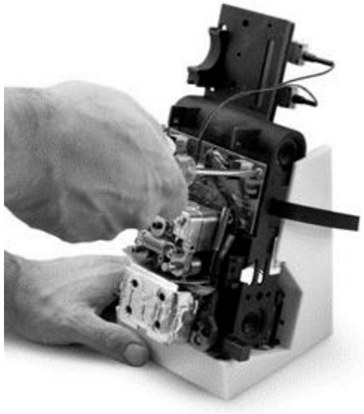
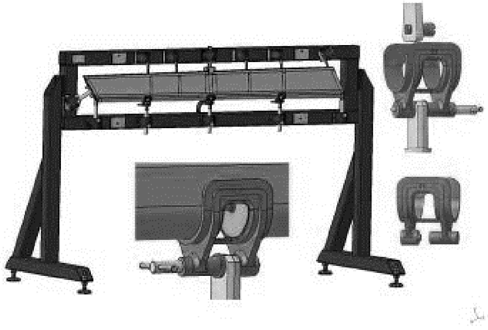




Jigs and Fixtures / Assembly Aids

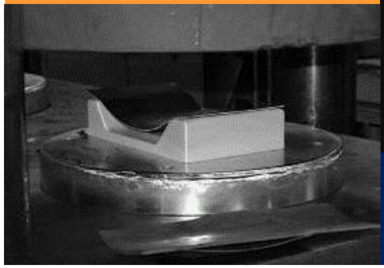
Complex Shapes Machined from CAD



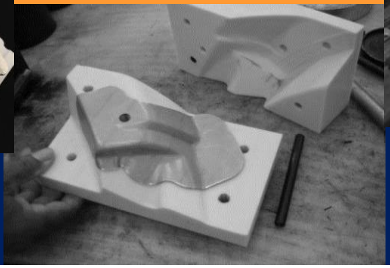
Metal Forming

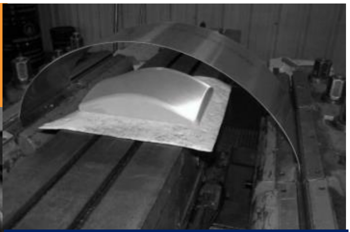
Rubber Pad Press



Hydro Forming

Stamping



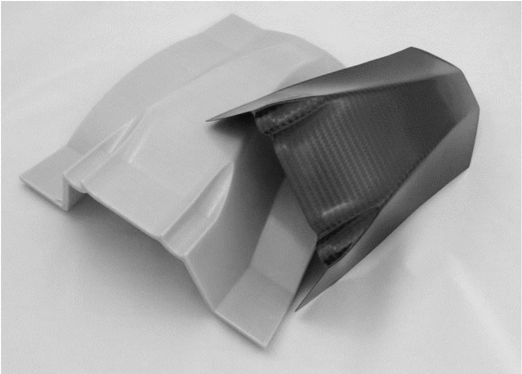


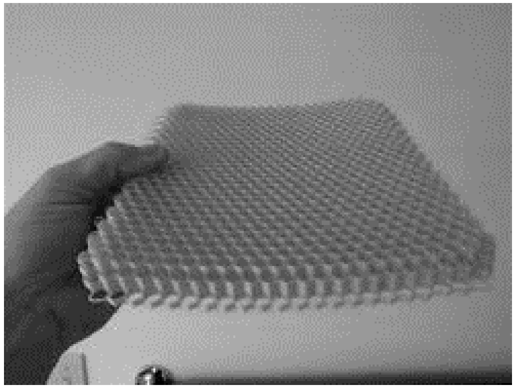
Stretch Forming

Composite Tooling

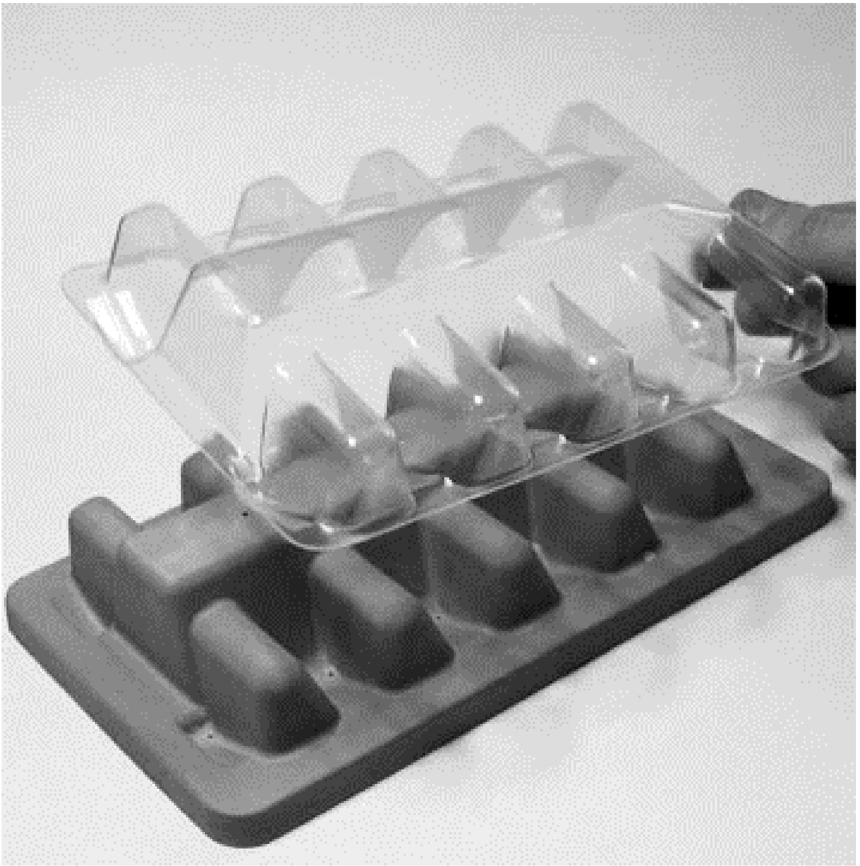
Material Limits:

ABS – 80C   ULTEM – 150C   PPSF – 175C

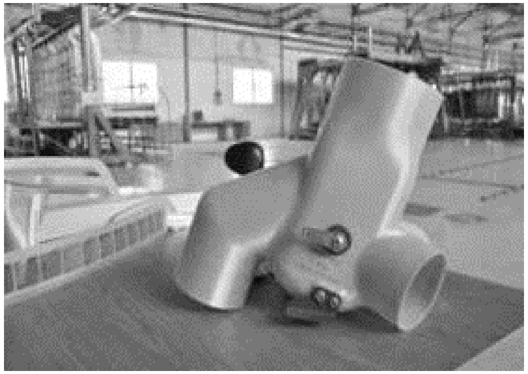


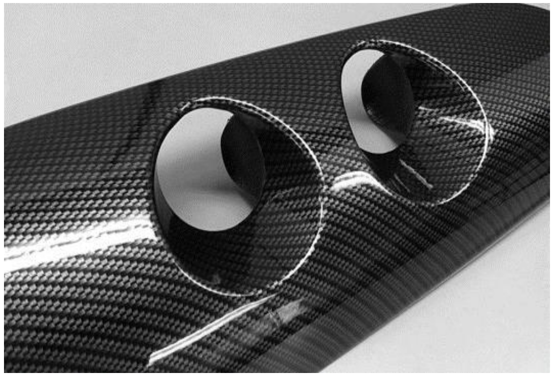


Vacuum Forming

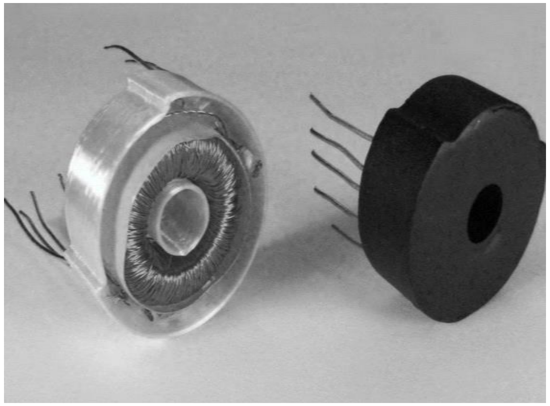


End use parts





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)**

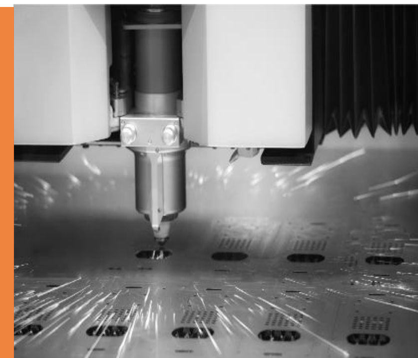
HK 3D Printing

The Pexion Group

An integral part of your success

What we do

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



Heritage

Founded in 1876.

Who we are

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

Where we work

We are a focused on providing engineering solutions globally.

The Pexion Group

HK 3D Partners

Stratasys
FOR A 3D WORLD™

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

REALIZER SLM

- Founded in 1990
- Dr. Matthias Fockele and Dr. Dieter Schwarze pioneers of RPD
- 1999 Delivered 1st 3D Metal Printer
- Introduction of multiple metals

HK 3D Printing

Any Questions?

HK 3D Printing

Stratasys

FOR A 3D WORLD™

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.

HK 3D Printing

REALIZER SLM

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.

HK 3D Printing

3M Buckley Innovation Centre

IMI Group Workshop on Additive Manufacture

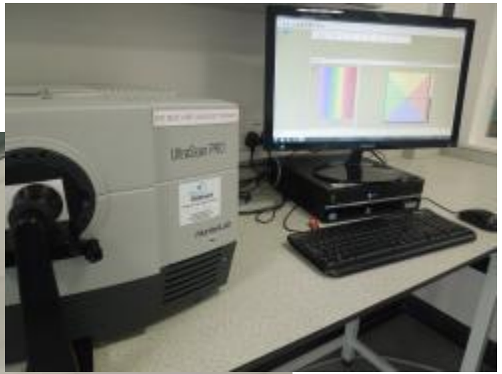
(3D Printing)

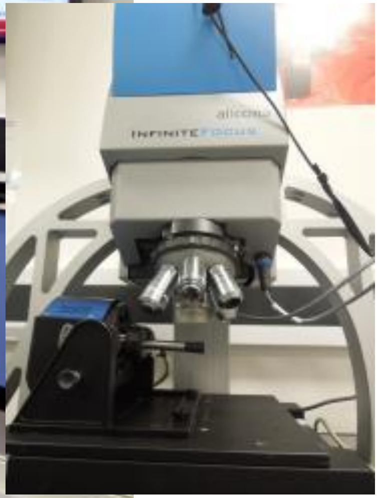
17th March 2015

EUROPEAN UNION
Investing In Your Future
European Regional Development Fund 2007-13
University of Huddersfield
Funded by Kirklees Council
3M

3M Buckley Innovation Centre, Huddersfield

Innovation Avenue





3M BUCKLEY INNOVATION CENTRE

- £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

EUROPEAN UNION
Investing In Your Future
European Regional
Development Fund 2007-13

University of HUDDERSFIELD

Funded by Kirklees COUNCIL

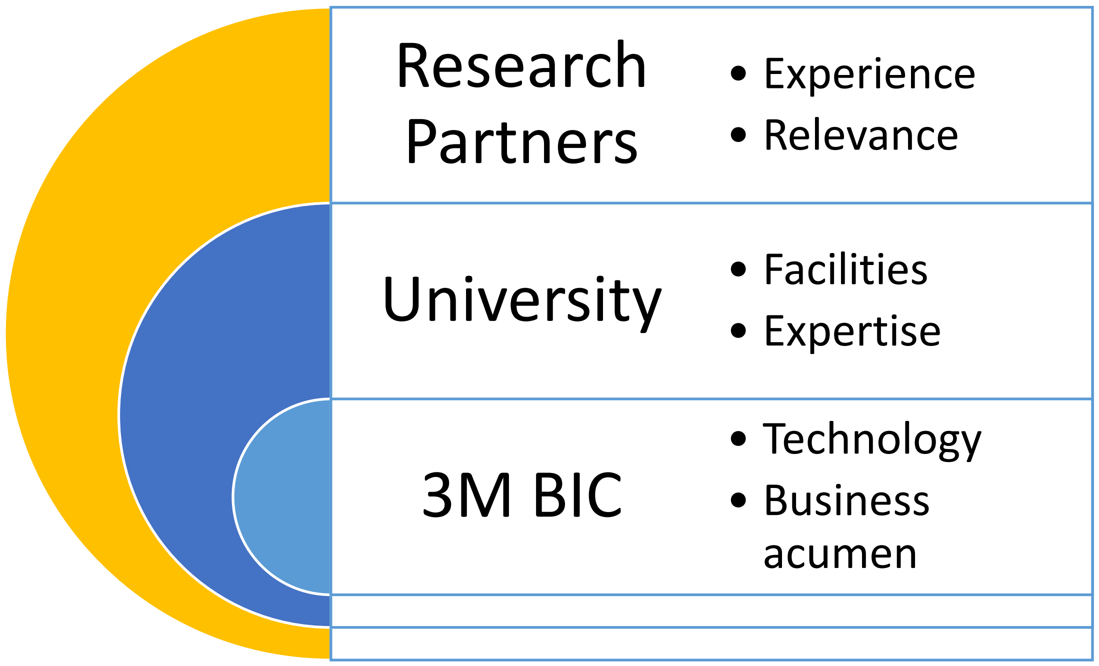
3M

3M BIC is here to:

3M BUCKLEY INNOVATION CENTRE

- 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



3M BUCKLEY INNOVATION CENTRE

FURTHER INFORMATION: WWW.3MBIC.COM/

EUROPEAN UNION
Investing In Your Future
European Regional Development Fund 2007-13

University of Huddersfield

Funded by Kirklees Council

3M

IMI Event Photographs


3D PRINTING
FUTURE: NOW
IMI Workshop
'Additive Manufacture' Workshop


Electro Optical Systems
IMI


3M BIC is here to:
3M BUCKLEY INNOVATION CENTRE


3M BUCKLEY INNOVATION CENTRE
3M Buckley Innovation Centre
IMI Group Worshop on Additive Manufacture
(3D Printing)
17th March 2015


IMI


3M
BUCKLEY
INNOVATION
CENTRE
IMI
NORGREN