CAN 3D PRINTING CHANGE YOUR BUSINESS?

Organised by the Calderdale and Kirklees Manufacturing Alliance

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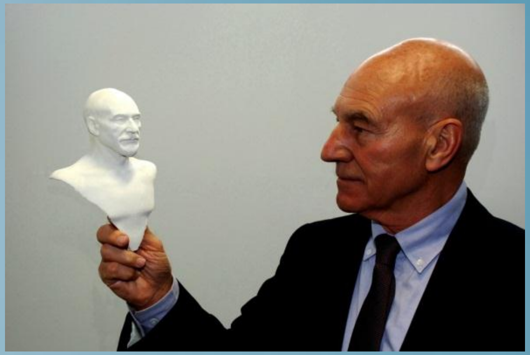
Product Design / MA 3D Digital Design
University of Huddersfield

Location : 3M BIC
Date : 11th April
Time : 5.30 – 8pm

This presentation is given to businesses / *companies* with an interest in 3D Printing and Additive *Manufacturing in West Yorkshire, UK*

WHAT IS 3D PRINTING / ADDITIVE MANUFACTURING?



- **Additive manufacturing or 3D printing is a process of making a three-dimensional (3D) objects from a CAD model.**
- **3D printing is an additive process,** where layers of material are laid down. 3D printing **differs from traditional machining techniques, which generally rely on the removal of material** by methods such as machining, cutting, drilling etc.
- **The technology is currently used for both prototyping and manufacturing** in:

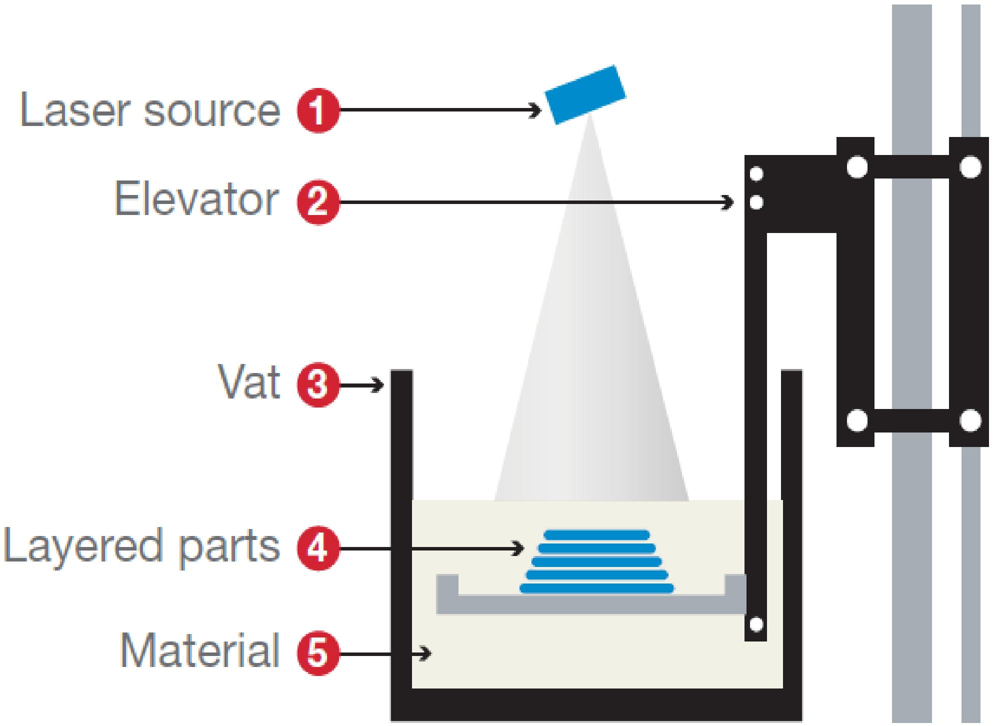
Jewellery, footwear, industrial design, architecture, engineering, automotive, aerospace, dental and medical industries, education, geographic information systems, and many other field.

Currently being used / researched to built titanium aircraft parts, human bones, complex, nano-scale machines.

HOW DOES IT WORK?

HOW 3D PRINTING WORKS

3D printers work like inkjet printers. Instead of ink, 3D printers deposit the desired material in successive layers to create a physical object from a digital file.



1 A laser source sends a laser beam to solidify the material.

2 The elevator raises and lowers the platform to help lay the layers.

3 The vat contains the material used to create the 3D object.

4 The 3D object is created as parts are layered on top of each other.

5 Advanced 3D printers use one or more materials, including plastic, resin, titanium, polymers and even gold and silver.

Source: http://individual.troweprice.com/staticFiles/Retail/Shared/PDFs/3D_Printing_Infographic_FINAL.pdf

WHAT ARE THE 3D PRINTING METHODS?

Type	Technologies	Materials
Extrusion	Fused deposition modeling (FDM)	Thermoplastics (e.g. PLA, ABS),HDPE , eutectic metals, edible materials
Granular (Powder based)	Direct metal laser sintering (DMLS)	Almost any metal alloy
	Electron beam melting (EBM)	Titanium alloys
	Selective heat sintering (SHS)	Thermoplastic powder
	Selective laser sintering (SLS)	Thermoplastics, metal powders, ceramic powders
	Powder bed and inkjet head 3d printing, Plaster-based 3D printing (PP)	Plaster
Light polymerised	Stereolithography (SLA) or Digital Light Processing (DLP)	photopolymer
Laminated	Laminated object manufacturing (LOM)	Paper, metal foil, plastic film
Wire	Electron Beam Freeform Fabrication	Almost any metal alloy

WHY IS 3D PRINTING DIFFERENT?

New:

1984

THE BIRTH OF 3D PRINTING

Charles Hull, later the co-founder of 3D Systems, invents stereolithography, a printing process that enables a tangible 3D object to be created from digital data. The technology is used to create a 3D model from a picture and allows users to test a design before investing in a larger manufacturing program.

First Macintosh Computer is released with 128k RAM in the same year

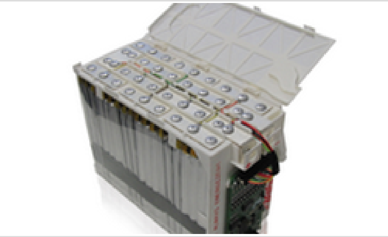
Has the following advantages:

- **Creates parts quickly**
- **Enables customisations & personalised items,** digital object storage
- **Faster design cycle** with greater accuracy
- Rapid Prototyping **helps to identify design errors earlier** and cuts traditional prototyping and tooling costs
- Enables low **volume manufacturing, local manufacturing**
- **Enables the production of shapes impossible to manufacture** with other methods
- Shape **optimisation for weight, strength** resulting in reduced material and energy usage

Source / Further Info: http://individual.troweprice.com/staticFiles/Retail/Shared/PDFs/3D_Printing_Infographic_FINAL.pdf

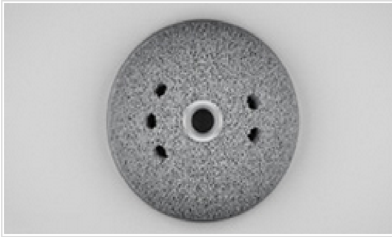
WHY IS 3D PRINTING DIFFERENT?

The Challenge of Lightweight Construction



Additive Manufacturing enables the construction of highly stable lightweight structures that cannot be produced using conventional production processes. ❯

The Challenge of Complex Geometries

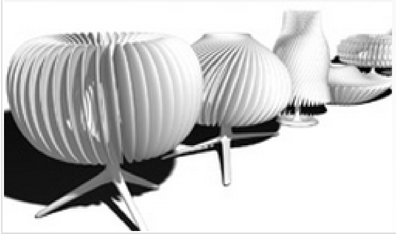


Additive Manufacturing makes design-driven production a reality. Innovative EOS technology offers the greatest possible freedom and enables complex structures. ❯

The Challenge of Functional Integration

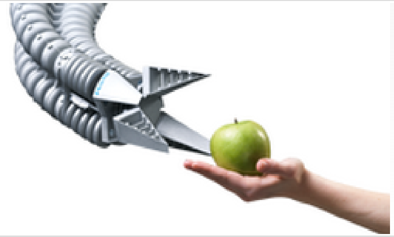
Fewer assembly components, less logistical effort and greater flexibility: Additive Manufacturing technology makes it possible to integrate functions in parts. ❯

The Challenge of Customised Products



Tool-less production with Additive Manufacturing technology permits customised, batch-size-appropriate serial production. ❯

The Challenge of Bionic Structures



Conventional production processes are pushed to their absolute limits with bionic structures. Additive Manufacturing offers maximum construction freedom. ❯

P3 uses EOSINT M system to produce a bionic bracket that is 40% lighter than the original

e-Manufacturing Solutions

Aerospace

Original milled and new designed bracket manufactured on EOSINT M system

Light-weight bracket

Requirements
- Reduce weight by keeping product requirements for use in aerospace industry

Solution
- Innovatively designed bionic bracket
- Manufactured on EOSINT M system using aluminum material

Result
- Weight reduction by 40% (23g)
- Concave bionic bracket weights only 33g (original bracket weights 56g)
- Built full automatically in one piece
- Integrated thread and thus reduction of assembly parts

Source: EOS GmbH, P3

Source: http://www.eos.info/en

Lightweight components, complex geometries , fewer assemblies, customised products, (Bracket 40% lighter)

WHAT 3D PRINTING SYSTEMS ARE AVAILABLE?

Personalised : Small size, relatively cheap, limited material options and thickness,

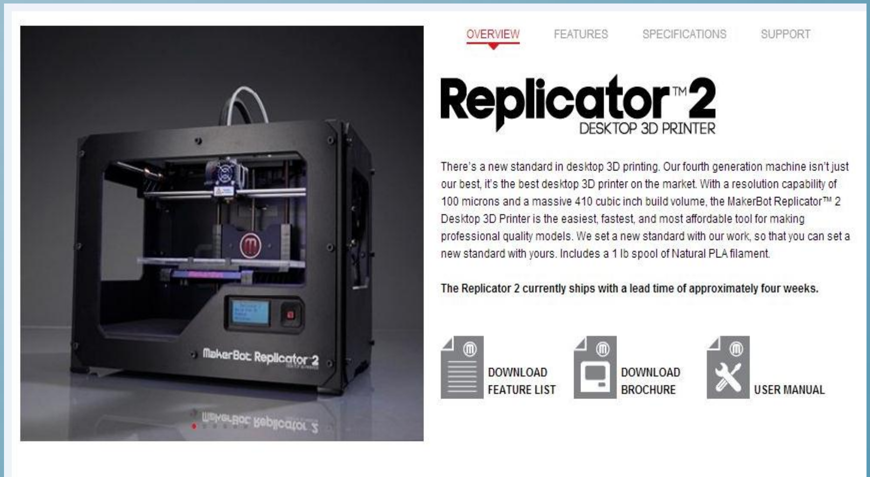
Commercial : **Better surface finish**, increased material options, larger part sizes, **improved tolerances** but expensive

Research : Synthetic **cells, tissues**, high speed **micro machines,**

Personalised systems include:

3D systems Cube:

Makerbot Replicator:

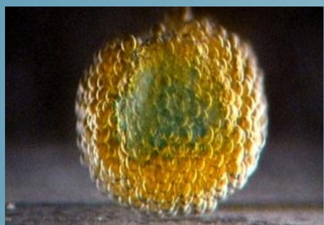
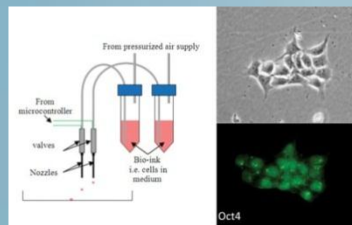


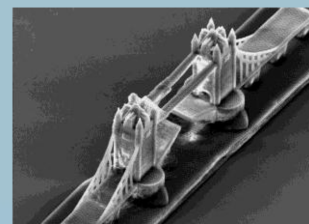
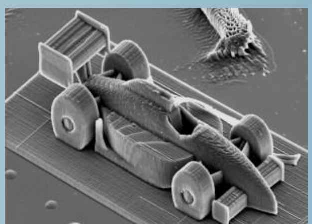
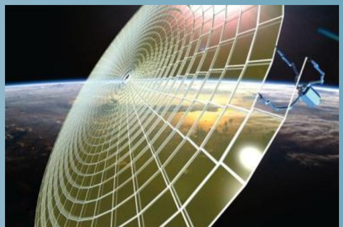
Personal 3D Printing list: http://www.engadget.com/2013/01/29/3d-printer-guide/

VIDEO: (5min) 3D Printshow London 2012: https://www.youtube.com/watch?v=S-E6vRfnijw

WHAT 3D PRINTING SYSTEMS ARE AVAILABLE?

Research : Synthetic **cells and tissues, high speed micro machines,**

In recent years, the use of a 3D printing technology for cell printing has triggered tremendous interest and there are some exciting demonstrations of printing 3D structures such **as artery and kidney**. Scottish scientists have figured out how to use 3D printer to create the world's first artificial **liver tissue** made from **human cells**. *Schematic drawing of the cell printer system*, credit: Will Wenmiao Shu, Ph.D., Jason King, Ph.D.

Scientists at the **Vienna Institute of Technology** have demonstrated a polymer and laser etching technique that promises to dramatically speed up the printing of tiny 3D objects as seen. Tower Bridge: **the towers are a mere 90µm** apart and **micro model** of a **285µm (0.3mm) Formula 1 car**.

Spiderfab is a new concept introduced by **NASA** and Tethers that could **change the way that space craft are buil**t in the near future. They propose to build **large structures in space rather .**

The MicroGravity Foundry **is the first 3D printer** that creates high-density, **high-strength metal components even in zero gravity**, company co-founder and MicroGravity.

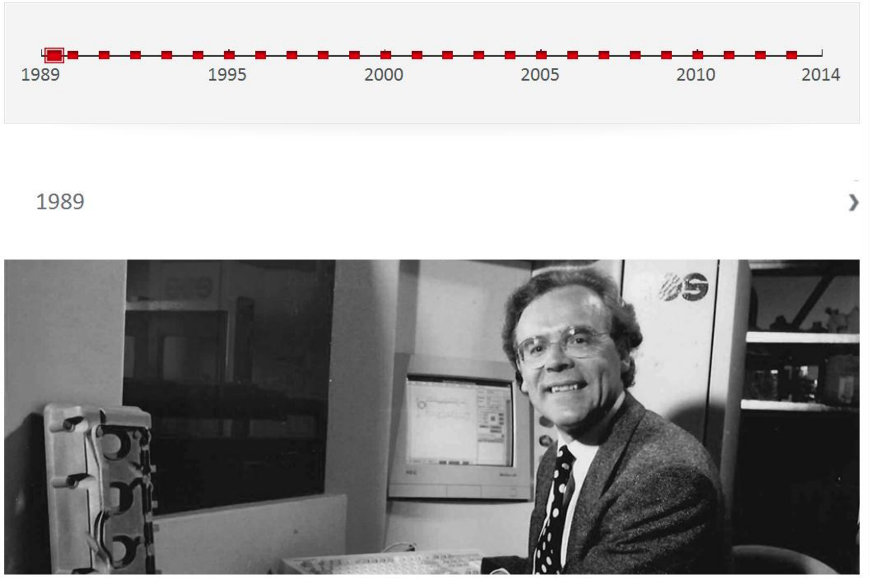
Video: (1:43 hour) Deep Space Industries Live Announcement. **To mine asteroids**' using MicroGravity Foundry 3D printer
See http://www.youtube.com/watch?feature=player_embedded&v=ht1_VIw6C98

NASA tests 3D printers: http://www.dailymail.co.uk/sciencetech/article-2177626/Made-space-Nasa-tests-3D-printers-let-Mars-bound-astronauts-craft-equipment-travel.ht

WHAT 3D PRINTING SYSTEMS ARE AVAILABLE?

Commercial systems include:

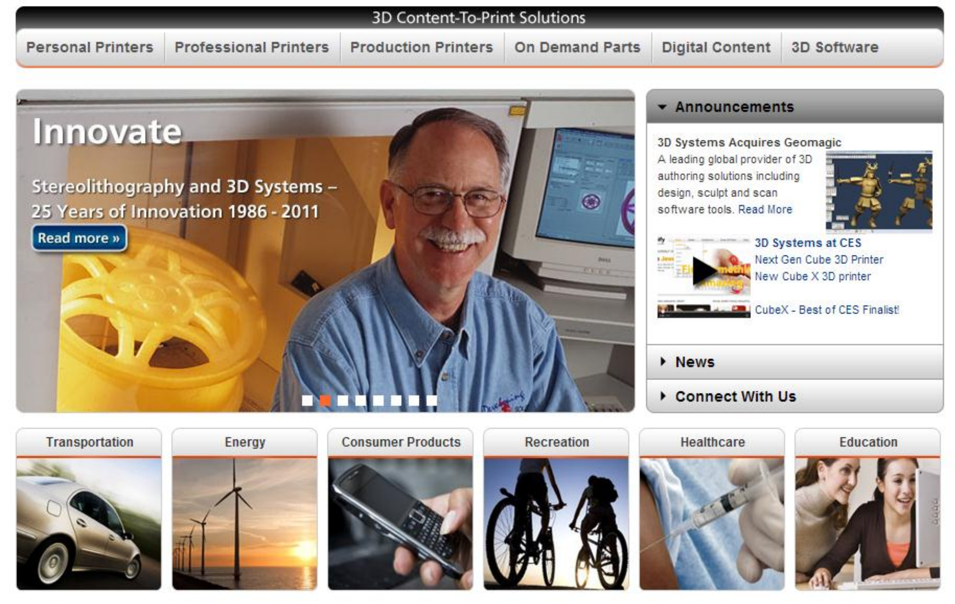
EOS:



EOS founder Dr Hans Langer

Source: http://www.eos.info/en

3D Systems:



Source: http://www.3dsystems.com/

Please note: **there are many other 3D printing companies available**, only these companies are included as we have their machines installed

EOS 3D PRINTERS

Plastic Additive Manufacturing (AM) using Selective Laser Sintering

Plastic Additive Manufacturing (AM) - also **referred to as 3D Printing** - produces parts suitable for both **prototyping and production applications using Selective Laser Sintering.** The process generates accurate models and **one-off prototype parts for design approval**, trial and testing purposes, through to **production components** to be used in true working environments.

The data is sliced into layers, loaded onto the AM machine and a computer-directed CO_2 **heat laser fuses, or sinters, layers of Nylon powder together. After each solidified layer, another layer of powder is deposited and again sintered until the part is complete.**

Once the build chamber has cooled, the component is removed with any 'unsintered' or loose material being recycled for future use, making it an economical and environmentally friendly process. Plastic AM can be used across a vast number of industry sectors.

Future Factories Research Project: http://www.futurefactories.com, Product Design at Huddersfield http://www.huddersfield3d.co.uk/

Plastic Additive Manufacturing (AM) using Selective Laser Sintering

Plastic Materials:

Generally Parts are produced in Nylon 12 and Glass-Filled Nylon 12 which provide good long term stability, strength and durability required for form, fit and functional testing

Other plastic materials includes:

Alumide® - Polyamide aluminium-filled
CarbonMide® - Polyamide carbon fibre-reinforced
PA 2200 / 2201
PrimePart PLUS (PA 2221)
PA 2202 black – Parts with continuous colouring
PA 2210 FR - Flame-retarding Polyamide
PA 3200 GF - Glass bead filled polyamide
EOS PEEK HP3 - Polyaryletherketone
PrimeCast® 101 – Polystyrene

Air ducts for laminar flow, Material: PA 2200 (Source: EOS)

Source / See for details: http://www.eos.info/systems_solutions/plastic/materials_material_management

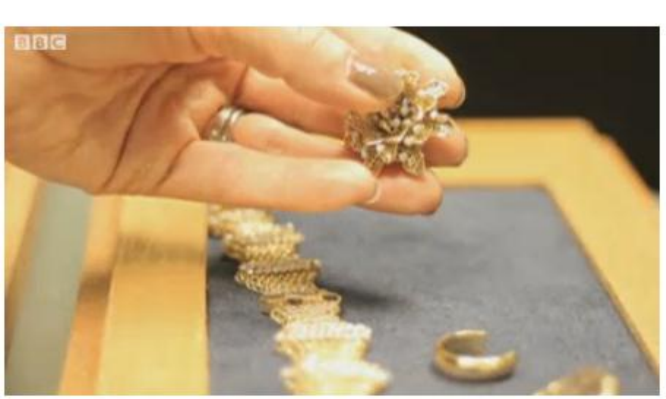
EOS 3D PRINTERS : MATERIALS

There are a number of 3D Printing bureaus available in UK. As an example I-materialise offers the following materials (Not all for EOS): http://i.materialise.com/materials

Polyamide : A strong and flexible material with a high level of detail
Alumide : A polyamide-like material with a distinctive look
Multicolor : A full color plaster
High detail resin: Lovely fine details on this photopolymer
Paintable resin : Beautiful when painted. Water resistant. If it has to be flawless
Transparent resin : See through
ABS : Strong and tough with the highest level of dimensional accuracy
Titanium : Light and the strongest 3D printing material in the world
Stainless steel: Not your grandmother's stainless steel
Silver : Sterling silver
Gold : 14 carat solid gold
Prime grey : Very smooth, detailed and "luxurious" to the touch
Brass : Copper and Zinc, united as one
Bronze
Ceramics : A food safe material that shines
Stainless steel : High grade stainless steel with detail

Lightweight seat belt buckles, Material: EOS Titanium Ti64 (Source: 3T RPD Ltd/The SAVING Project (www.manufacturingthefuture.co.uk))

Source: http://www.eos.info/aerospace



Source: http://www.bbc.co.uk/news/technology-21754924

Source: http://www.youtube.com/watch?v=iNpbLRrdJxQ

EOS 3D PRINTERS Direct Metal Laser Sintering (DMLS)

Additive Manufacturing | Systems & Solutions | Industries & Markets

Prototypes, standard production parts and spare parts – innovative e-Manufacturing technology is ideally suited to the production of individualised products with highly complex shapes, such as those used in bionics.

e-Manufacturing enables the production of extremely complex structures unattainable using conventional manufacturing methods. The bionics field in particular benefits greatly from Additive Manufacturing.
Prototypes, standard production parts and spare parts – EOS offers different ways to manufacture parts directly or via laser-sintered tools, moulds and dies.

Aerospace

Using innovative, toolless laser sintering, e-Manufacturing enables cost-effective production of lightweight high-tech components, even with small batch sizes.

Automotive

Additive Manufacturing provides automobile manufacturers with the basis for low-cost rapid prototyping and individualised serial production of high-end parts.

Industry

EOS laser sintering technology simplifies the production and delivery to schedule of small series productions and special-purpose parts.

Lifestyle Products

Create designs free of restrictions - EOS laser sintering technology opens up a whole new universe of serial production possibilities for designers and design engineers.

Medical

EOS delivers tailor-made solutions for Additive Manufacturing of medical products. Manufacturers benefit from increased flexibility and cost-effectiveness.

Tooling

EOS e-Manufacturing technology offers the greatest possible freedom in terms of design and construction. Highly productive tools reduce scrap rate and cost per part.

Rapid Prototyping

Additive Manufacturing developed by EOS based on laser sintering technology is ideally suited for Rapid Prototyping (RP).

Video: 1:13 min http://www.youtube.com/watch?v=zApmGFDA6ow
3d printing with metal, titanium & aluminium demo by EOS

Show: (0:0 - 1:04)

EOS 3D PRINTERS
Direct Metal Laser Sintering (DMLS)

Function integration for fuel systems

e-Manufacturing Solutions

Aerospace

Fuel Injector & Swirler

Challenge
- Improve fuel efficiency of jet engines
- Optimize airflow and fuel swirling
- Cooling with integrated fuel channels

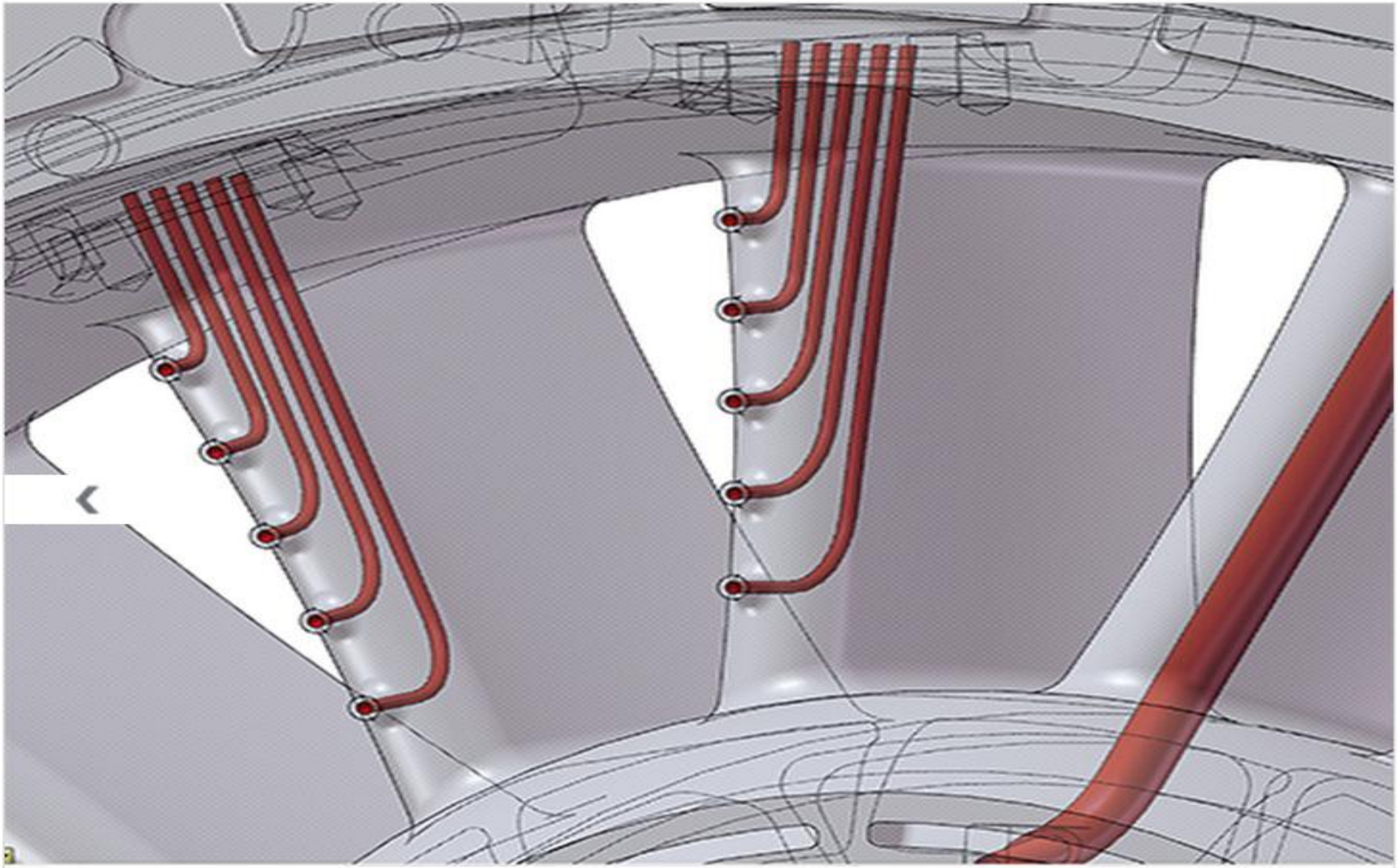
Solution
- Laser sintered on EOS M system
- Material: EOS CobaltChrome MP1

Benefits
- Highly complex design built as "one piece"
- Cost - < 50%
- Weight reduction - < 40%
- Increased robustness – no joining sections

Source: EOS GmbH, Morris Technologies

Source: http://www.eos.info/aerospace

EOS 3D PRINTERS Direct Metal Laser Sintering (DMLS)



Integral instrumentation with curved pressure tubes, Material: StainlessSteel PH1
(Source: 3T RPD Ltd, Assystem)

How EOS is used for tooling: http://www.youtube.com/watch?v=USZ_z7bIetU
Creation of integrated cooling channels, hardening of 3D printed steel and application of its use on an injection moulding machine.

WHAT OTHER ASPECTS ARE RELEVANT TO 3D PRINTERS?

- Size limitations, 3D printers can only print certain sizes, (A3 / A4 cube)
- Imperfections: most of the printed parts possess a rough and ribbed surface finish, powder based machines produce particles stacked on top of each other, resulting the end product having unfinished look
- Cost: 3D printers are an expensive investment, maintenance and material cost could be problem for small companies
- Printing speed: 3D printing speed is a slow process, the part(s) might take days to print
- Supportive material needs to be removed
- Low tolerances
- Issues with repeatability
- Limited material choice few options to mould multi-material on a single part but no over moulding. (Materials are specifically developed to work on the 3D printer, less well understood)
- 3D CAD Modelling, learning packages to produce professional models is time consuming
- Issues with copying design: IP - patents , copyright, registered designs, ethical issues such as printing weapons

WHICH SYSTEMS DOES THE UNIVERSITY OF HUDDERSFIELD OFFER?

In the 3M Buckley Centre we have **EOS FORMIGA P 110**

ORMIGA P 110 is a flexible, cost-efficient and highly productive system for the Additive Manufacturing of plastic parts. Without requiring tools, the laser sintering system makes direct use of digital CAD data to produce plastic parts of the highest surface quality to a maximum construction height of 330 mm.

Source: http://www.eos.info

In the 3M centre we have EOS FORMIGA P 110 featuring:

Source: http://www.eos.info/aerospace

Features:

Cost-efficient, batch-size appropriate production
Good reproducible part quality
High level of recyclable materials
Low operating costs thanks to minimised energy consumption
A wide range of materials is available
Design for low-dust, ergonomic work conditions

Layer thickness (depending on material): 0.06 mm, 0.1 mm, 0.12 mm
Effective building volume: 200 mm x 250 mm x 330 mm
Building speed (depending on material): up to 20 mm/h

Further details: http://www.eos.info/systems_solutions/plastic/systems_equipment/formiga_p_110

Video by Shapeway: (1:59min) http://www.youtube.com/watch?v=aBNGnfoGGfQ

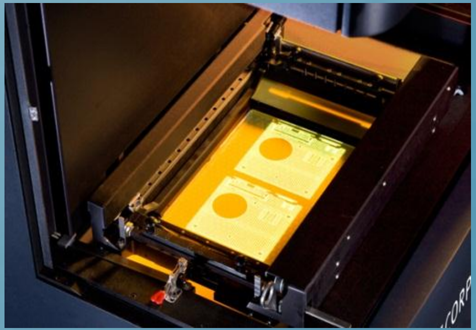
OTHER SYSTEMS AVAILABLE AT THE UNIVERSITY OF HUDDERSFIELD

School of Art, Design and Architecture has the following 3D printers

Zcorp 650 uses **similar technology to inkjet printing** where parts are produced layer by layer using various types of **powder and binder**.
Faster than most of other technologies,
Colour if wanted
One-fifth the cost of other technologies, material and initial investment.
But …issues include : surface finish quality, requires glue after the parts are manufactured, issue with minimal wall thickness

Z Builder Ultra :

Similar to SLA systems
High-resolution DLP system instead of complex laser technology
Exposed photopolymer solidifies into robust solid plastic



Further Info: http://www.hud.ac.uk/
http://www.zcorp.com/documents/14_CaseStudy-Huddersfield-FINAL.pdf

Stratasys Fortus FDM 360

FDM works on laying down layer of plastic filaments from a nozzle which can turn the flow on and off.

Used for producing functional prototypes, tooling and end-use parts in standard engineering materials.

Ideal for demanding prototyping needs, tooling and fixtures, and patterns for metal bending and composite work (several production grade engineering thermoplastics – ABS, PC with different properties)
Low-volume manufacturing and customisation become feasible

Further Info: http://www.stratasys.com/
http://www.hud.ac.uk/
http://www.zcorp.com/documents/14_CaseStudy-Huddersfield-FINAL.pdf

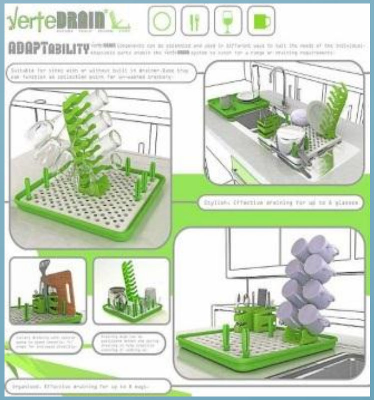
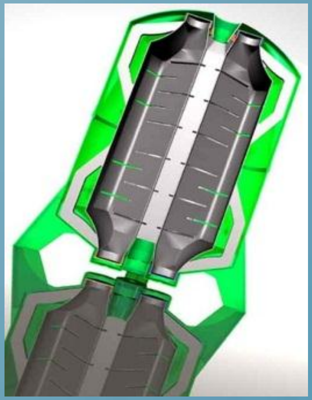
3D SOFTWARE

3D Software:
3D Solid: Solidworks, Catia, Unigraphics, Autodesk Inventor, ProEngineer or similar
Surface modelling: NURBs: including Alias Design Studio, Rhino, ICEM
Surface modelling: Polygon, Mesh : Low tolerances, easy to model: includes, 3D Studio max, Maya, Zbrush, Modo
Other 3D software: Autodesk products including Revit Architecture,

Education: Students in Huddersfield use various 3D CAD packages:

Solid modelling



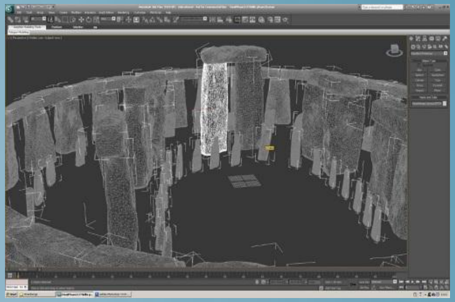



Source: www.huddersfield3d.co.uk

Students in Huddersfield, Product Design course use various 3D CAD packages:

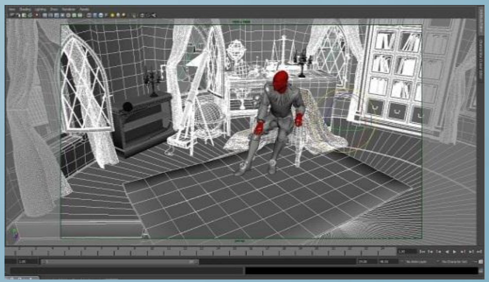
Surface modelling



Polygonal modelling & Animation





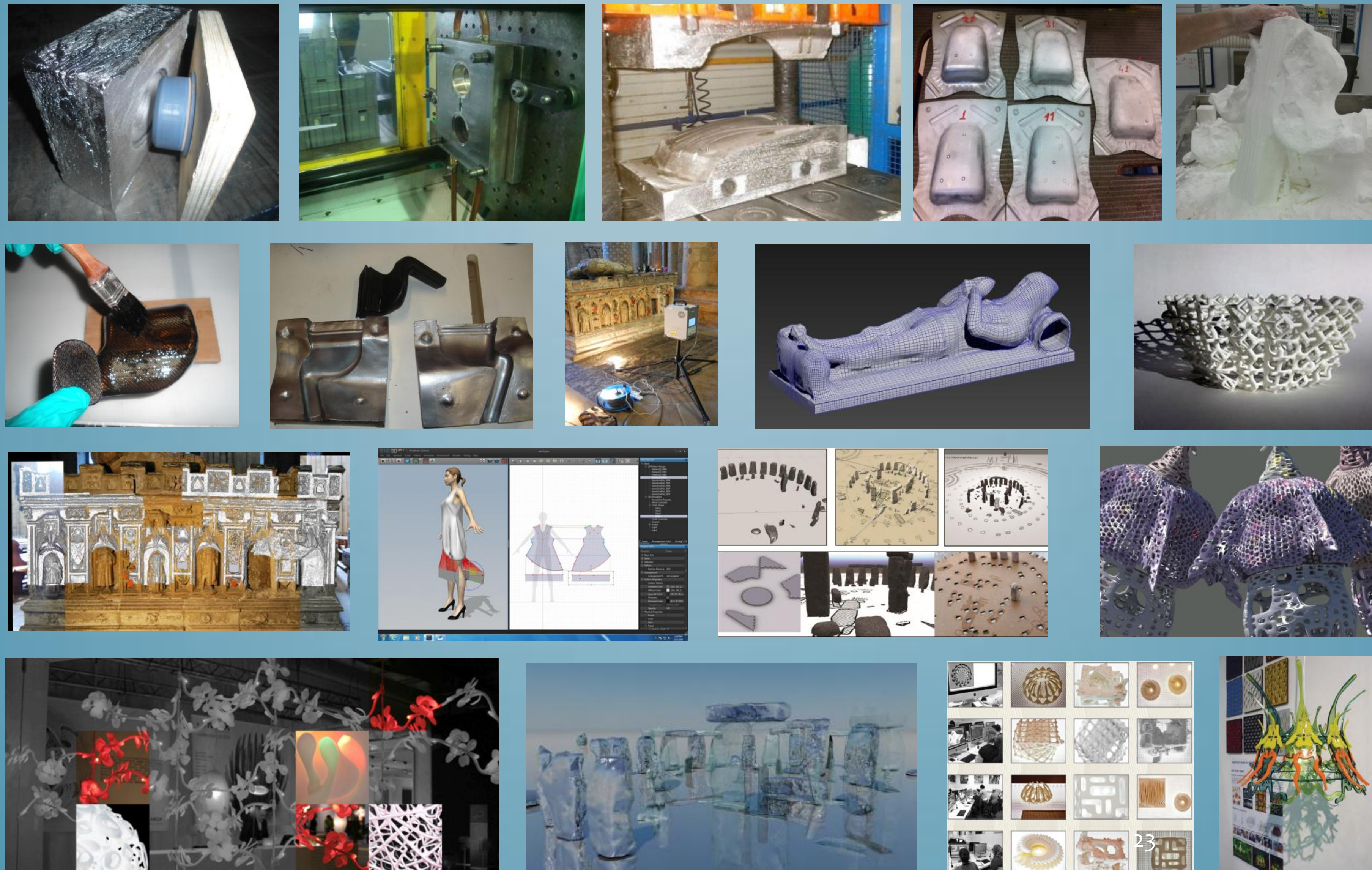

Digital clay modelling




Source: www.huddersfield3d.co.uk

3D Printing Related Research in School of Art, Design and Architecture:

Low Melting Alloy : Bismuth for Injection moulding / Sheet metal forming; Application of Carbon Fiber Composites with RP; 3D Design of Surface, Garment, Fashion, Ornament, Archaeological, Architectural objects; Programmable changing & Animated 3D printing items,



Further Info: http://eprints.hud.ac.uk/view/authors_id/96.html and/or http://www.hud.ac.uk/ourstaff/profile/index.php?staffuid=sdeseu

QUESTIONS AND ANSWERS

This presentation will be available on eprints.hud.ac.uk See: http://eprints.hud.ac.uk/view/authors_id/96.html

References:

http://www.eos.info/en
http://www.3dsystems.com/
http://www.stratasys.com/
http://www.zcorp.com/en/home.aspx
http://en.wikipedia.org/wiki/3D_printing

Useful Selected videos:

3D Printshow London 2012: https://www.youtube.com/watch?v=S-E6vRfnijw
Artist: Leaders Of The 3D Printing Revolution : Shapeways online 3D https://www.youtube.com/watch?v=IS4Xw8f9LCc
How 3D Metal Printing May Change Manufacturing: https://www.youtube.com/watch?v=zT63OOLADU8
Future: TED: Skylar Tibbits: The emergence of "4D printing: https://www.youtube.com/watch?v=0gMCZFHv9v8
BBC: Printing a bicycle with a 3D printer: https://www.youtube.com/watch?v=hmxjLpu2BvY
Bio Printing: http://www.youtube.com/watch?v=9D749wZSlb0
Functioning tissue printing: http://www.organovo.com/
Electron Beam Freeform Fabrication http://www.youtube.com/watch?v=0RL4cBbKYb8

Other Useful Links:

How to do online Printing and costing using i-materialise: http://www.youtube.com/watch?v=FdTmh5j6SPM
Could 3D Printing Change the World? Technologies, Potential, and Implications of Additive Manufacturing: http://www.acus.org/files/publication_pdfs/403/101711_ACUS_3DPrinting.PDF
Astroid http://www.businessinsider.com/deep-space-industries-asteroid-mining-plans-2013-1
http://www.rapidtoday.com/design.html
http://www.3dprintingnews.co.uk/page/3/

CAD Packages:

Alias Design Studio: http://www.autodesk.com/products/autodesk-alias-products/overview
CATIA: http://www.3ds.com/products/catia/welcome/
Solidworks : http://www.solidworks.co.uk/
Pro Engineer: http://www.ptc.com/
Rhino: http://www.rhino3d.com/nurbs/
ICEM http://www.3ds.com/products/catia/portfolio/icem-surf/icem-surf-overview/
MODO: http://www.luxology.com/modo/
NX : ttp://www.plm.automation.siemens.com/en_gb/products/nx/for-design/index.shtml

3D Printed items for sale / 3D services:
http://makie.me/
http://www.thingiverse.com/
http://www.kraftwurx.com/
http://www.sculpteo.com/en/
http://www.shapeways.com/
http://www.freedomofcreation.com/
http://www.makeeyewear.com/about-our-eyewear/
http://i.materialise.com/
https://www.ponoko.com/
http://www.quickforge.co.uk/
http://www.3trpd.co.uk/
http://www.futurefactories.com/
http://www.automake.co.uk/

Books:

1) Rapid Prototyping: Principles and Applications by Rafiq I. Noorani (8 Nov 2005)

2) Stereolithography & Other RP&M Technologies: From Rapid Prototyping to Rapid Tooling (Hardcover) By: **Paul F. Jacobs (Author)**

3) Rapid Manufacturing: An Industrial Revolution for a Digital Age: An Industrial Revolution for the Digital Age 2005, N.Hopkinson, R. Hague , P. Dickens

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