Loughborough University

Rapid Manufacturing Research Group

Making products without tools

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Loughborough University

Rapid Manufacturing Research Group

Loughborough University: Strength in research

- Our research generates nearly half of the University's income
- Rated World Class for Research by the Sunday Times 2006 for:

  Built Environment
  Electrical and Electronic Engineering
  English Language and Literature
  European Studies
  Geography
  Library and Information Management
  Sociology
  Sports-related Subjects
  Mechanical, Aeronautical and Manufacturing Engineering

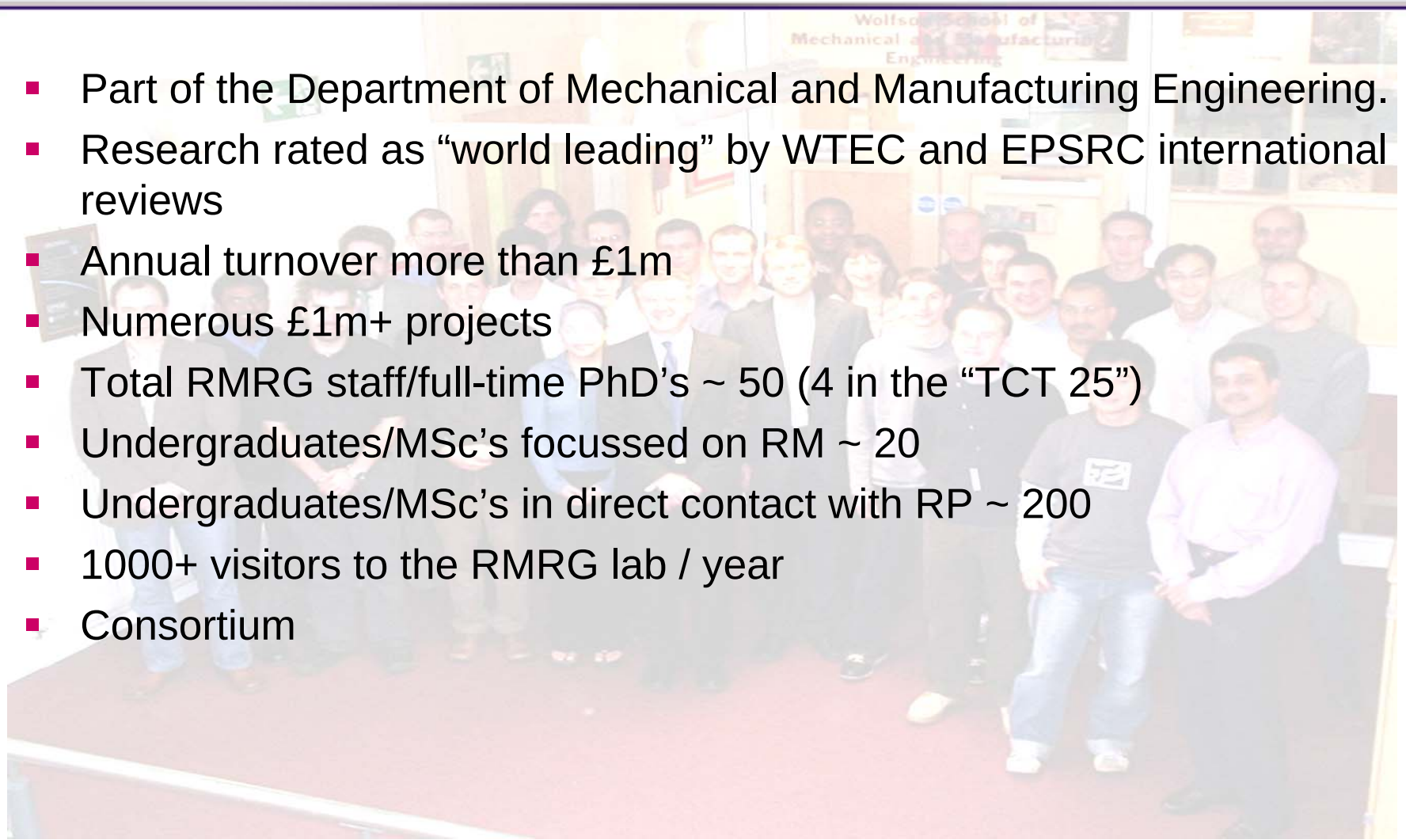
- Awarded the highest level of funding per grant of any UK university

  by the Engineering & Physical Sciences Research Council



Rapid Manufacturing Research Group

Rapid/Additive Manufacturing Research Group



- Part of the Department of Mechanical and Manufacturing Engineering.
- Research rated as “world leading” by WTEC and EPSRC international reviews
- Annual turnover more than £1m
- Numerous £1m+ projects
- Total RMRG staff/full-time PhD’s ~ 50 (4 in the “TCT 25”)
- Undergraduates/MSc’s focussed on RM ~ 20
- Undergraduates/MSc’s in direct contact with RP ~ 200
- 1000+ visitors to the RMRG lab / year
- Consortium

Rapid/Additive Manufacturing Research Group

- Some current partners

- Boeing
- Siemens
- Burton Snowboards
- New Balance
- Adidas
- UK Sport
- Most RP/T/M vendors

Some former partners

Lotus Cars
Rover
Volvo
Perkins Engines
DaimlerChrysler
Alstom
Jaguar

Rapid/Additive Manufacturing fundamentals

- **Also known as….**
- Direct Digital Manufacturing
- Solid Freeform Fabrication
- Layer Manufacturing*
- Personalised Manufacturing

- *note our definition is not restricted to layer based approaches

Rapid/Addtive Manufacturing fundamentals

Definition:

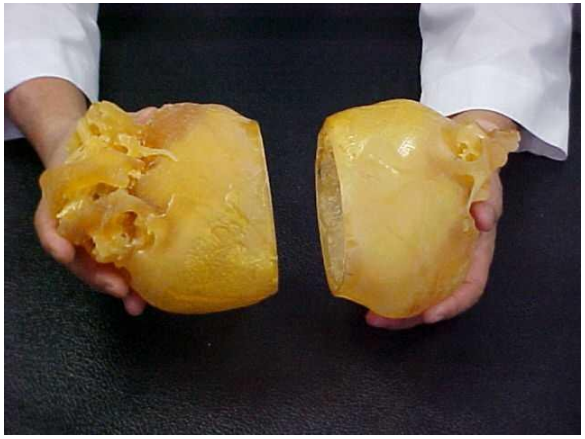
"the use of a CAD based automated additive manufacturing process to construct parts that are used as finished products or components"

Rapid/Additive Manufacturing fundamentals

- **Stereolithography**

Rapid/Additive Manufacturing fundamentals

- **Stereolithography**

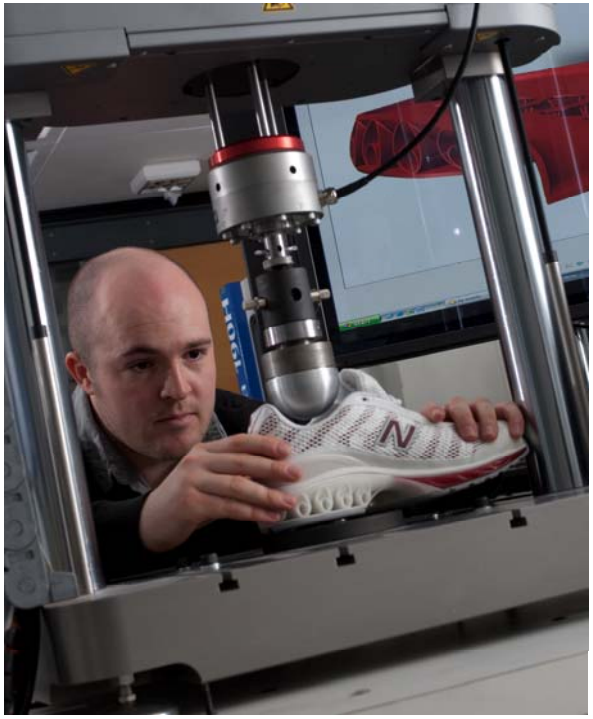

http://www.turkcadcam.net/rapor/otoinsa/uyg-medikal-conjoined-twins.html

Rapid/Additive Manufacturing fundamentals

- **Selective Laser Sintering**

Rapid/Additive Manufacturing fundamentals

- **Selective Laser Sintering**



Rapid/Additive Manufacturing fundamentals

- **Ink Jet (3D) Printing**

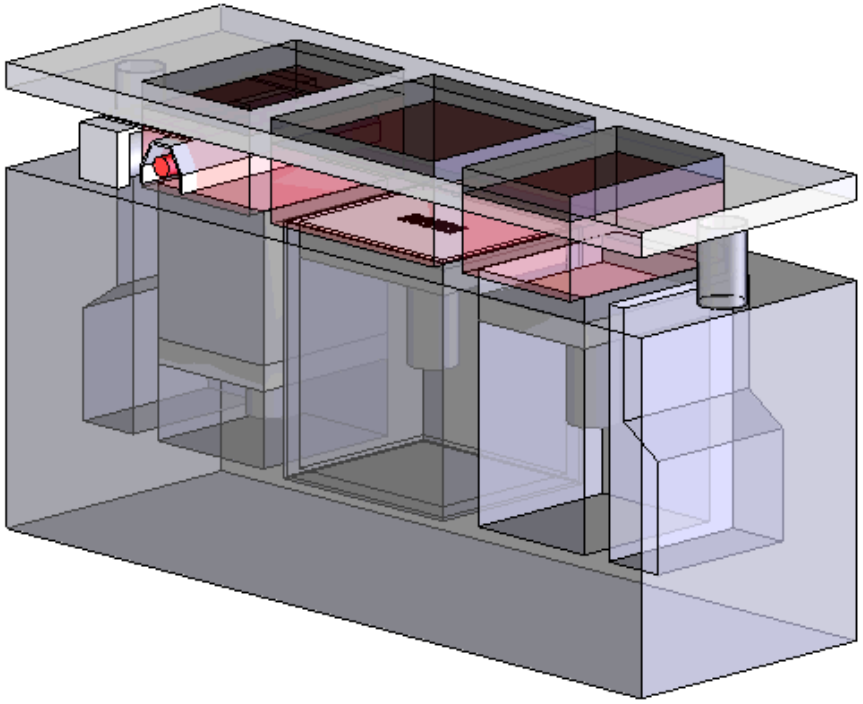
Rapid/Additive Manufacturing fundamentals

- **Ink Jet (3D) Printing**

http://www.objet.com/Case_Studies/Entertainment/

Rapid/Additive Manufacturing fundamentals

- **High Speed Sintering**



Rapid/Additive Manufacturing fundamentals

- **High Speed Sintering**

Rapid/Additive Manufacturing fundamentals

- **Other polymer processes:**
- Fused Deposition Modeling
- Plastic Sheet Laminate Object Manufacturing
- Flash curing processes
- Various others drifting in/out

Rapid/Additive Manufacturing fundamentals

- **Benefits:**
- **Elimination of tooling (cutting or forming)**
- Geometry freedom
- De-centralised manufacture (in the West)
- Cost effective for small volumes
- De-risking of projects
- Increased material utilisation compared with cutting
- etc

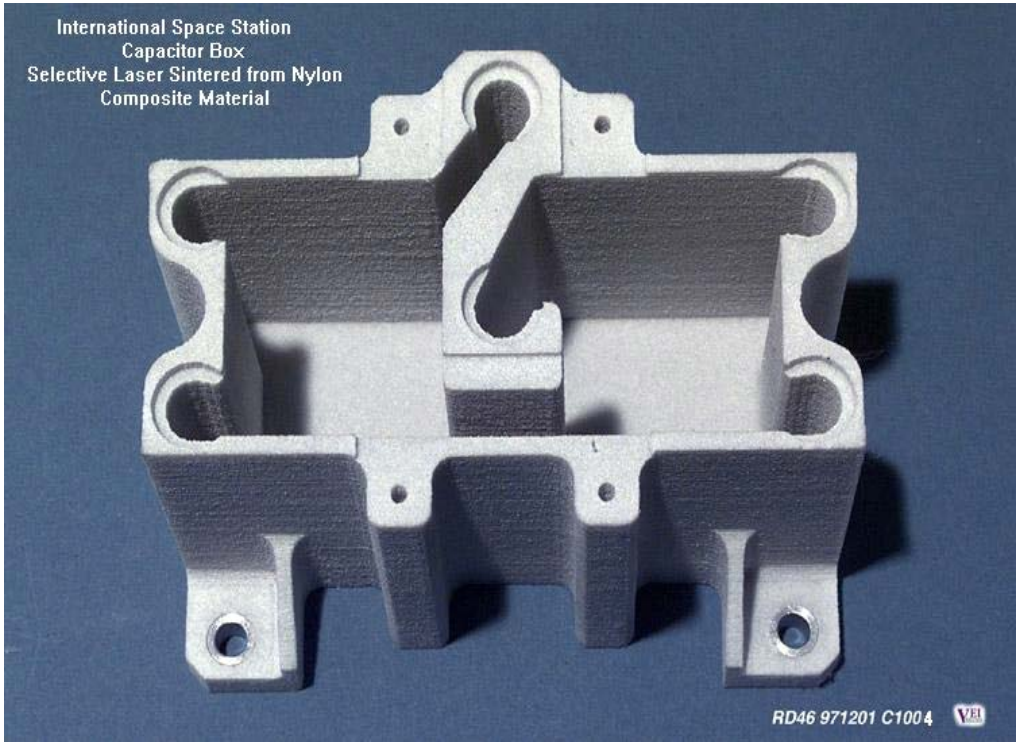
Rapid/Additive Manufacturing fundamentals

- **Problems (know as “research opportunities” in academia!):**
- Equipment / material cost
- Process speed
- Small range of materials
- Properties and repeatability require improvement
- Perception by engineers
- etc

Rapid/Additive Manufacturing history

- **The first "RP" part to be used as an end use product was an electrical housing made using selective laser sintering on the international space station**

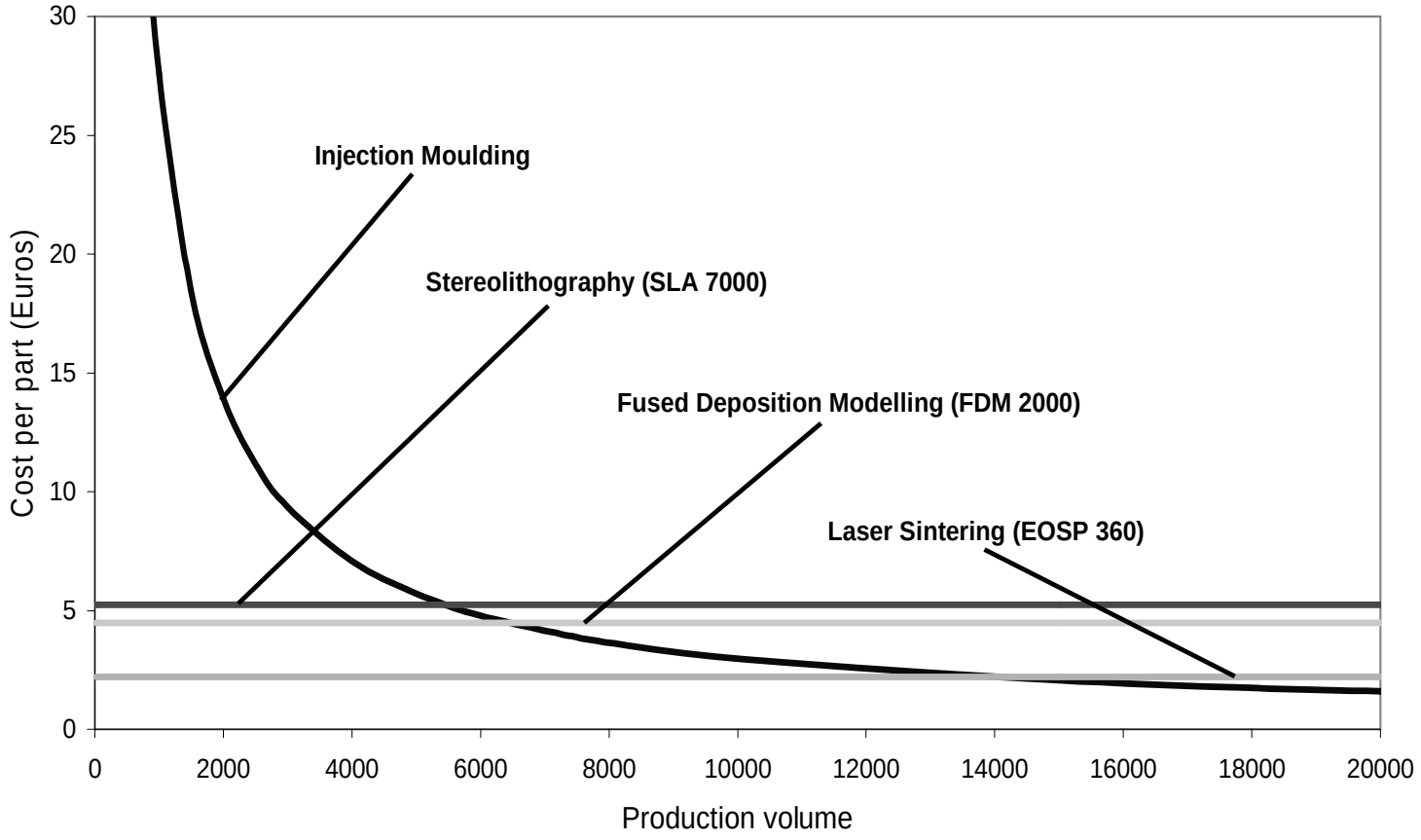
Taken from "Rapid Manufacturing: An industrial revolution for the digital age"



Source: Boeing

Rapid/Additive Manufacturing history

- **Study from 2000 (Hopkinson and Dickens, 2003)**

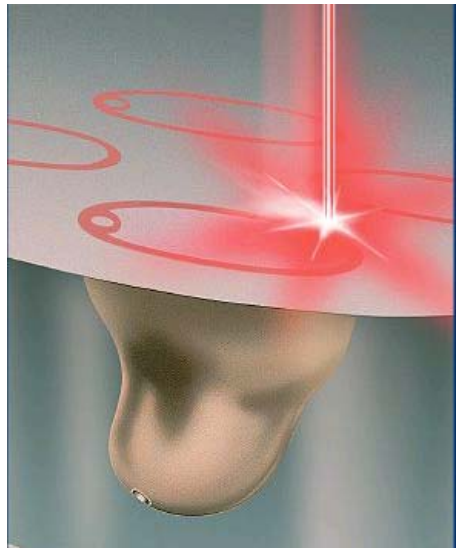


Rapid/Additive Manufacturing industry status

- **~10 years old**
- **Sintering of Nylon 12 dominates**
- **Almost exclusively short volume production**
- **Some high volume “one-off” production**
- **Difficult to quantify market size**
- **System level benefits of RM are important but difficult to quantify**
- **Economics of RM ≠ economics of RP**

Rapid/Additive Manufacturing industry status

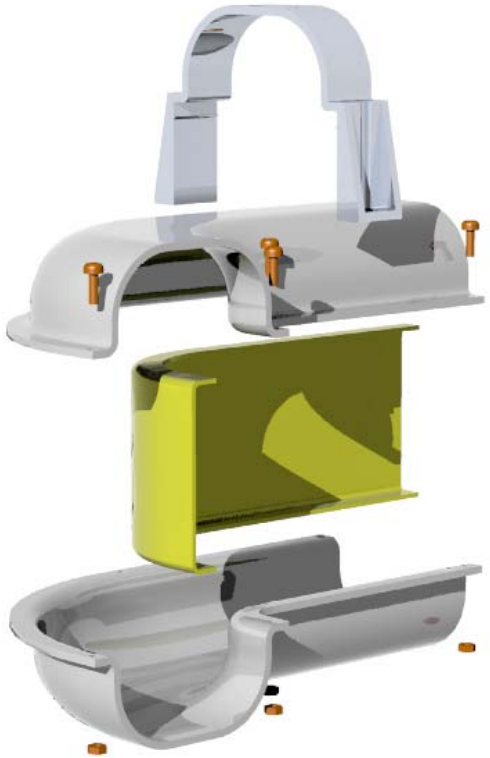
- **Hearing aids**
- **SLS User Group 2002, Martin Masters from Siemens quotes manufacturing cost of hearing aid shells as….**
- **“about a buck”**



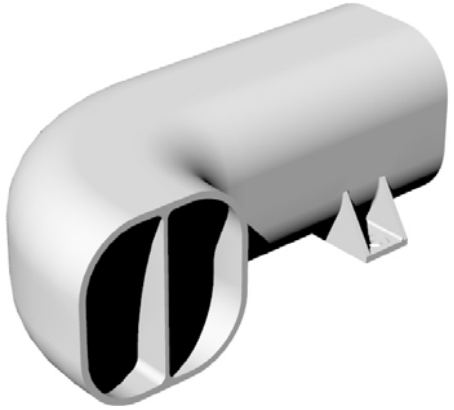
Source: Siemens

Rapid/Additive Manufacturing industry status

- **Boeing identifying “system level” benefits**

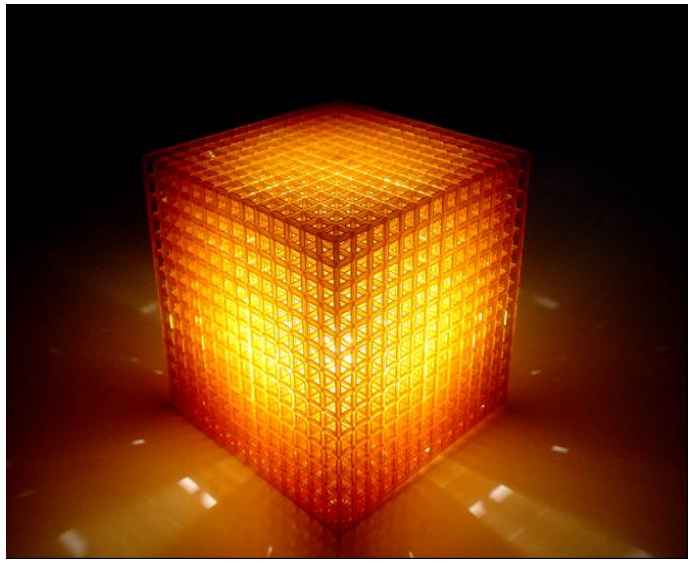


Source: Boeing / 3D Systems



Rapid/Additive Manufacturing industry status

- **Series manufacture in the low thousands….**



Source: FoC

Rapid/Additive Manufacturing for running shoes

- **Personalised sprint spikes at Loughborough University**
- **Film commissioned by the UK Institute of Engineering and Technology**

- **IET video**

Rapid/Additive Manufacturing for running shoes

- **Personalised sprint spikes at Loughborough University**

Source: Sunday Times

Rapid/Additive Manufacturing for running shoes

- **Elite athletes will allow us to understand how to provide personalised sports footwear**
- **…they will also provide high profile**
- **By 2012 we are aiming to have personalised footwear available to the public.**

Rapid/Additive Manufacturing outlook

- **Machine / material cost**
- **Process speed**
- **Repeatability**
- **Surface finish?**
- **Feature resolution**
- **Material choice**
- **etc**

Rapid/Additive Manufacturing outlook

- **High Speed Sintering**

High Speed Sintering: Build speed projections

- 300mm x 300mm x 300 bed:
- Parts per level = 105, number of levels = 72 => Parts per build = 7560
- Build time = 20 seconds x 2800 + 3 hours = 66800 seconds = 18.5 hours
- Build rate = 8.80 seconds per part

High Speed Sintering: Build speed projections

- 1000mm x 1000mm x 1000 mm bed:
- Parts per level = 1250, number of levels = 247 => Parts per build = 308,750
- Build time = 20 seconds x 9800 + 3 hours = 206800 seconds = 57.4 hours
- Build rate = 0.67 seconds per part
- (At 30 second layer cycle, build rate = 0.99 seconds per part)

High Speed Sintering: Part cost projections

- This is more difficult than calculating build time projections, please bear with me on assumptions!

- Ruffo cost model applied to 300x300x300mm machine assuming:
  - Machine cost (£250,000) = £29 per hour
  - Material cost ~ £30/Kg assuming 50% recycle rate

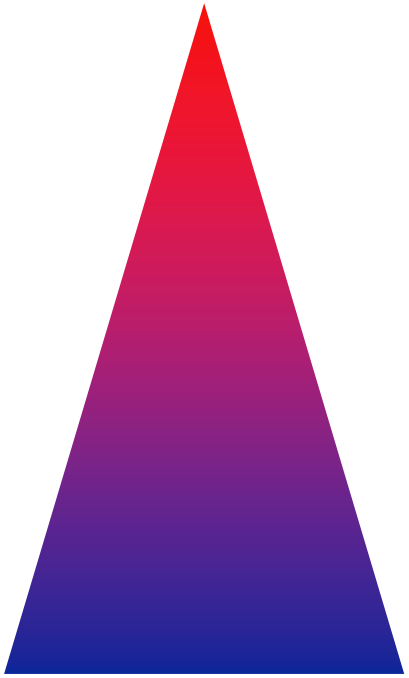
- Machine cost per build = £29 x 18.5 hours = £536.50
- Material cost per build = £30 x 15.56Kg = £466.80
- Total cost per build = £1003.30

- Cost per part = £1003.30 / 7560 = £0.13

Rapid Manufacturing outlook

- **Still niche solutions in high added value applications**
- **But……**

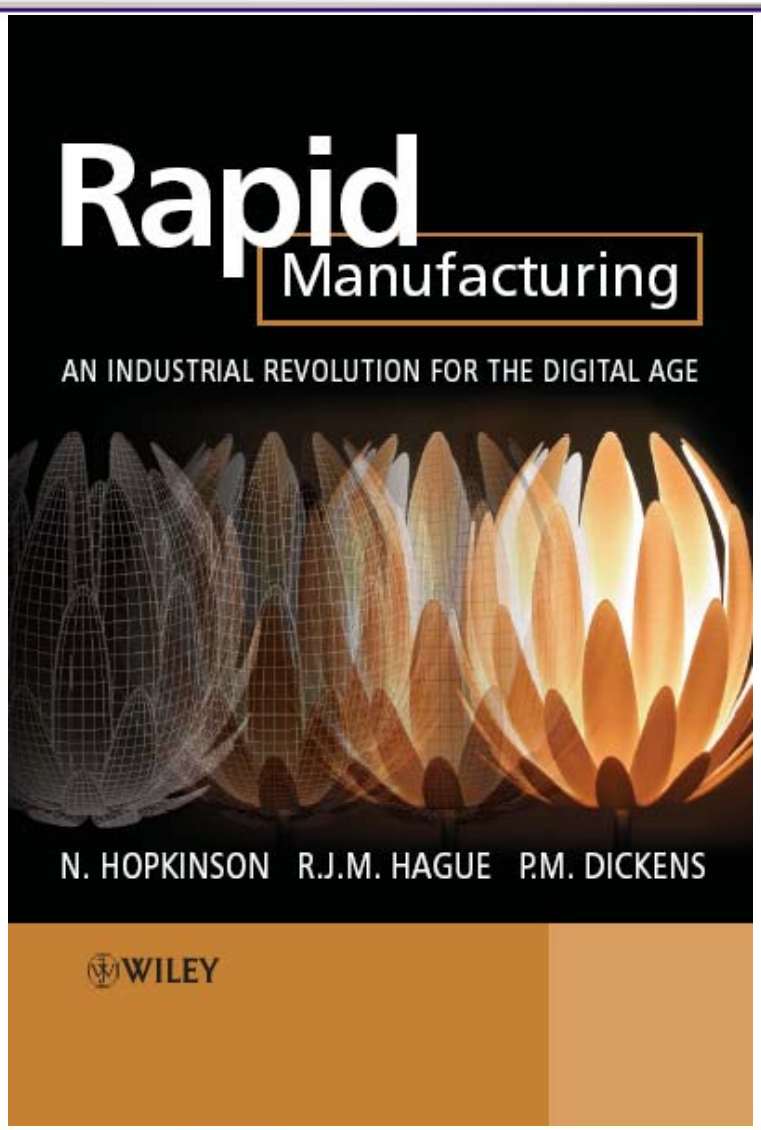
- Space shuttle / station
- Formula 1
- Personalised sports footwear
- Personalised Hearing aids
- Aerospace ducting
- Lamp shades
- Electrical connectors



Niche

Niche?

A plug for our book and conference!



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