



Making products without tools

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Contents

- **Loughborough University and the Rapid/Additive Manufacturing Research Group**
- **Rapid/Additive Manufacturing - fundamentals**
- **Rapid/Additive Manufacturing - history**
- **Rapid/Additive Manufacturing - industry status**
- **Rapid/Additive for running shoes**
- **Rapid/Additive Manufacturing - outlook**

THE SUNDAY TIMES
**UNIVERSITY
OF THE YEAR**

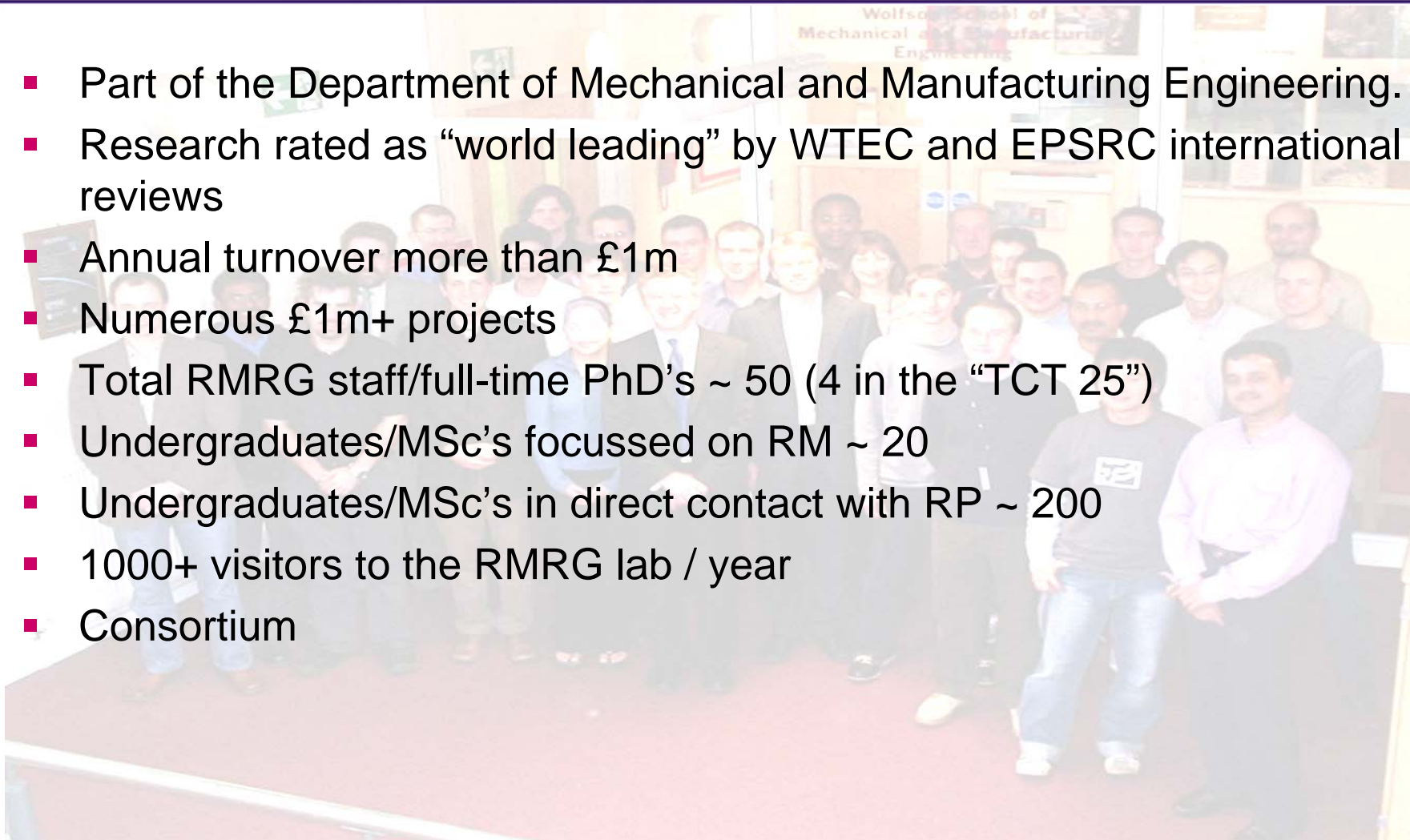
Loughborough University: Strength in research

- 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/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/Additive Manufacturing fundamentals

Definition:

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

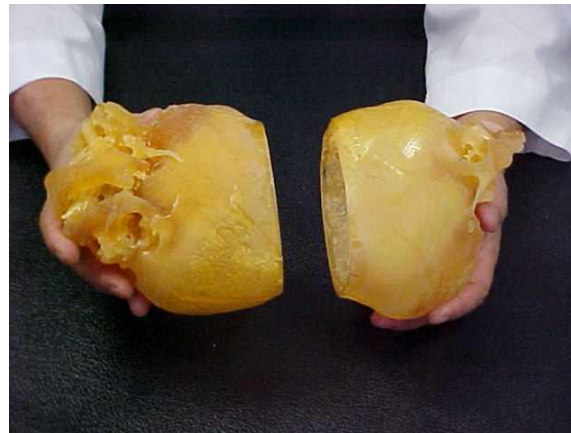
Rapid/Additive Manufacturing fundamentals

- **Stereolithography**



Rapid/Additive Manufacturing fundamentals

- **Stereolithography**



<http://www.turkcam.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

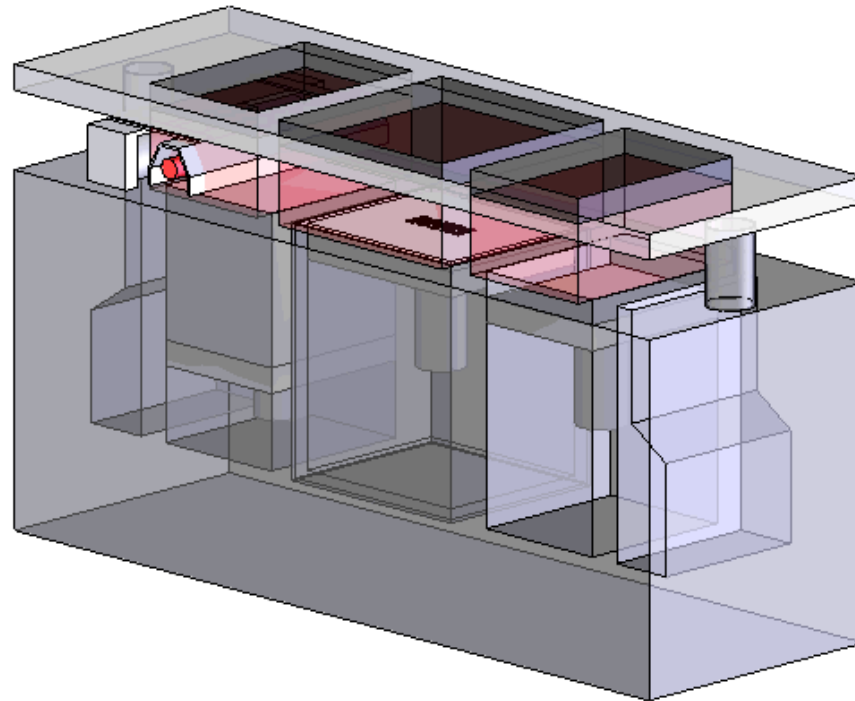
- Ink Jet (3D) Printing



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**

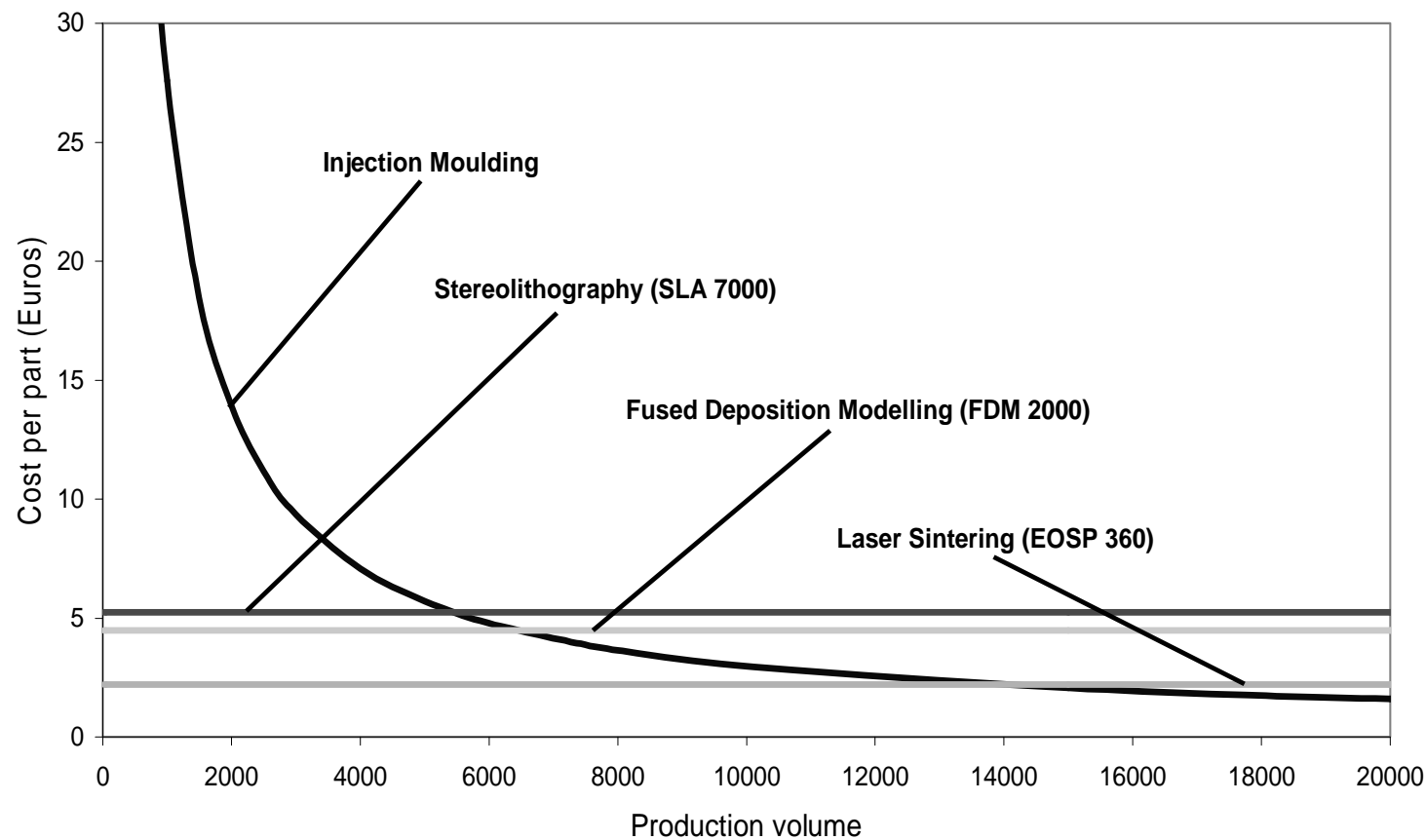
Taken from
“Rapid
Manufacturing:
An industrial
revolution for
the digital age”



Source: Boeing

Rapid/Additive Manufacturing history

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

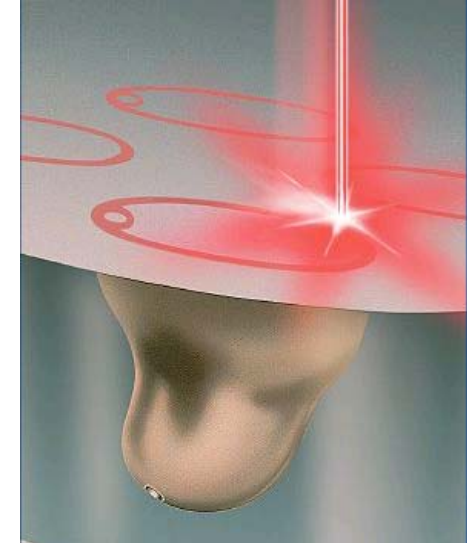


Rapid/Additive Manufacturing industry status

- **~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 \neq economics of RP**

Rapid/Additive Manufacturing industry status

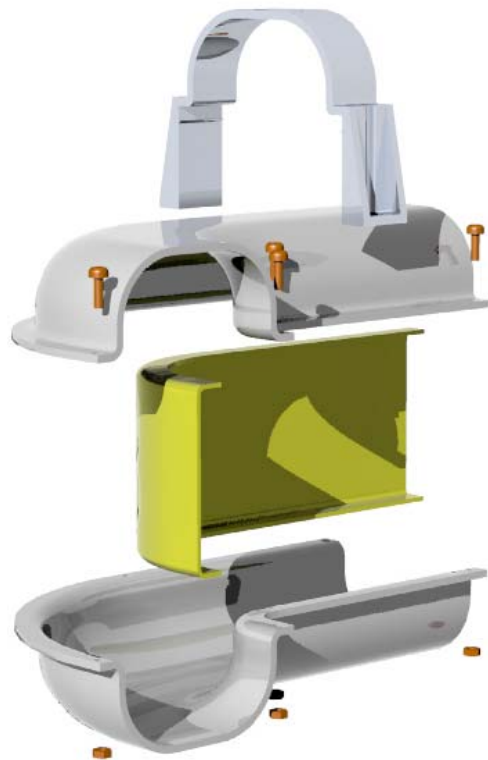
- **Hearing aids**
- **SLS User Group 2002, Martin Masters from Siemens quotes manufacturing cost of hearing aid shells as....**
- **“about a buck”**



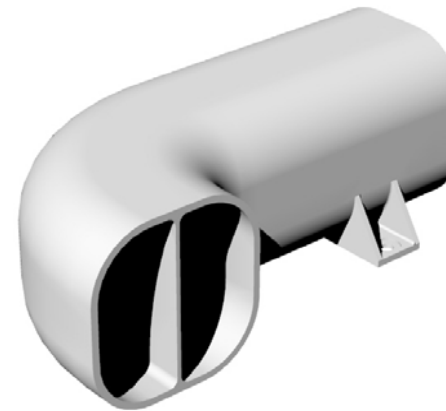
Source: Siemens

Rapid/Additive Manufacturing industry status

- Boeing identifying “system level” benefits

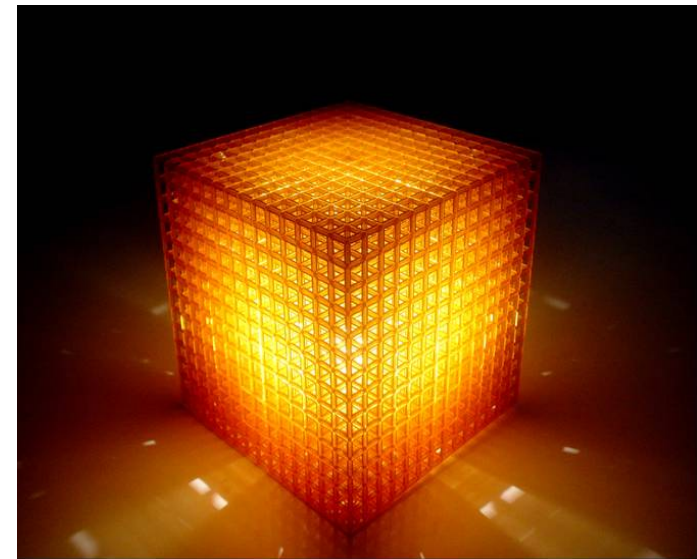


Source: Boeing / 3D Systems



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

8 The Visa London 2012 Party

Bend it like Bolt

Researchers at Loughborough University are working on new technology to tailor the soles of sprinters' shoes to individual athletes in time for 2012

1 Dynamics

The angles of an athlete's feet and ankles are measured using high-speed digital video at different stages of a sprint, to quantify the effect of the shoe on the foot's movement. The aim is to harness the full explosive power of an athlete – crucial to success in sprinting or jumping

2 Production

A process called "Selective Laser Sintering" uses small particles of plastic to create precise 3D components. This allows the researchers to change the properties of footwear in order to match the needs of each athlete – without the need for expensive moulding and tooling

3 Stiffness

Loughborough researcher Dan Toon, who heads the programme, says that calibrating the stiffness of the soles of a pair of runner's spikes can double the amount of mechanical energy generated at the ankle – enough to give the athlete a definite advantage

4 In a shop near you

Once tested and proven by elite athletes, shoes with personalised soles will be available to the public, suitable for a wide range of sports and activities

Jamaica's Usain Bolt won the 100m and 200m sprint double in Beijing wearing customised golden running shoes

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.**



© Brian Bell Photography

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

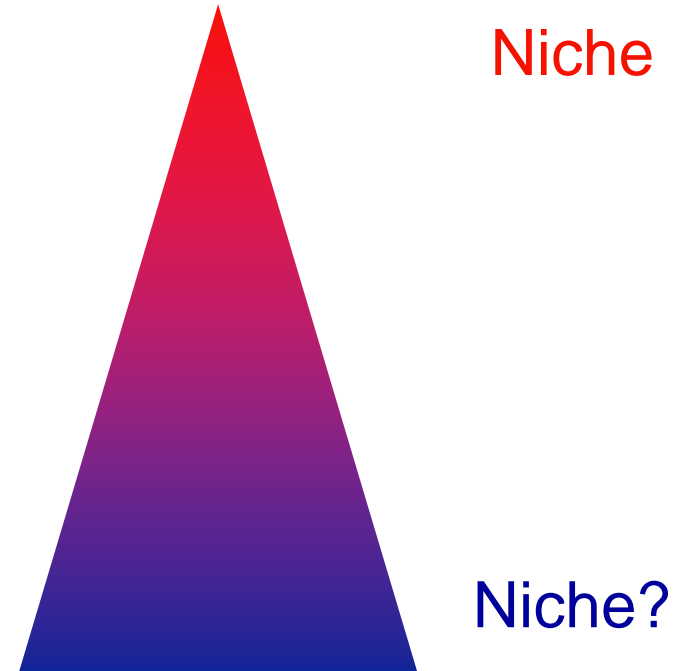
- 1000mm x 1000mm x 1000 mm bed:
- Parts per level = 1250, number of levels = 247 => Parts per build = 308,750
- Build time = 20 seconds x 9800 + 3 hours = 206800 seconds = 57.4 hours
- Build rate = 0.67 seconds per part
- (At 30 second layer cycle, build rate = 0.99 seconds per part)

High Speed Sintering: Part cost projections

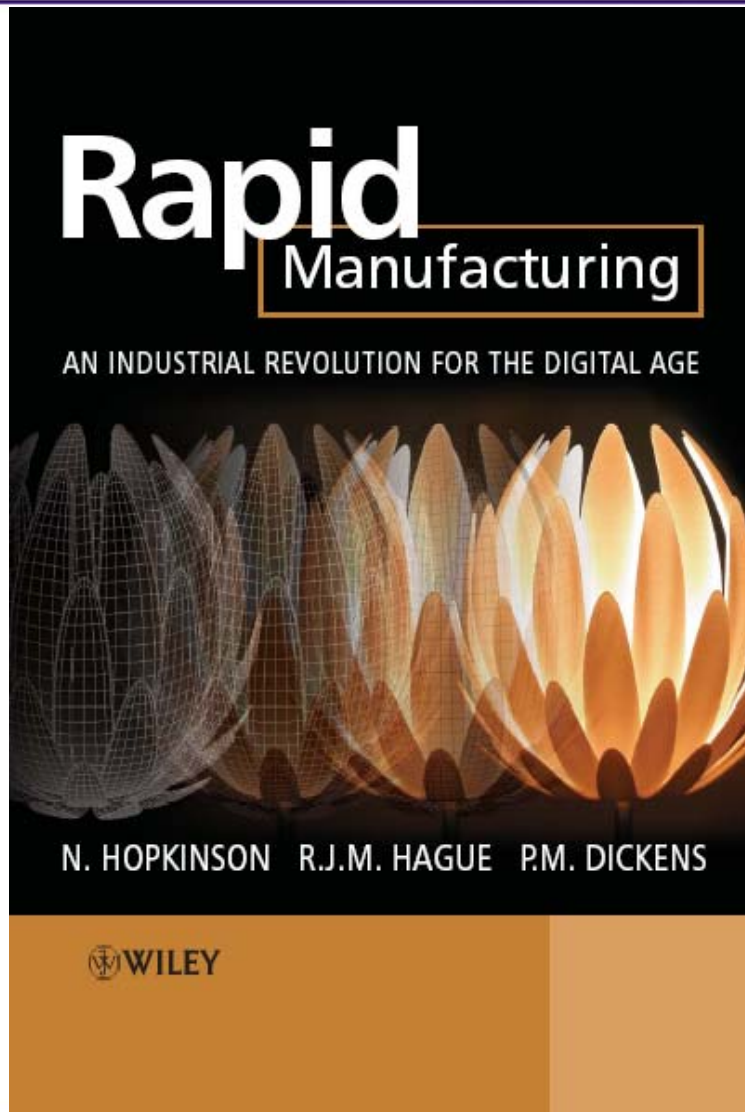
- This is more difficult than calculating build time projections, please bear with me on assumptions!
- Ruffo cost model applied to 300x300x300mm machine assuming:
 - Machine cost (£250,000) = £29 per hour
 - Material cost ~ £30/Kg assuming 50% recycle rate
- Machine cost per build = $£29 \times 18.5 \text{ hours} = £536.50$
- Material cost per build = $£30 \times 15.56\text{Kg} = £466.80$
- 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



A plug for our book and conference!



rapidmanufacturing
2ND INTERNATIONAL CONFERENCE

conference

July 14-15 2010

Sir Dennis Rooke Conference Centre
holywell park
loughborough university
united kingdom



Rapid Manufacturing Research Group | **econolyst** | **RPMA** | Loughborough University