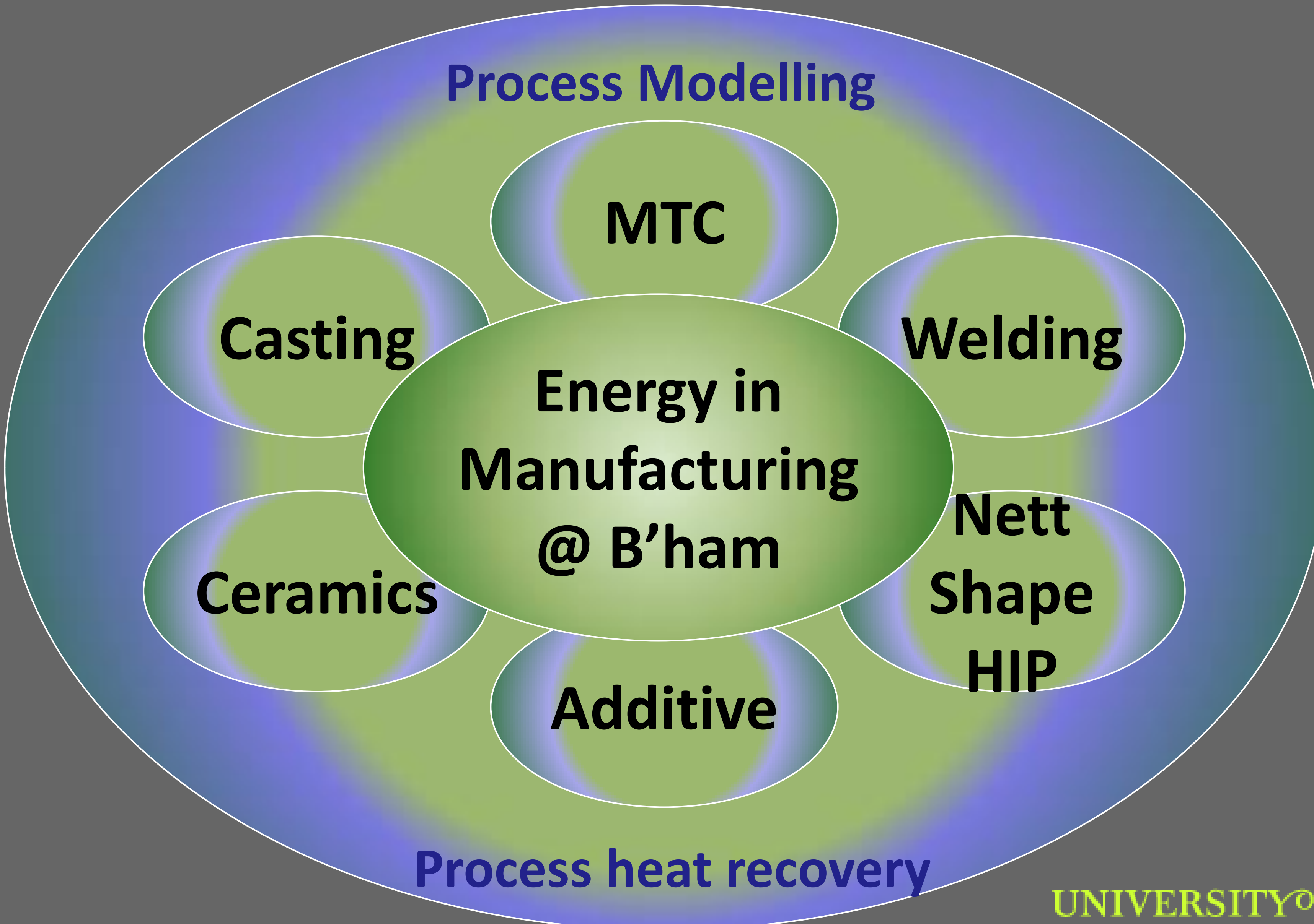
Manufacturing

Mark Jolly

Energy at Birmingham

July 8th 2011



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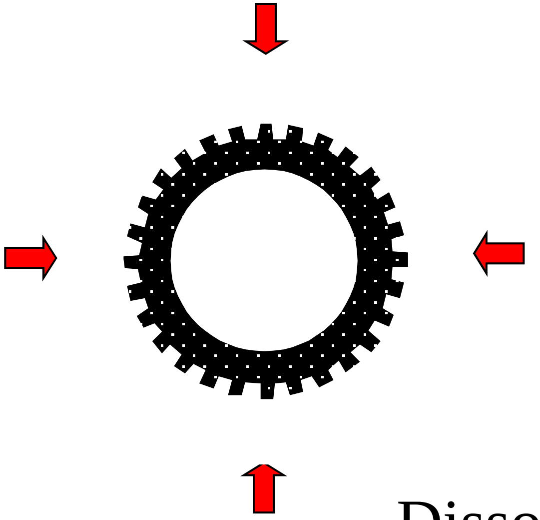
Net Shape HIPping

Energy saving through reduced materials wastage



Dissolve away Capsule

T = 950 °C

P = 100 MPa (1000 bar)

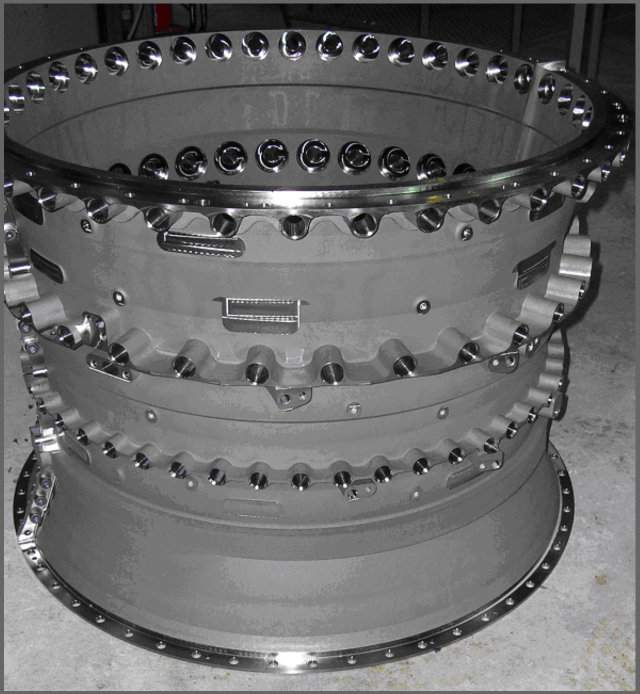
Application in Aerospace
50kg Casing

machined

500kg ring-rolled ingot (10%)

HIPped

54kg powder (93%)



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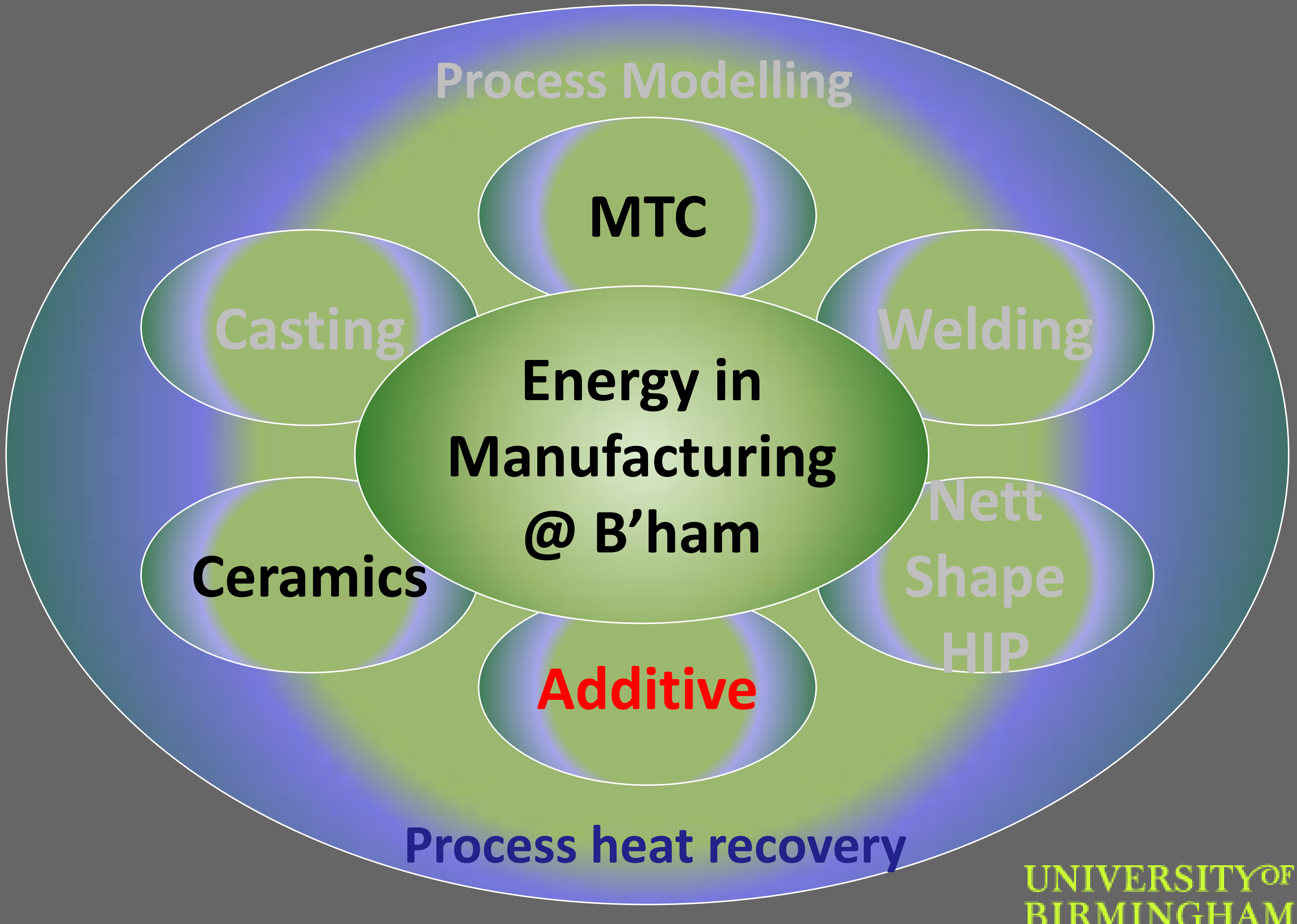
Process Modelling
MTC
Casting
Welding
Energy in Manufacturing @ B’ham
Ceramics
Nett Shape HIP
Additive
Process heat recovery
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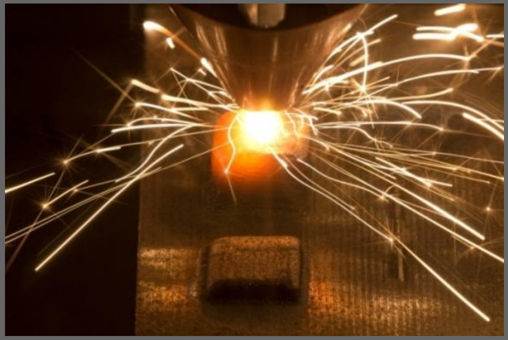
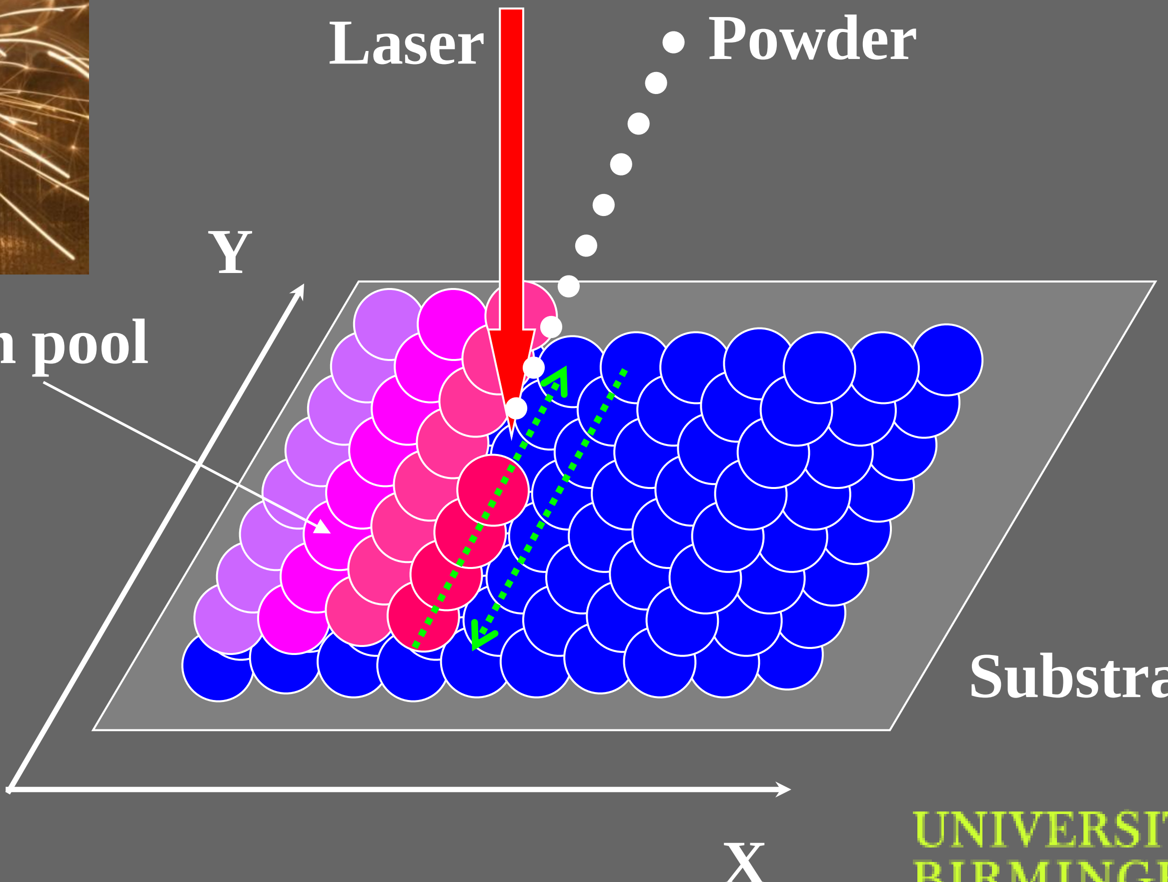
Direct Laser Fabrication (DLF)

Use off-shelf powder: Ti, Ni, Steel





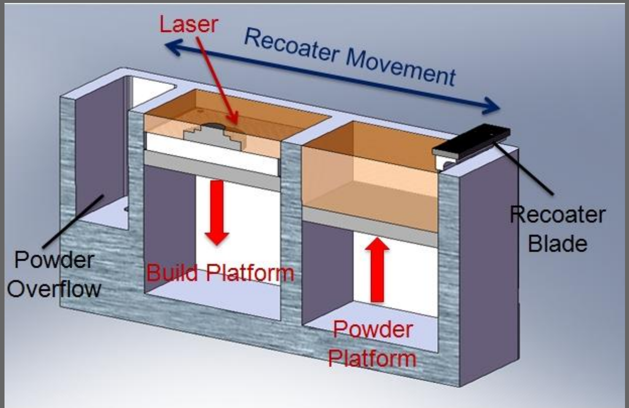
Direct Laser Fabrication (DLF)

Multi axis Blown Powder DLF

- 4 kW disc laser
- also 3 kW & 1 kW lasers
- Build cabinet 1.5x1.0x3.0 m
- Auto-change laser capability
- Spot size from 0.2 to 6 mm
- Powder and wire feeder
- Additional laser for in-situ heat treatment

Selective Laser Melting/Sintering (Rapid manufacturing)

- Precise fibre laser powder selectively fused layer by layer
- Un-fused material acts as supports
- Components near to 0% porosity



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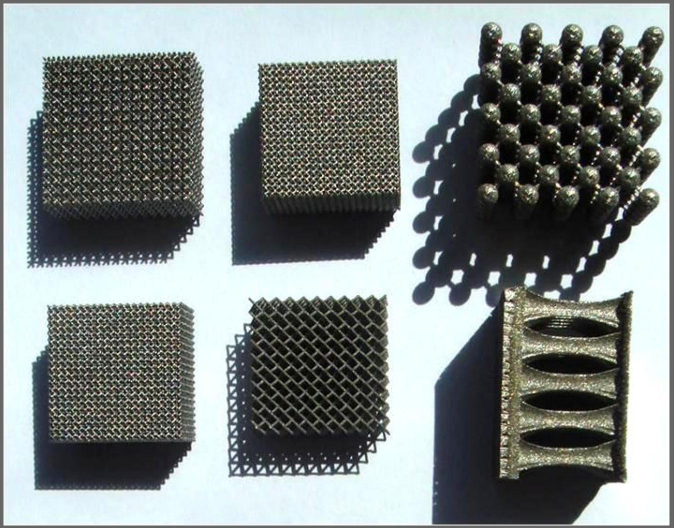
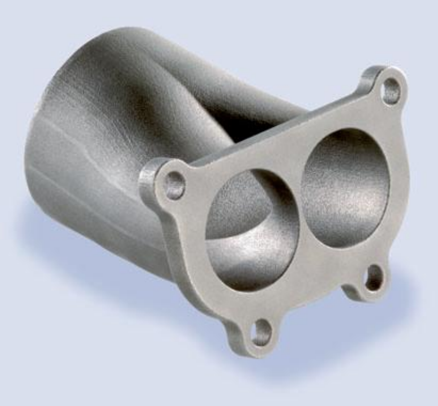
Selective laser melting – powder bed

Build envelope 250 x 250 x 280 mm
Production speed 2 – 20 cm^3/hr
Laser system Fibre laser 200W cw





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Additive manufacturing
Energy benefits

- Better material utilisation, compared to subtractive methods like machining
- No tooling → a rapid manufacturing approach
- Repair technology → materials and energy savings

Projects

- SAMULET3
  - TSB-funded project (with Rolls-Royce plc, started December 2010):
  - utilisation of laser powder-bed net-shape processing for titanium aerospace components
  - competition between centrifugal casting and laser powder-bed processing

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Projects

- SAMULET4
  - TBS-funded project (Rolls-Royce plc & BAE systems)
  - use of net-shape HIPing (with R-R) and Direct Laser Deposition (blown powder) (with BAE).
- MicroTurbo
  - Industry funded project (Feb 2011)
  - various structures in Ni Superalloys, Al & SiAlONS.

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Projects

- Accelerated Metallurgy
  - (FP7 project, June 2011), 31 collaborators
    - 9 universities, 16 companies, 2 synchrotron light sources and 4 research centres
  - DLF work to be done in Birmingham
  - Accelerated Discovery of Alloy Formulations using combinatorial principles
  - DLF to make compositions of different alloy systems not previously studied

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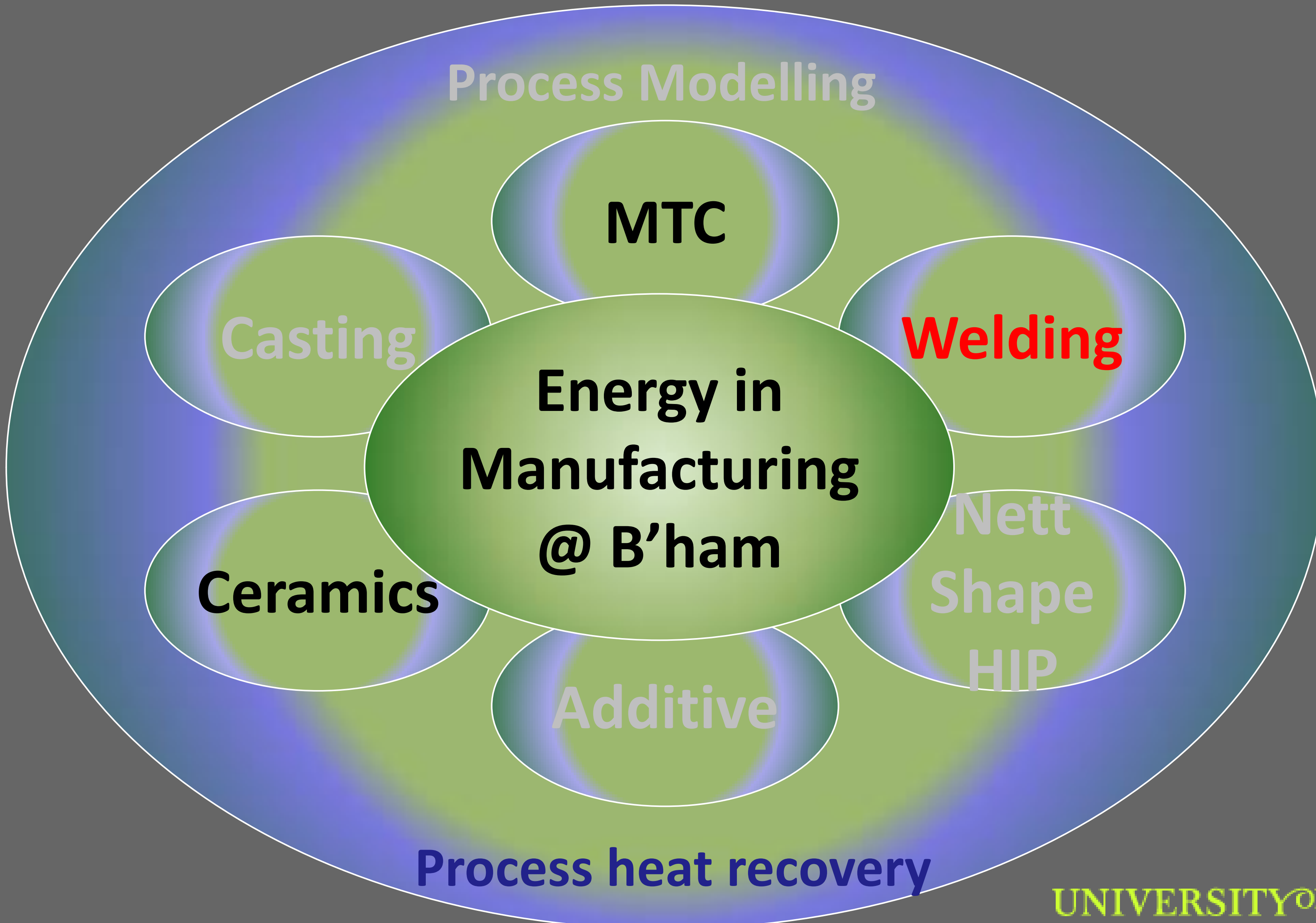

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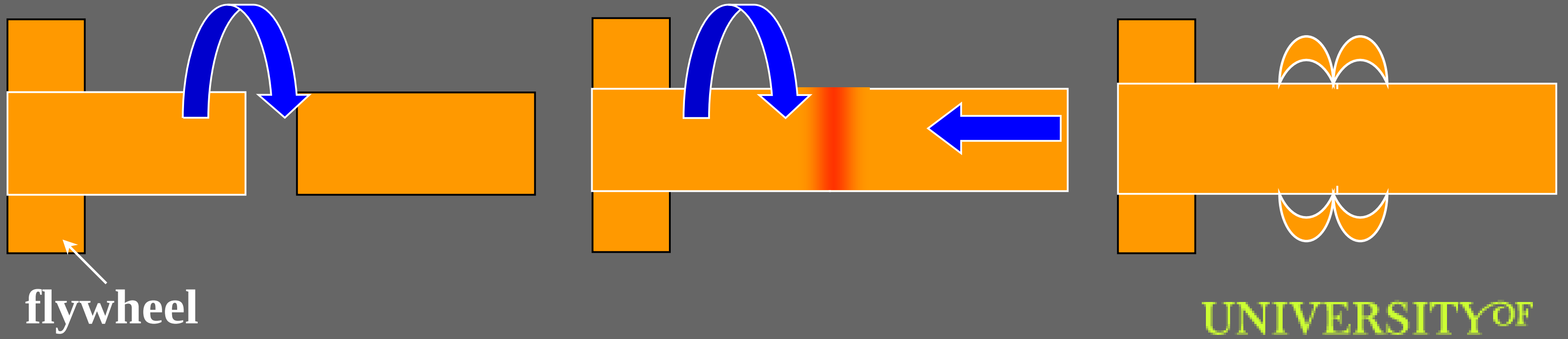
Inertia Friction Welding

- solid-state joining process
- energy of a rotating flywheel is conserved into frictional heating to join cylindrical components
  - rotating part attached to the flywheel
  - axial pressure applied to stationary cylinder
  - weld formed



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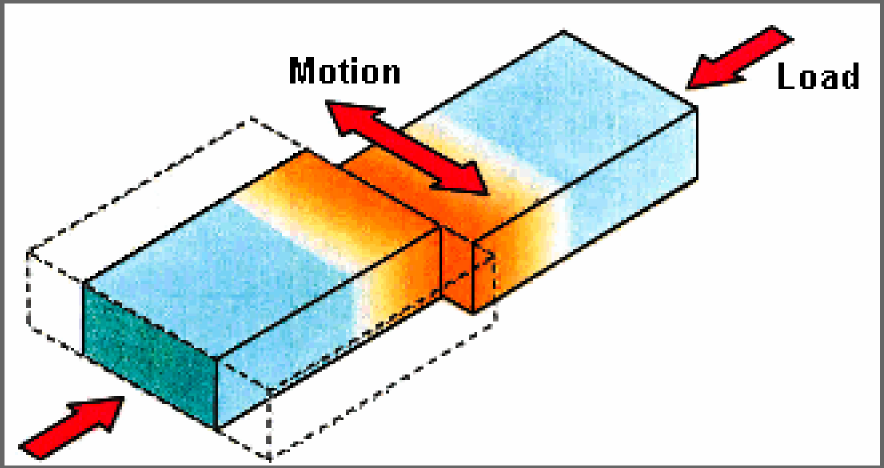
Linear Friction Welding

- A solid-state joining process
- frictional heat generated is utilised to join two rubbing components under an axial pressure, one of which is rigidly clamped, while the other moves in a reciprocating manner while in contact.



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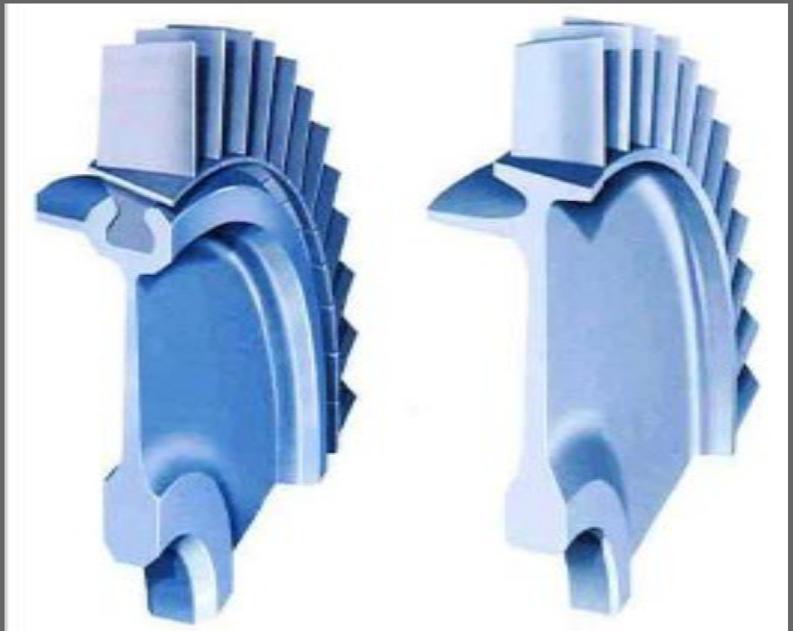
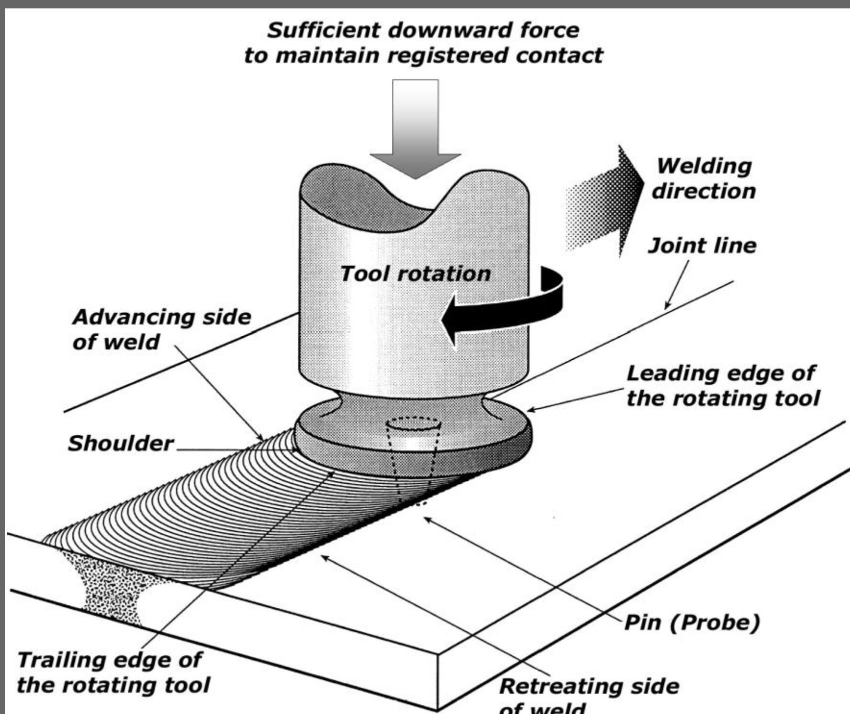
Linear Friction Welding

- More efficient material usage cf machining.
- No melting, fewer oxides cf fusion welding
- Reduce weight → lighter engine structures



Friction Stir Welding

- solid-state joining technique
- applicability for Ti is being investigated



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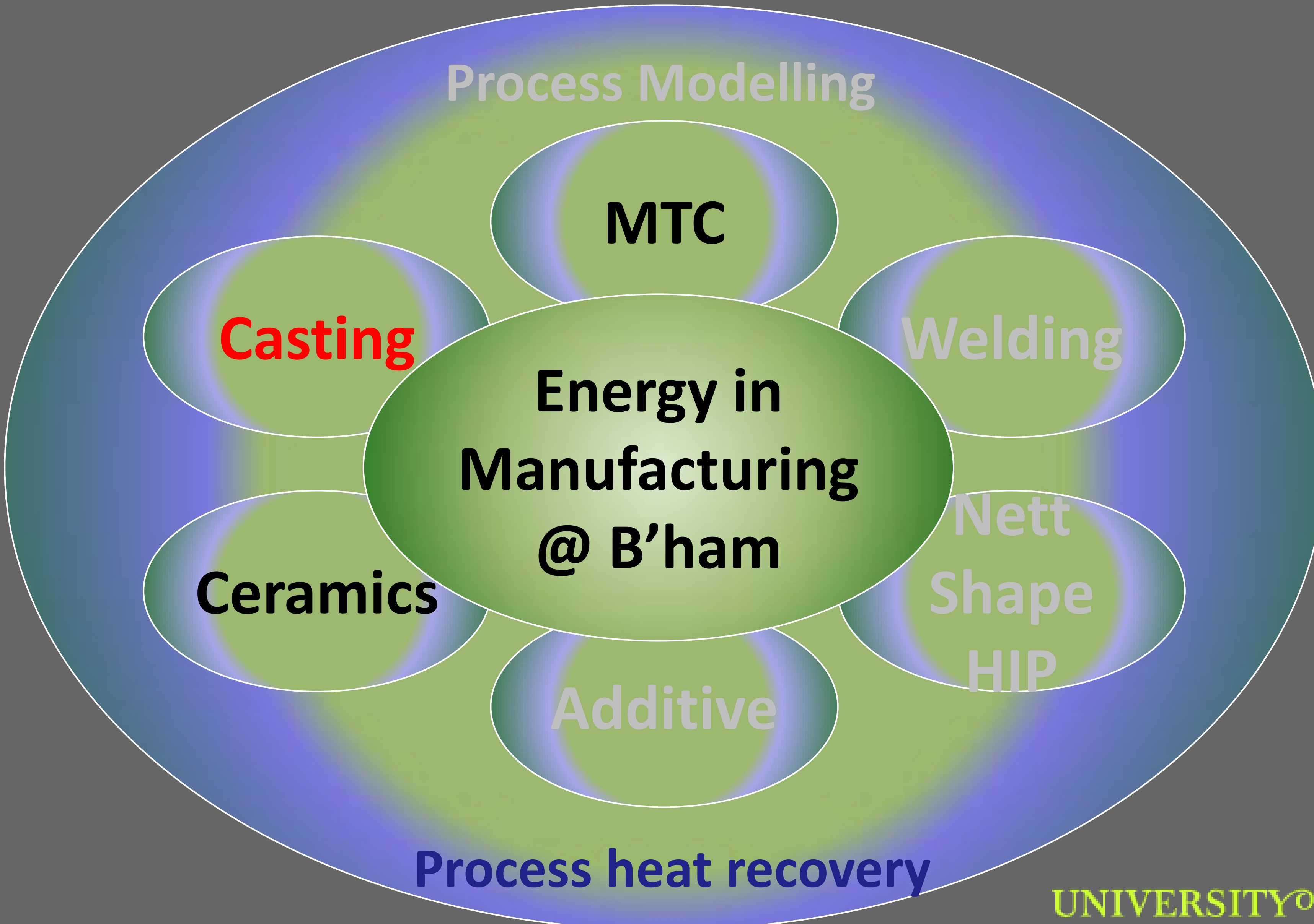

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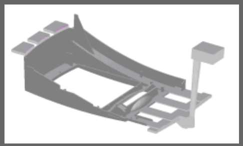
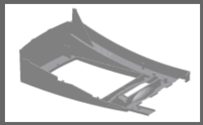
PYTHON CRANES

input

Energy Input
To raise to Tm+100°C
Al & Mg ≈ 1.1 GJ/tonne
Cu ≈ 0.7 GJ/tonne

metal flow





output

Charge	Melting Furnace	Holding Furnace	Metal cleaning	Casting process	Finishing	Finished Casting
Ingot or DC cast billet In-house returns from scrap and machining	Tower Bale out* Crucible* Induction (Oil, gas or electricity)	Bale out* Crucible* Induction (*Gas or electricity)	Degassing Drossing off	Gravity Counter-gravity Pressurised Mould material Sand Ceramic Metallic	Fettling Grinding Machining	Quality Inspection

losses

	Melting Furnace	Holding Furnace	Metal cleaning	Casting process	Finishing	Finished Casting
losses	Oxidation (2%by wt) Conduction Radiation (50% Furnace efficiency claimed)	Oxidation (2% by wt) Conduction Radiation (55% Furnace Efficiency)	Oxidation (2% by wt) Conduction Radiation		Fettling (up to 60% by wt) Grinding and machining (up to 25% by wt)	Scrap (up to 20% by wt)
Aggregated Energy required to produce 1 tonne Al castings (GJ)	2.20 Efficiency 2.25 Losses	42.0 Holding 42.8 Losses	43.7 Degassing		109 Fettling 146 Machining	182 Scrap

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CRIMSON: Aim and Objectives

To quantify and model the energy savings achieved by a novel single shot casting process and compare with traditional foundry process routes.

- Heat in bulk metal melting, holding and transfer
- Energy in post-casting processes
- Comparison of: scrap, quality and yield

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CRIMSON: the process

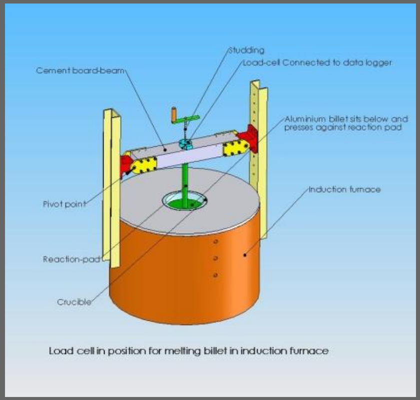
Constrained Rapid Induction Melting

- 10 kg in 90 s
- 33 kg in 300 s

- Reduced melt losses
- No holding losses
- Reduced H_2 absorption

Single shot net-shape casting

- Counter-gravity filling
- Significantly improved yields
- No mould material restrictions



Deliverables

- Understanding that could deliver 30% savings in energy
- Software tools that will help foundries achieve energy savings

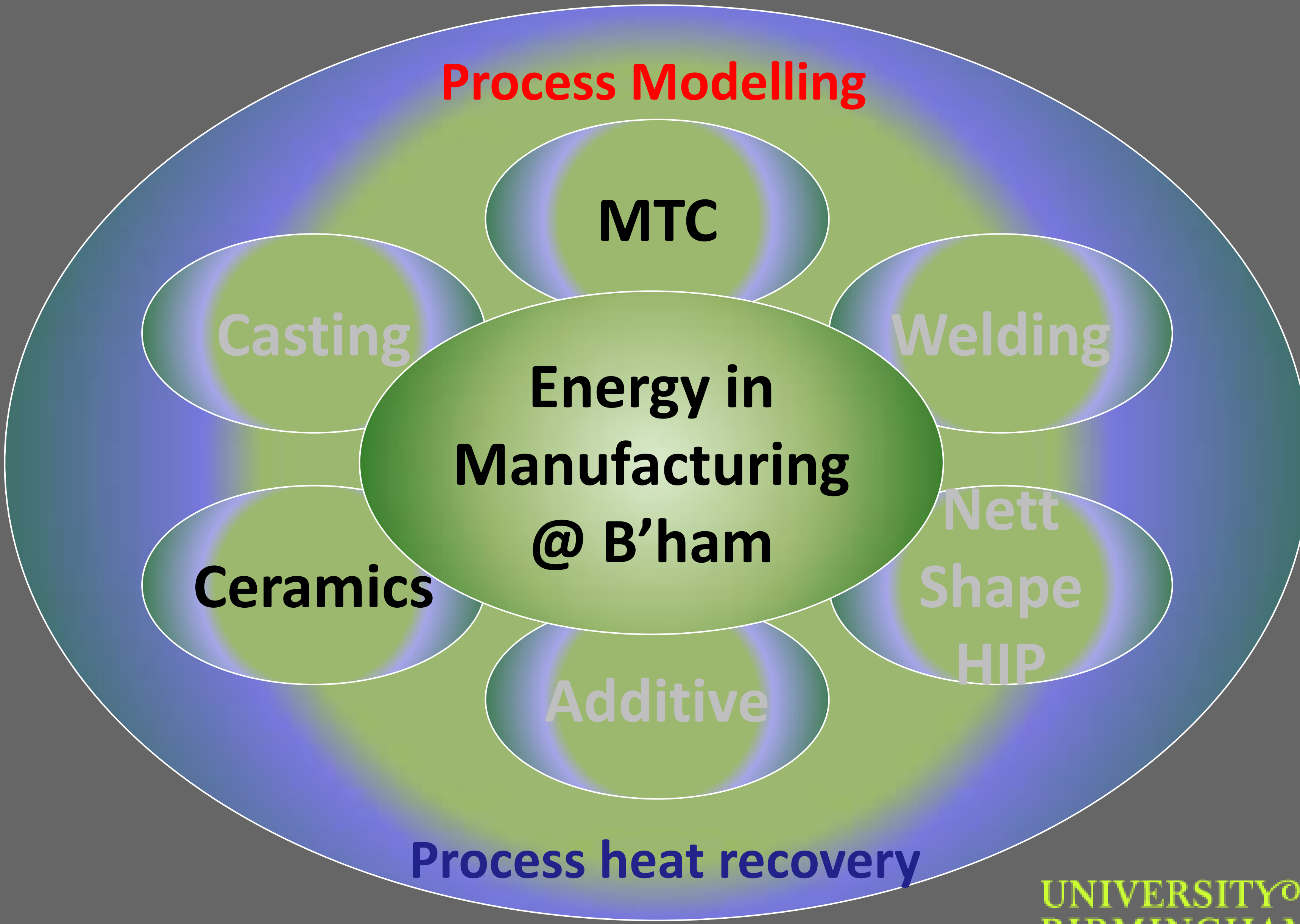
Crimson with added benefits

- No holding losses
- No degassing losses
- Box yield of 70%
- Internal scrap down to 10%

- OME 47%

Comparisons of Crimson to traditional processes

Process/Sector	Energy burden input Al (GJ/t)	OME (%)	Energy burden output Al (GJ/t)
Aerospace no recycling	55.1	5.5	1001
Aerospace with recycling	14.4	5.5	258
Automotive/General	25.0	27	93
Crimson no added benefits	18.8	30	63
Crimson with added benefits	18.8	47	40



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Numerical process modelling

- Wide range of software
- Mech Eng and Met & Mat
- Experience in
  - Metal casting (all processes)
  - Extrusion
  - Forging/forming
  - Machining
  - Vacuum Arc Re-melting
  - Welding
  - Polymer injection moulding
  - Ceramic extrusion
- Developing expertise in DLF

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Examples

- Aerospace casting
  - Investment cast Al alloy
  - Current yield 5-10%
  - Improved yield to 55%
  - Concomitant energy savings
- Medical Prosthetic Casting
  - Investment cast CoCr Mo alloy
  - reduced oxide formation crucible
  - reduced inclusions from 45% to below 20%
  - Saving of order of €100k
  - ↓rework ↑ productivity → + €150K
  - Concomitant energy savings

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Examples

- Glass making industry
  - KTP redesign charging equipment
  - Model thermal and mass flows
  - Objectives
    - Reduce water usage
    - Reduce energy consumption
    - Improve life of components

Summary

- UoB Academics
  - Expertise in a wide range of processes
  - Support with Process and Materials Modelling
  - Links through networks to wider expertise
- UoB facilities
  - Wide range of process capabilities
  - Edgbaston
  - Manufacturing Technology Centre (Ansty)

Philosophy (1)

Improve material efficiency

Reduce scrap

Improve quality

Reduce losses

↓

Direct reduction in energy of manufacture

without loss of integrity of product

Philosophy (2)

Energy recovery

Waste heat recycling

Direct reduction bought-in energy

The academics

- Dr Nick Adkins
- Dr Moataz Attallah
- Dr Brian Connolly
- Dr Mike Ward
- Prof. Nick Green
- Dr Bill Griffiths
- Prof Stuart Blackburn
- Dr Jean-Christophe Gebelin
- Dr Leung Soo
- Prof Trevor Dean

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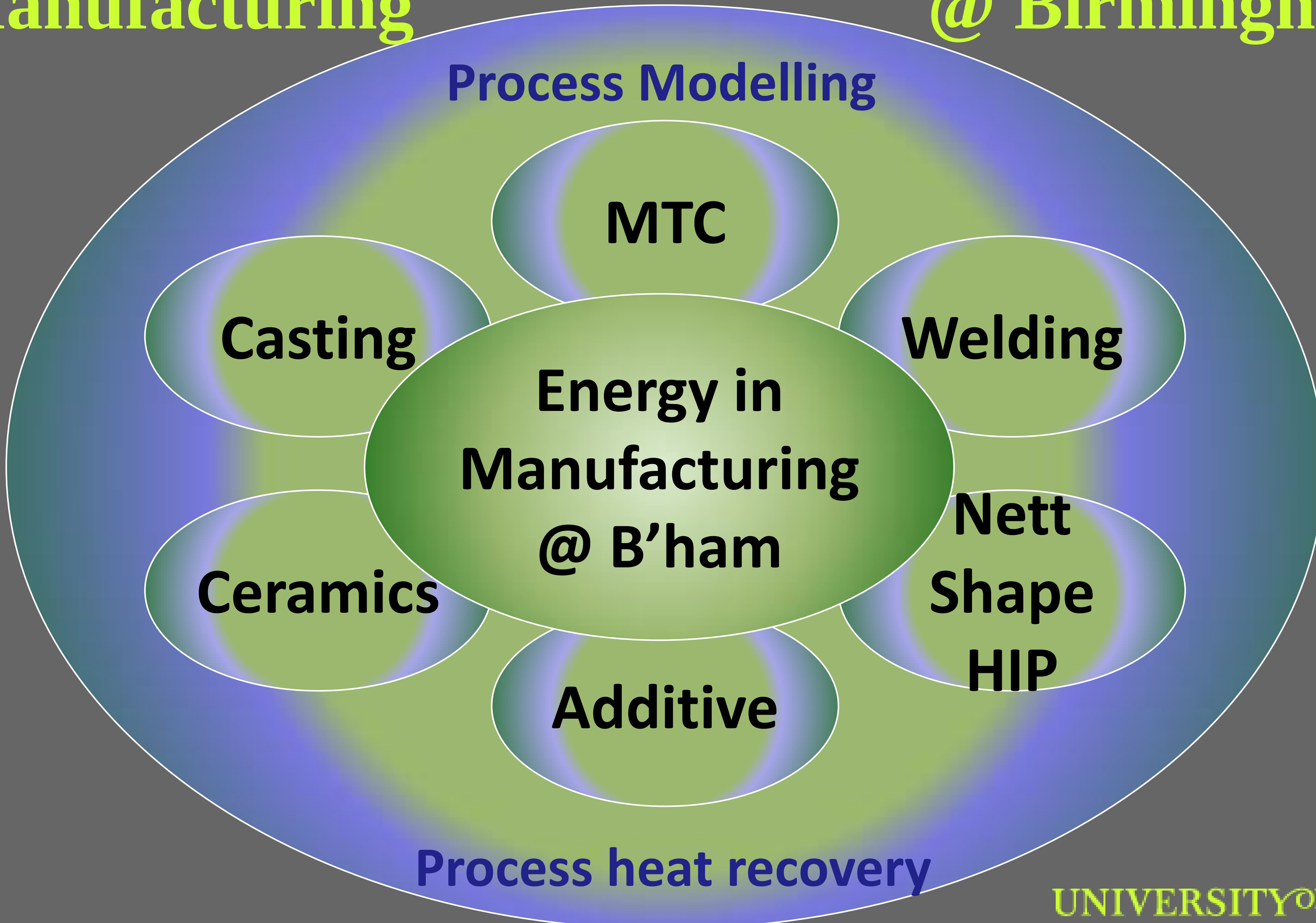
Manufacturing @ Birmingham



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