South Eastern Applied Materials Research Centre

Waterford Institute of Technology
INSTITIÚID TEICNEOLAÍOCHTA PHORT LÁIRGE

# Energy Conservation through Metal Additive Manufacturing & What SEAM can offer for Irish industries in Metal AM

## Presented at Energy Symposium , Cong-Mayo 14th October 2016


**Dr. Ramesh Raghavendra,**
**SEAM Centre Director & Technology Gateway Manager**



Ireland's EU Structural and Investment Funds Programmes 2014 - 2020
Co-funded by the Irish Government and the European Union
EUROPEAN REGIONAL DEVELOPMENT FUND
ENTERPRISE IRELAND where innovation means business
TECHNOLOGY GATEWAYS delivering solutions for industry
SEAM - Engineered Material Technologies
an Enterprise Ireland network

# Presentation Outline

- SEAM- Brief Introduction
- Energy conservation through Additive Manufacturing –Introduction
- What is Additive Manufacturing?  Concept & Principles
- Why Additive Manufacturing?
- Benefits  & Classical Examples of Energy conservation through Metal AM
- What SEAM can offer in Metal AM?

# SEAM – A Brief Introduction

- **SEAM is a Materials Science and Engineering Research Centre within School of Engineering, WIT**

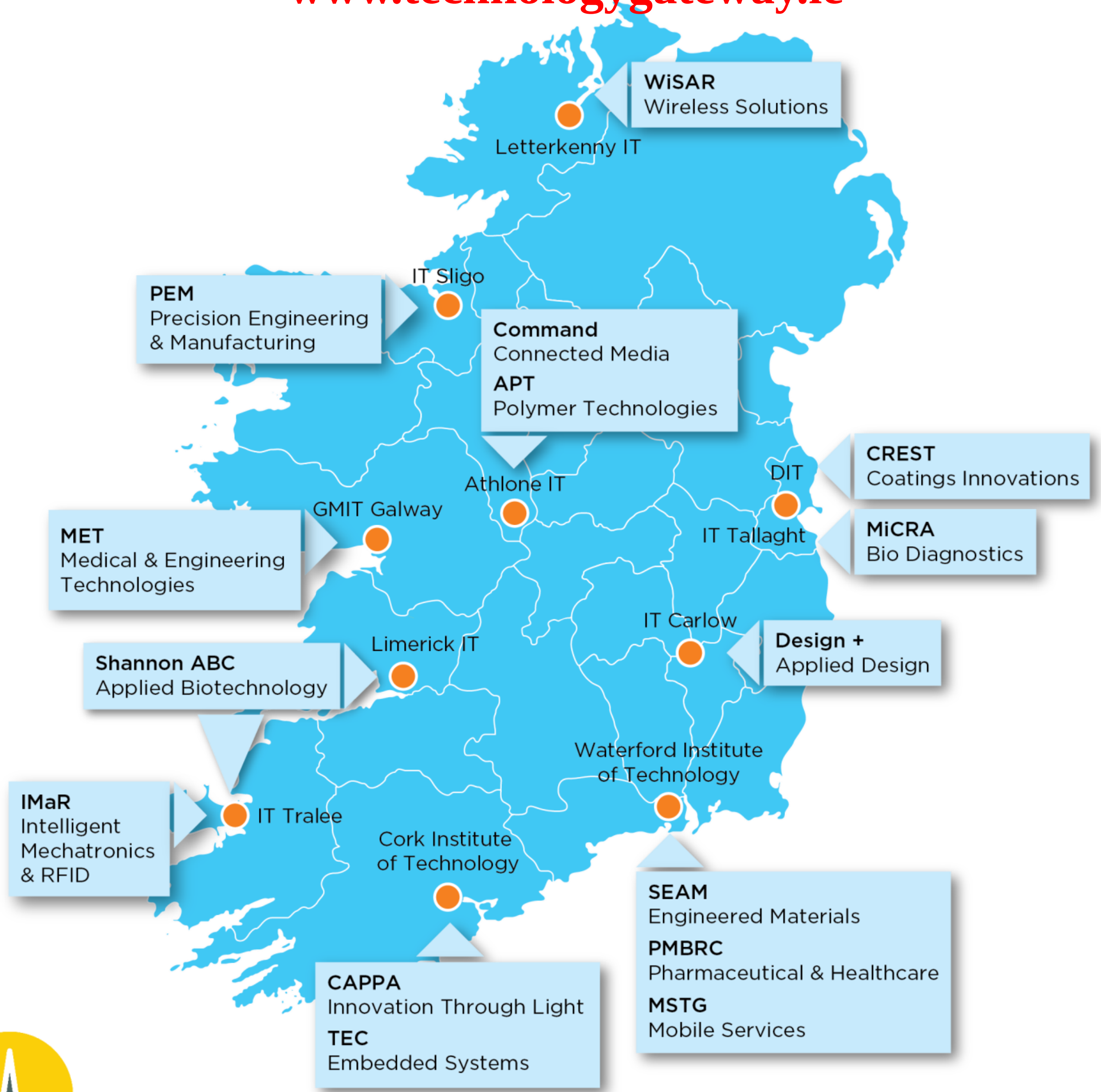
- **Formally launched in Feb. 2009**

- **SEAM currently is part of EI Technology Gateway Network, a nationwide resource for industry based in the IoTs delivering solutions on near to market problems for industrial partners**


SEAM

# Technology Gateway Centre Locations in Ireland

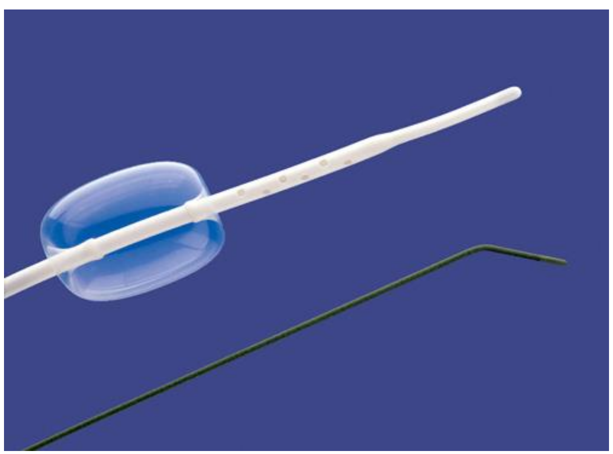
# www.technologygateway.ie

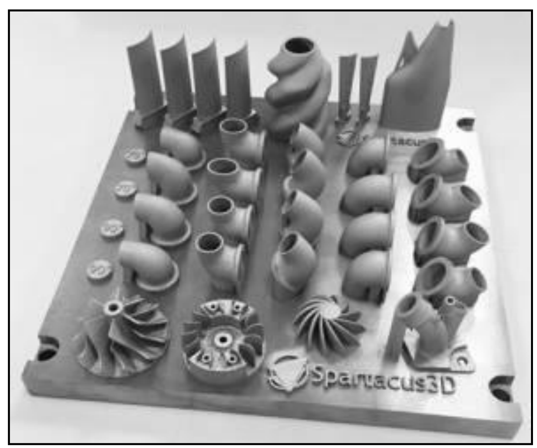


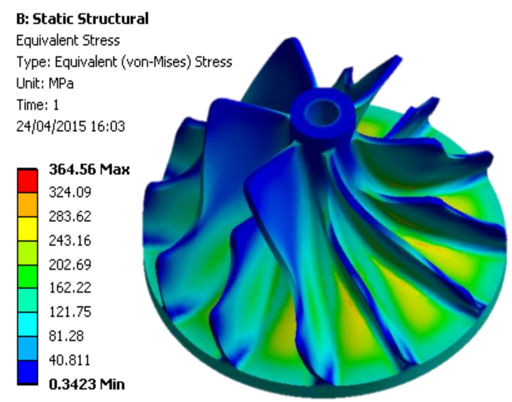
# What does SEAM do ?

- **Provide unique world class professional services in terms of delivering innovative Engineered Material solutions**

- **Resolves day to day bread and butter issue of industries using the latest technologies to deliver real solutions for real problems**



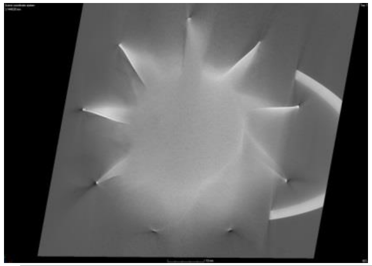


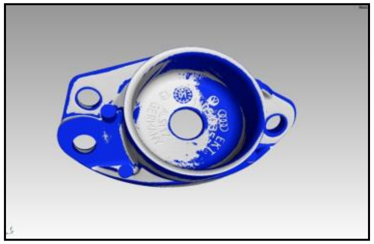



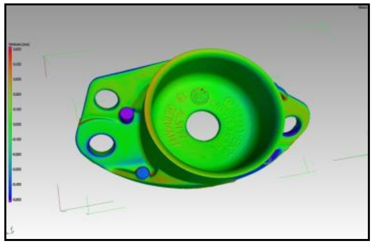
# Unique Selling Point of SEAM Gateway

## (Core capabilities)

**Centre of Excellence in X-ray Tomography (CT) Applications**

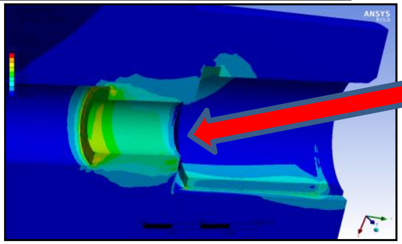






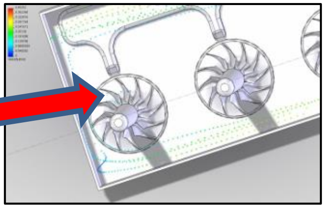
Actual and 3D Component overlaid

**Expertise in Finite Element Analysis & Computational Fluid Dynamics**



Stress analysis

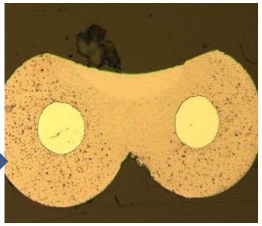
Fluid Dynamics



**Expertise in Failure Analysis & Mitigation strategies**

Inspect

X-section Analysis



**Key solutions One stop shop**

## Metal AM:Offering Full Design to Prototyping Service

### Design & Optimise

- Concept Development
- 3D CAD Modeling
- FEA & 3D Scanning

### Build

- AM Metal Prototyping
- Heat Treatment
- Surface Finishing

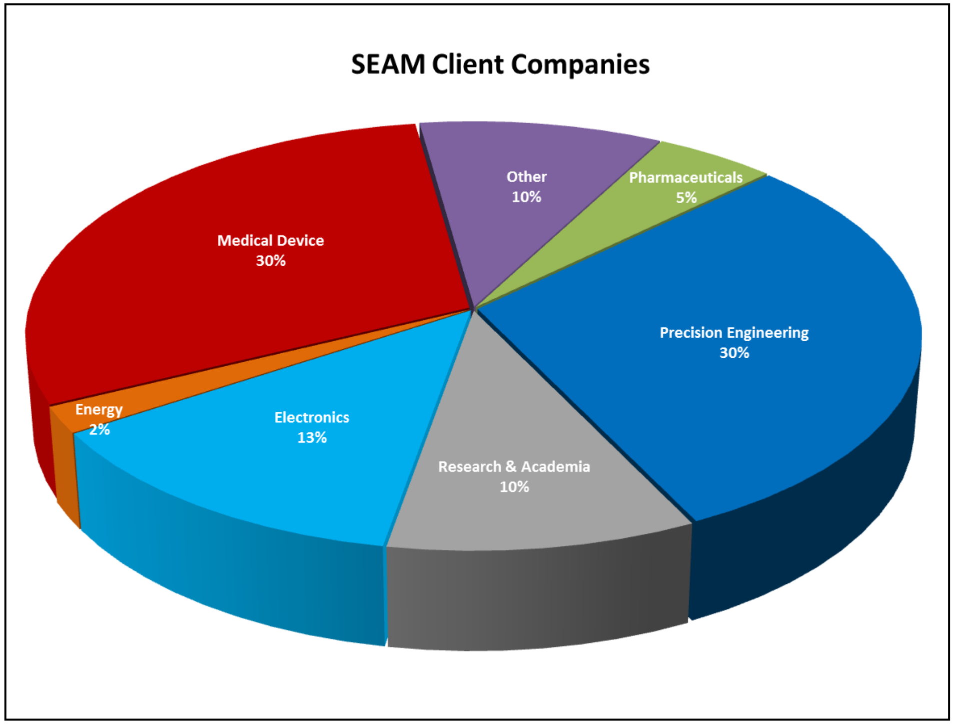
### Verification

- Destructive & Non-Destructive Testing
- Metrology
- Validation Testing
- Finished Part

# SEAM's Key Accomplishments

## 1. Impeccable Industry Collaborative Record

- Established collaborations with over 130 Irish Based Industries / RPO
- Executed over 975 direct funded Industrial projects since 2009
- Now one of the leading Technology Gateway Centres in the country

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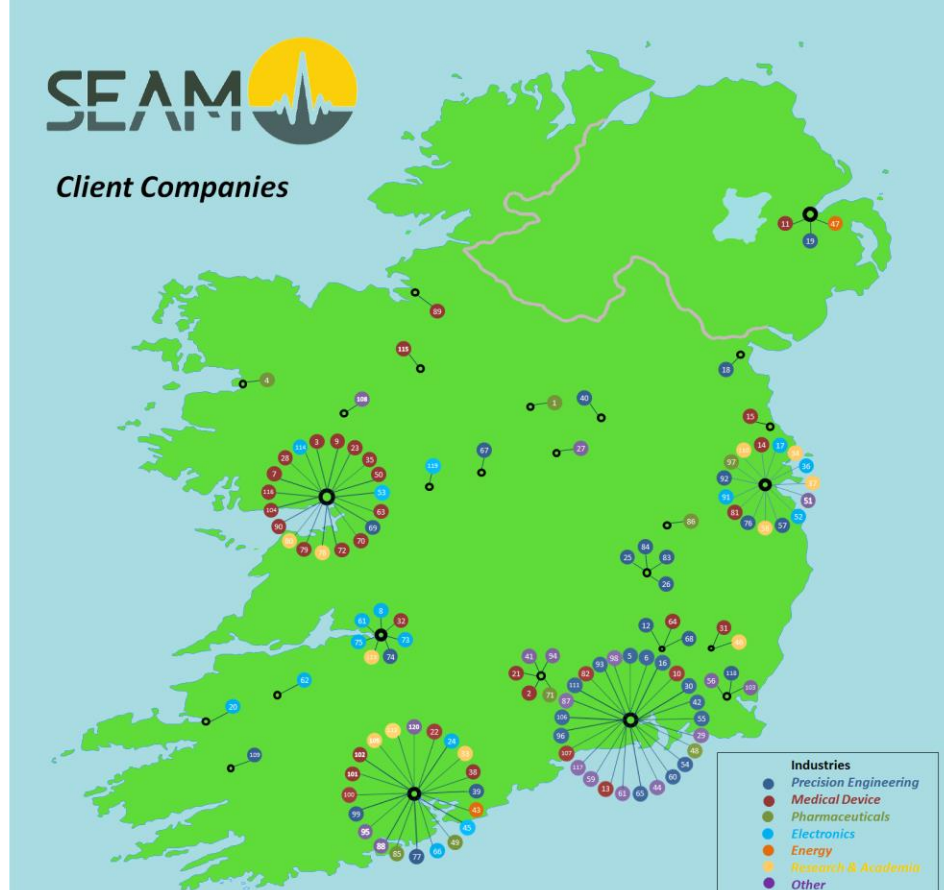
# 2. SEAM Client base grown from zero to >130 in 7 years




1. Abbott Diagnostic
2. Abbott Vascular
3. Aerogen
4. Allergan
5. Allied Turned Parts Ltd
6. Allsop Europe Ltd
7. Alt Surgical
8. Analog Devices
9. Anecto Ltd
10. APS Materials
11. ARC Devices
12. Atto Abrasives Ltd
13. Bausch & Lomb
14. BD Components, Drogheda
15. BD Components, Dublin
16. Blacksmith Stoves
17. Blue Bridge Technologies
18. Blueacre Technology
19. Bombardier
20. BorgWarner BERU Systems
21. Boston Scientific, Clonmel
22. Boston Scientific, Cork
23. Boston Scientific, Galway
23. Bourns Electronics
25. Burnside Autocyl Ltd
26. Burnside Eurocyl Ltd
27. C&F Automotive Ltd
28. Capsos Medicals
29. Cartamundi
30. Carten Controls Ltd
31. Clearstream Technologies
32. Cook Medicals
33. Cork Institute of Technology
34. CREST DIT
35. Crospon Ltd
36. Curtis-Wright Control
37. DCU
38. Depuy
39. DexGreen
40. Dromone Engineering
41. Dunnes Sawmills
42. ECO Burner
43. ESB International
44. Eurobase Ltd
45. Excelsys Technologies Ltd
45. FF Conservation Services
46. GE (Energy)
47. Genzyme
49. Gilead Sciences
50. Goodman Medical
51. Henkel Ltd
52. Hewlett Packard
53. HID Global
54. Honeywell Engines & Systems
55. Honeywell Turbo Technologies
56. IDH Cables Ltd
57. Innalabs Ltd
58. IT, Tallaght
59. Kavanagh Lighting & Electrical
60. Kel-Tech Engineering
61. Kenlis Construction
62. Kostal Ltd
63. Lake Region Medical, Galway
64. Lake Region Medical, Wexford
65. Lisnabrin Engineering Ltd
66. Logitec
67. Lund Precision Products Ltd
67. Mann Engineering
68. Measurement Specialties Ltd
69. Medtronic Ireland
70. Merck (MSD)
71. Merit Medicals Ltd
73. MicroSemi Ireland
74. Mincon
75. Molex
76. Moog
77. MTD Precision Engineering
78. NCLA
79. Novate Medical Ltd
80. NUIG
81. Nypro Healthcare, Bray
82. Nypro Healthcare, Waterford
83. Oglesby & Butler
84. PB Machine Tech Ltd
85. Pfizer/Wyeth, Cork
86. Pfizer/Wyeth, Newbridge
87. PPI Adhesive Products Ltd
88. Proteck Performance Plastics Ltd
89. Protek Medical Ltd
90. Proxy Biomedical
91. Realtime Technologies Ltd
92. Renishaw
93. REXAM
94. ROCG Consulting
95. Sanmina
96. Schivo Group
97. Sigmoid Pharma
98. SmartPly
99. SR Technics
100. Stryker Instruments
101. Stryker Neurovascular
102. Stryker Orthopaedics
103. Sulzer
104. Synecco
105. Teagasc
106. Tegan Innovations Ltd
107. Teva Pharmaceuticals
108. Theta Chemicals
109. Tricel Ltd
110. Trinity College Dublin
111. Trio Engineering Co Ltd
112. University College Cork
113. University of Limerick
114. Valeo Vision Systems
115. Vention Medical Ireland Ltd
116. Veryan Medical Ltd
117. Waterford Stanley
118. Waters Technologies Ltd
119. Western Automation
120. WiseTeK Solutions Ltd

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Lake Region Medical

ESB International — ESBI Energy Innovation

Mincon

TEVA

Nypro — Where success takes shape

Pfizer

**SEAM currently assists over 130 companies in Ireland**

# 3. Awards

- For our services to Industries, Won **Knowledge Transfer Ireland** Award 2015 (Like Oscars for research centres !!) under Industrial Consultancy Impact category

- Shortlisted for Research to Business KTI Collaborative Award 2016

# Energy Conservation through Additive Manufacturing (AM)

## Introduction

- Climate change reports and policies (Kyoto Protocol, Paris Agreement 2015 etc) relating to energy are causing manufacturers to examine the viability of Digital Manufacturing operations closely.

- Several reports (Eg.Wohlers) have pushed the economic and environmental benefits of AM and claims:

AM holds the potential to reduce carbon footprint and energy emissions through design optimization and the reduction in the material waste stream.

Advanced AM techniques shown to reduce energy consumption up to 35% of the energy required to manufacture the parts using traditional manufacturing processes.

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# What is Additive Manufacturing?

- **Additive Manufacturing** refers to a process by which digital 3D design data is used to build up a component in layers by depositing material.
- The term "3D printing" is increasingly used as a synonym for **Additive** Manufacturing.

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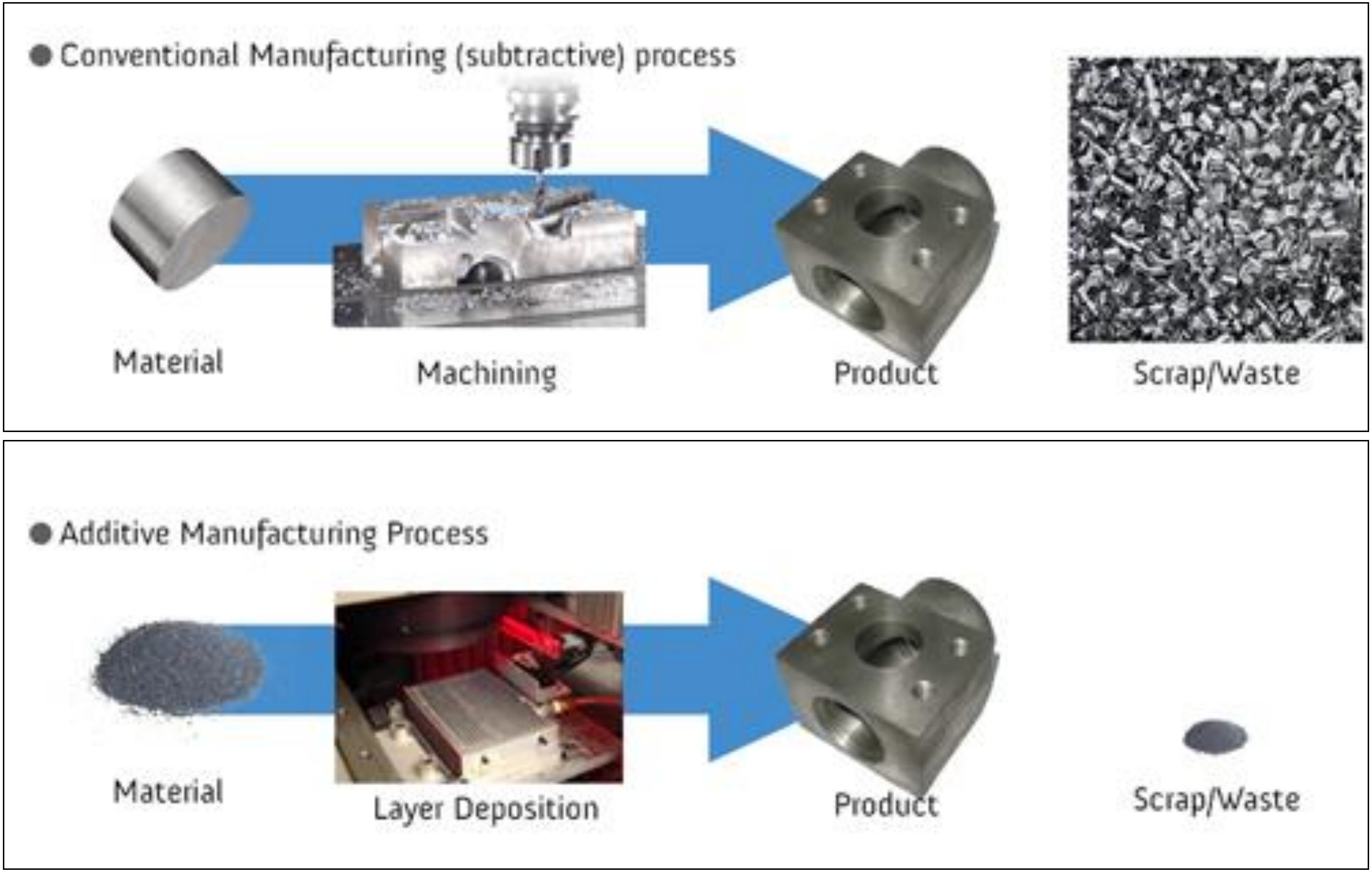
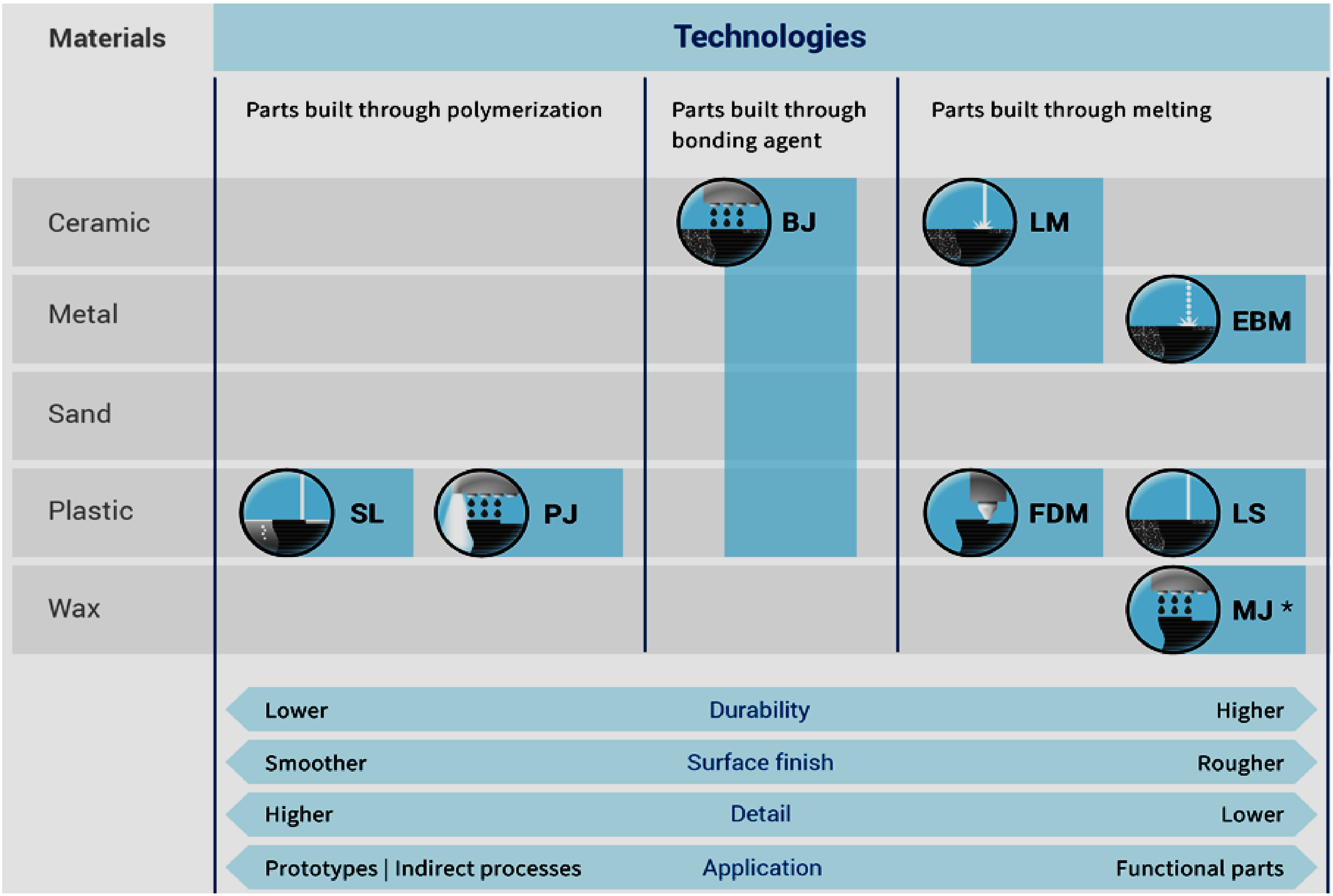
# AM Manufacturing Process Vs Conventional



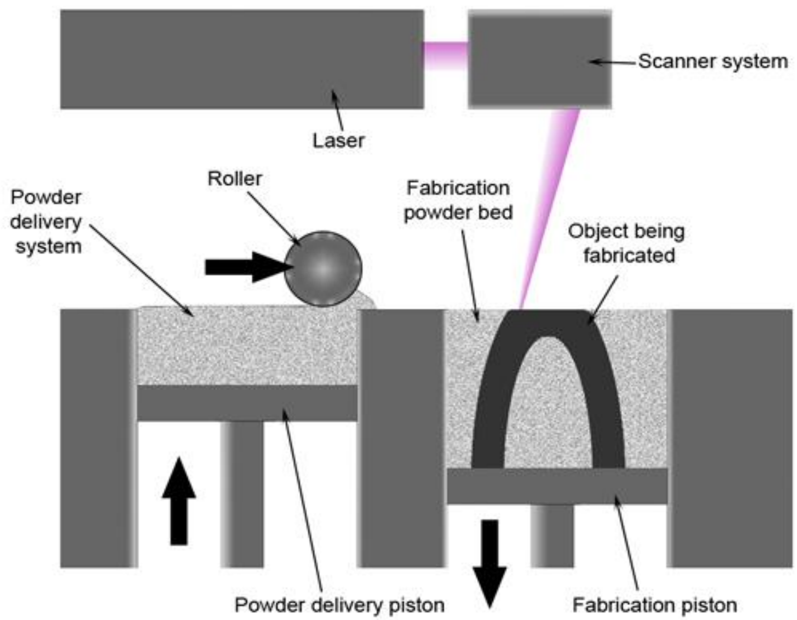
# Overview of Key 3D Printing Technologies

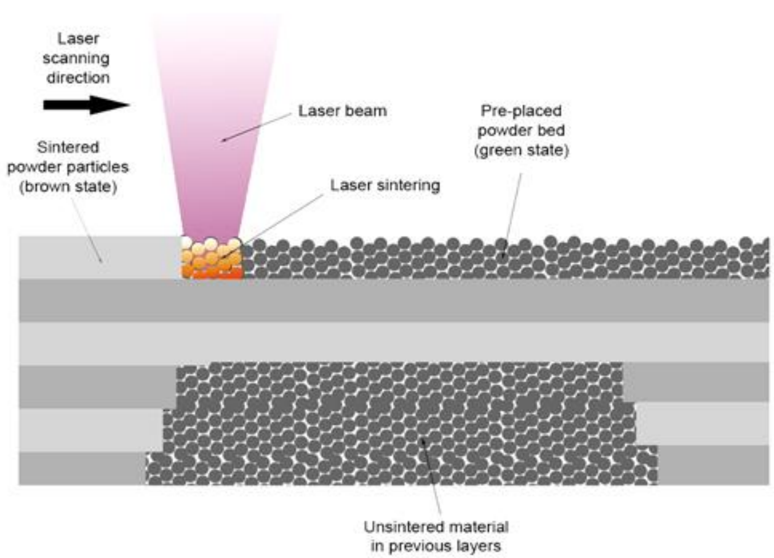



Source: www.additively.com

# 3D Metal Printing (SEAM has EOS M280)

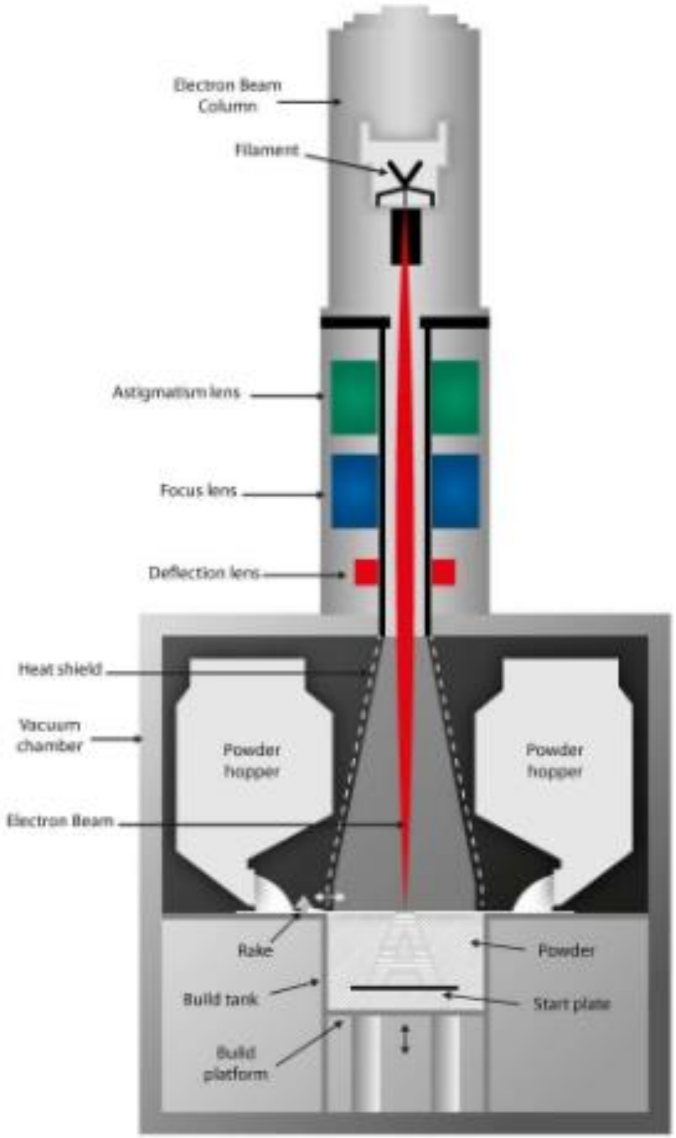
# Principles of Direct Metal Laser Sintering (DMLS)




- DMLS uses laser to selectively fuse metal powder by scanning cross-sections generated from 3-D CAD data on a powder bed surface.
- After each cross-section is scanned, the powder bed is lowered by one layer thickness, a new layer of material is applied on top, and the process is repeated until the part is completed.
- Characteristics: Build envelope: 250x250x300mm; Min. Feature size: 0.1-0.2mm; Min Layer thickness: 0.03mm; Typical surface finish-4-10μm; Density-99.9%

# Electron Beam Melting




ARCAM-Q20 EBM

Electron beam melting is similar to laser melting, but working with an electron beam instead of a laser. The machine distributes a layer of metal powder onto a build platform, which is melted by the electron beam.

General Characteristics

1. Build Envelope: 350x350x380mm
2. Min Feature Size: 0.1mm
3. Typical tolerance: ± 0.2mm
4. Min Layer thickness- 0.05mm
5. Typical surface finish = 20-25 μm (can be improved through post processing
6. Density= 99.9%

# Why Additive Manufacturing?

1. **Lowers energy consumption:** By eliminating production steps, using substantially less material and producing lighter products.

**2. Less Waste:** Building objects up layer by layer reduces material needs and costs by up to 90%. AM also reduce the 'cradle-to-gate'- environmental foot prints of component manufacturing through avoidance of the tools, dies, and materials scrap associated with CM processes.

**3. Reduced time to market:** Items can be fabricated as soon as the 3-D digital description of the part has been created, eliminating the need for expensive and time-consuming part tooling and prototype fabrication.

**4. Innovation:** AM enables designs with novel geometries (that would be difficult or impossible to achieve using CM processes) that can lead to performance and environmental benefits in a component's product application

# Why AM contd…

**4. Part Consolidation:** Ability to design products with fewer, more complex parts is the most important of these benefits. Reducing the number of parts in an assembly immediately

(a) cuts the overhead associated with documentation and production planning and control.

(b) Fewer parts mean less time and labor required for assembling the product resulting lower manuf.costs.

© Foot print of the assembly may also become smaller further cutting costs

**5. Lightweighting**

**6. Agility to manufacturing operations:** AM enables enable rapid response to markets and create new production options outside of factories. Spare parts can be produced on demand, reducing or eliminating the need for stockpiles and complex supply chains

# Classic AM Examples that result in Energy conservations

# Example 1: GE Leap Engine Fuel Nozzle
## (Co-Cr part produced using DMLS)

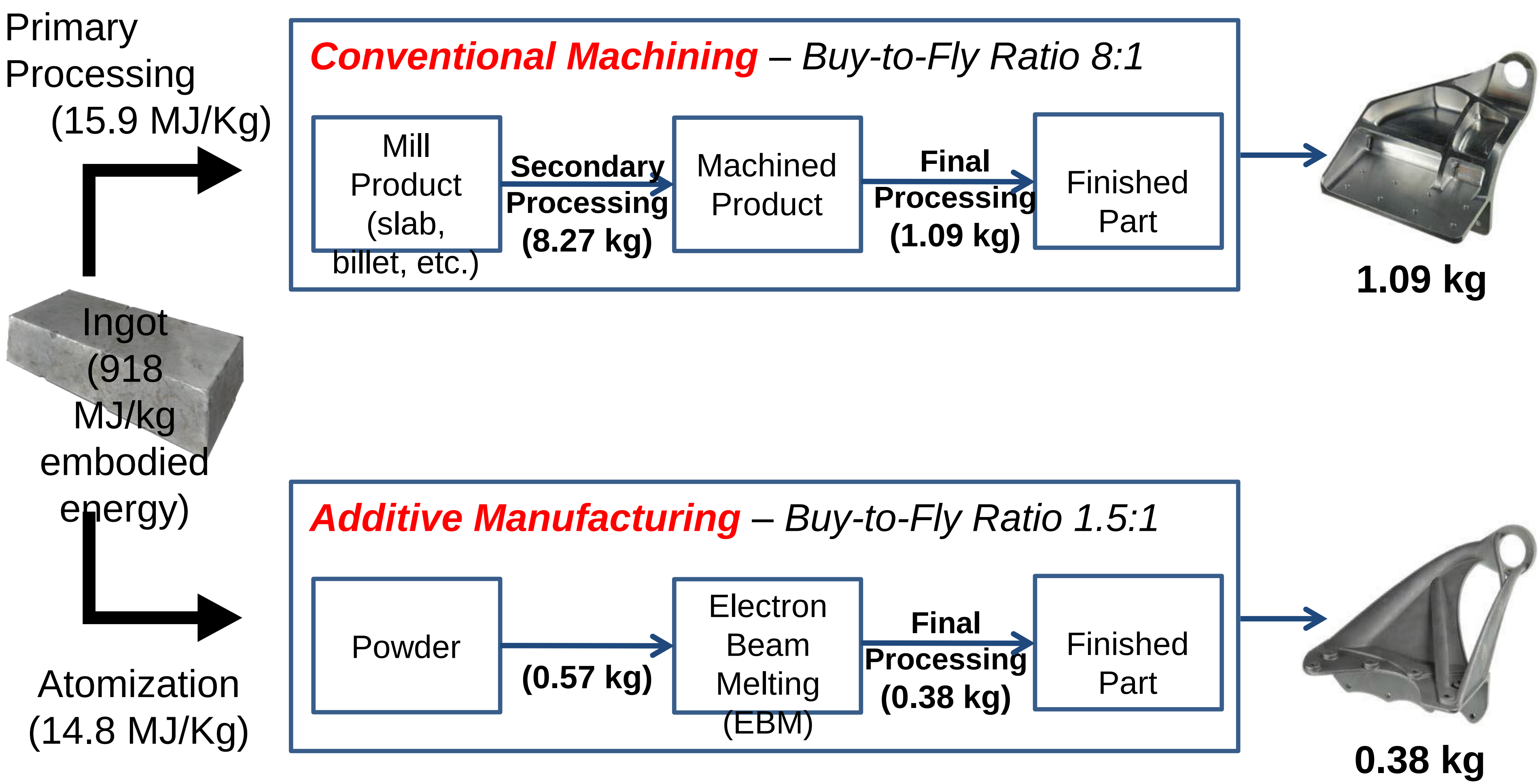
Key Advantages:

1. Combining 20 piece parts into one.
2. 5× more durable due to greater design freedom
3. 25% less weight
4. Further cost reductions arising from design optimization for AM process.

Note: (a) Leap is GE Aviation's best selling engine in history.
(b) GE's new $50m plant in Auburn (Germany) is a dedicated AM facility built to meet demand.

Source: Worlds first plant to print jet engine nozzles in mass production, July 15, 2014. (http://www.gereports.com/post/91763815095/worlds-first-plant-to-print-jet-engine-nozzles-in).

# Example 2: Manufacturing of Aircraft Bracket




***Source: US Department of Energy Report***

# Aircraft Bracket Manufacturing contd…

| Process | Final Part (kg) | Ingot consumed (kg) | Raw Material (MJ) | Manufa cturing (MJ) | Transport (MJ) | Use Phase (MJ) | Total Energy per Bracket (MJ) |
|---|---|---|---|---|---|---|---|
| **Conventional Machining** | 1.09 | 8.72 | 8,00 | 952 | 41 | 217,95 | **226,945** |
| **Additive Manufacture** | 0.38 | 0.57 | 525 | 115 | 14 | 76,28 | **76,937** |

***Source: US Department of Energy Report***

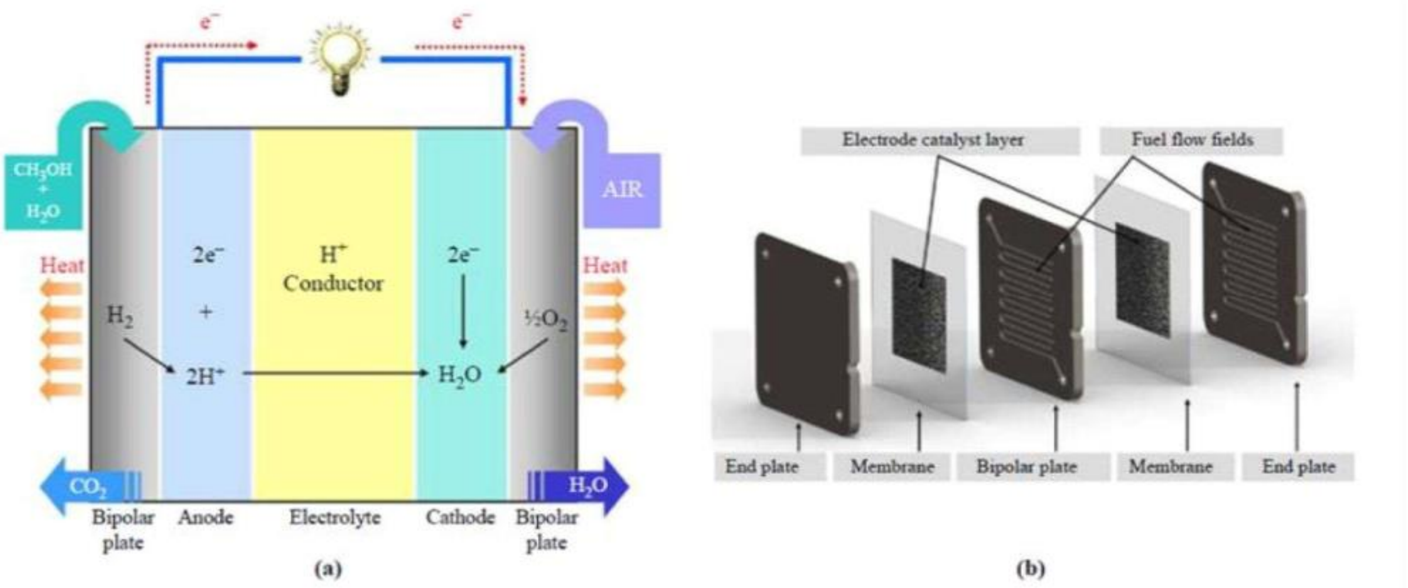
# Example 3: Aircraft Buckle manufacture

| Traditional Design | AM Optimized Design |
| --- | --- |
|  |  |

- A conventional steel buckle weights 0.34 lb (or 0.26 lb when made of aluminum)
- Titanium buckle designed with AM weighs 0.15 lb – reduction of 55%
- For an Airbus 380 with all economy seating (853 seats), this would mean a reduction of 160 lbs
- Over the airplane's lifetime, 872 thousand US gallons of fuel or approx. US$2.3 million could be saved, assuming a saving of 5,390 gallon per lb and airplane lifetime
- Project partners are Plunkett Associates, Crucible Industrial Design, EOS, 3T PRD, Simpleware, Delcam, University of Exeter

Source:http://www.rolandberger.com/media/pdf/Roland_Berger_Additive_Manufacturing_20131129. pdf.

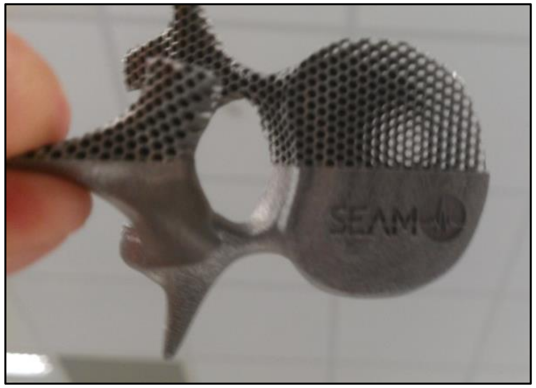
# Example 4: Manufacturing of Fuel Cells



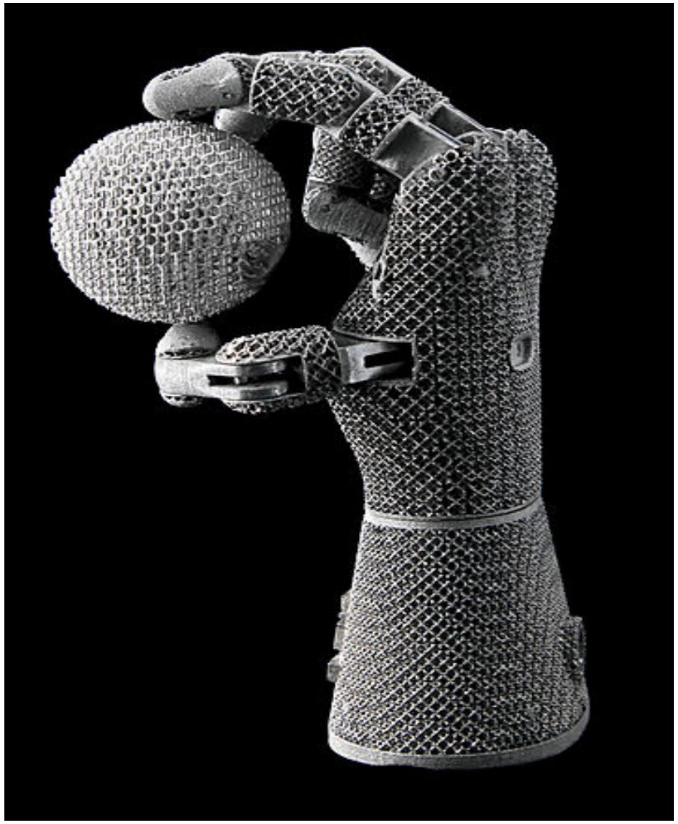

Graphite composite bipolar plate (important component in PEM fuel cell) produced by SLS process

NB: By using SLS the cost and lead-time of developing new bipolar plates can be reduced dramatically compared to conventional methods such as injection molding and compression molding, in which expensive metal molds have to be manufactured.

# Example 5: Implant  Manufacture


Vertebra/Honeycomb component produced in SEAM via AM



A Titanium prosthetic hand produced via AM  at Oak Ridge National Labortory

# AM holds great promise for Automotive Industry


AM is currently only used for prototyping and direct manufacturing of small, complex and non-safety relevant components within small series, as process reliability and consistency of products is still limited .

# Summary of Metal AM Current Status

- Today Industry are beginning to realise the advantage of AM to produce custom products without the cost, time, tooling, and overhead required in the traditional machining or manufacturing processes.

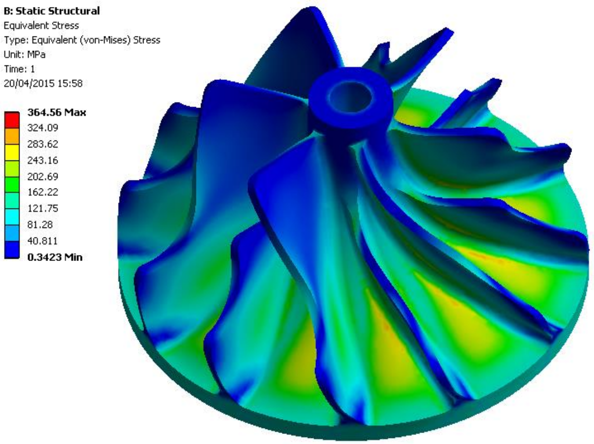
- AM technology is particularly advantageous in low-to-moderate volume markets (defense and aerospace) that regularly operate without economies of scale.

# What can SEAM can offer in Metal AM?

# Metal AM: SEAM Offers Full Design to Prototyping Service

## Design &Optimise

- Concept Development
- 3D CAD Modeling
- Finite Element Analysis
- 3D Scanning



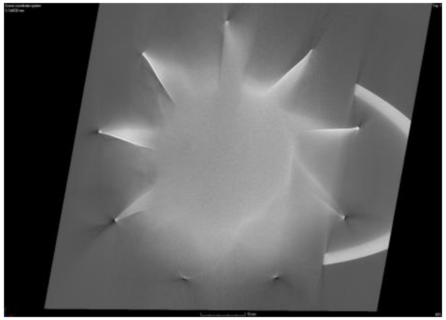

## Build

- AM Metal Prototyping
- Heat Treatment
- Surface Finishing

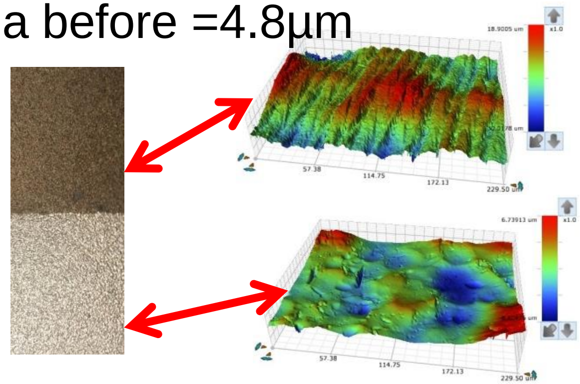
## Verification

- Destructive & Non-Destructive Testing
- Metrology
- Validation Testing
- Finished Part

CT inspection



Ra before =4.8µm



Ra after = 1.5 µm

# Build Process in SEAM: DMLS (EOS M280) System

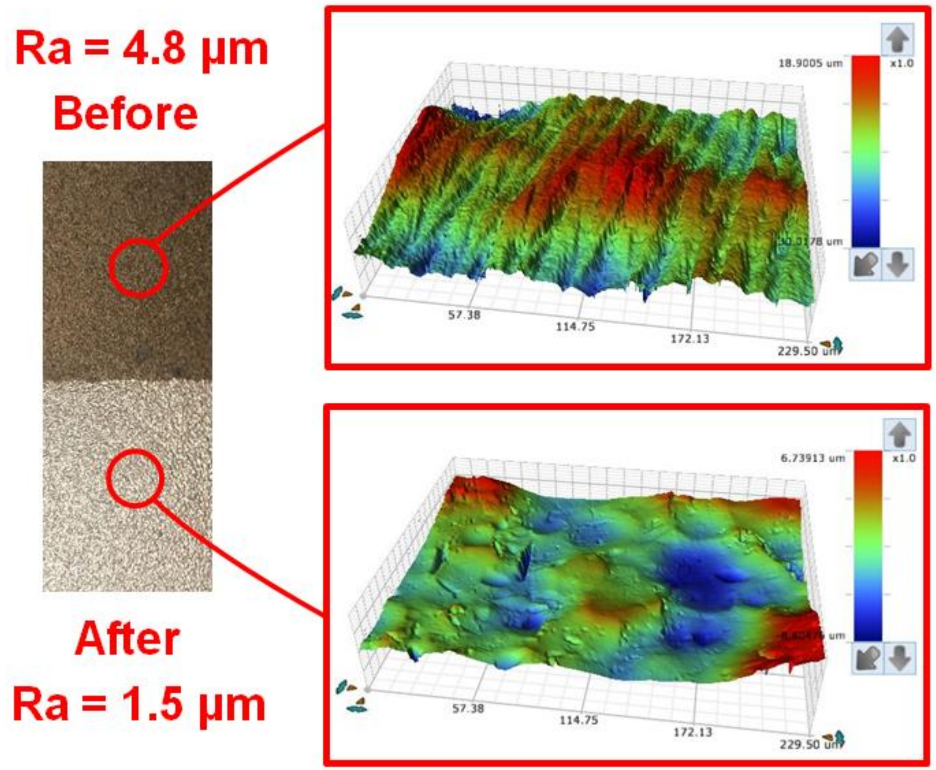
- System Spec;
  - 200 W Ytterbium fibre laser
  - Accepts 3D auto CAD .stl files
  - Build volume;
    250 x 250 mm by 300 mm high
  - Ability to optimise material parameters
  - Materials:
    - Maraging Steel – High strength, Easily machined, Post hardened (50 HRC).
    - 316L SS – Easily machined, Annealing not necessary, Good corrosion resistance.
    - Ti6Al4V – Light weight, Excellent corrosion resistance, Biocompatibility.
    - Nickel alloy IN718 – Good tensile and fatigue properties, Excellent at high temp.

**EOSINT M280**

# Surface Morphology; Pre and Post Processing

Micro shot peening via
Wet Blasting


Glass bead = 160 µm




Data from White Light
Interferometer

# Heat Treatment

- Heat treatment of Maraging Steel for example; 6 hrs - 490°.
- Hardness before and after age hardening = 34 RHC and 51 RHC respectively.

- Furnace capable of maximum temperature of 1280° and inert environment suitable for more exotic materials.

# SEAM has two walk–in CT Systems

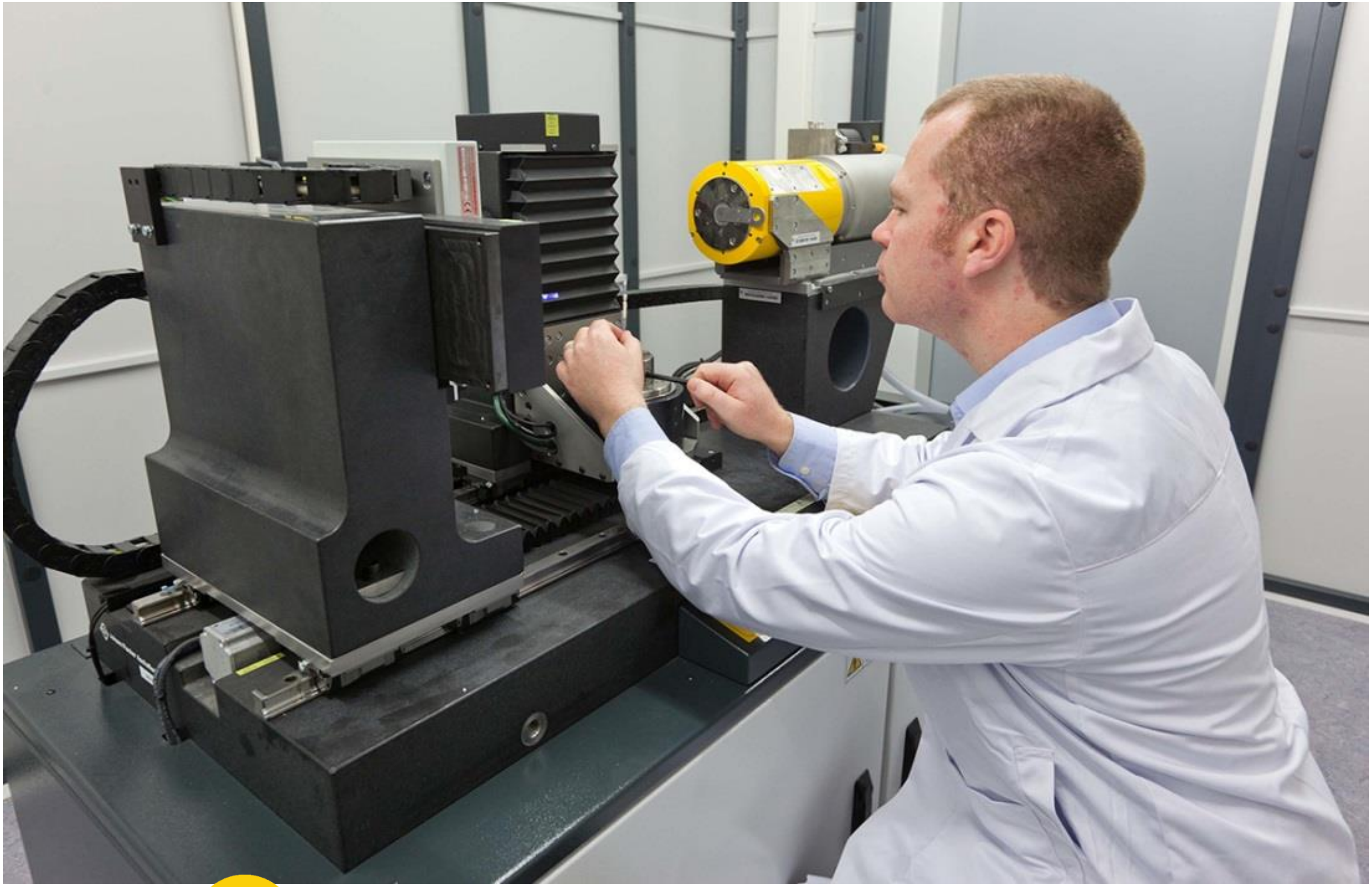

- Be used to generate require CAD Design files  for input to AM equipment
- Be used to validate AM printed parts
-  Determine the integrity and quality of the AM printed parts

180kV Nanotom

300kV Vtomex-L

SEAM

# 180kV Nanotom (CT system)



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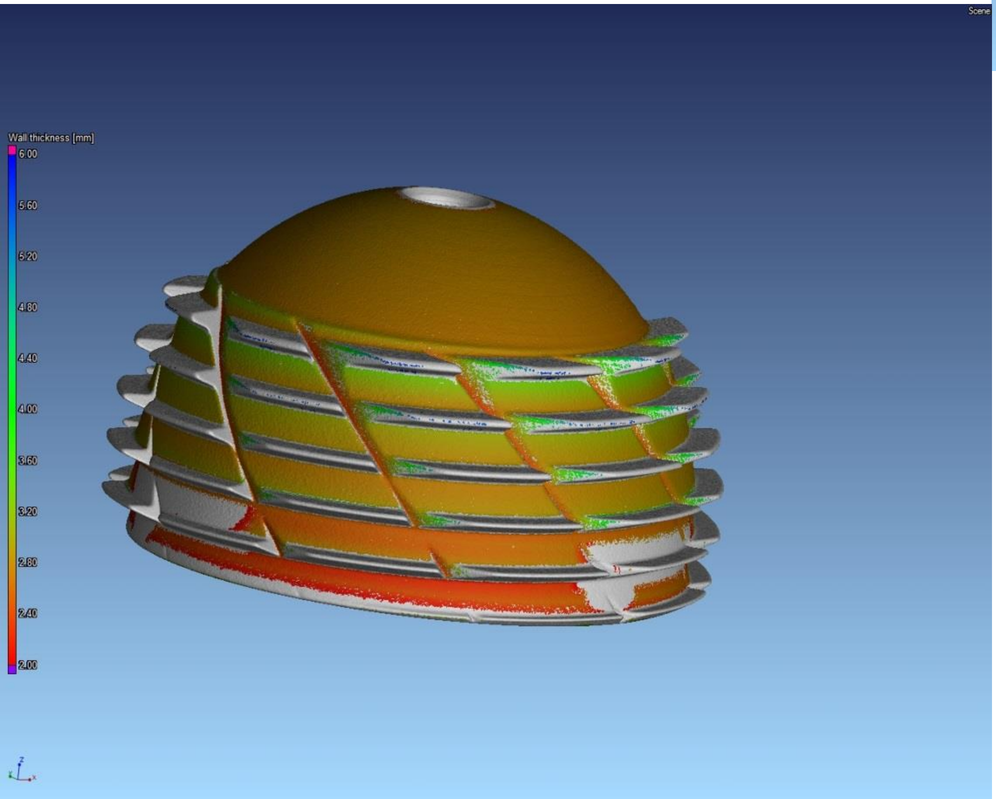
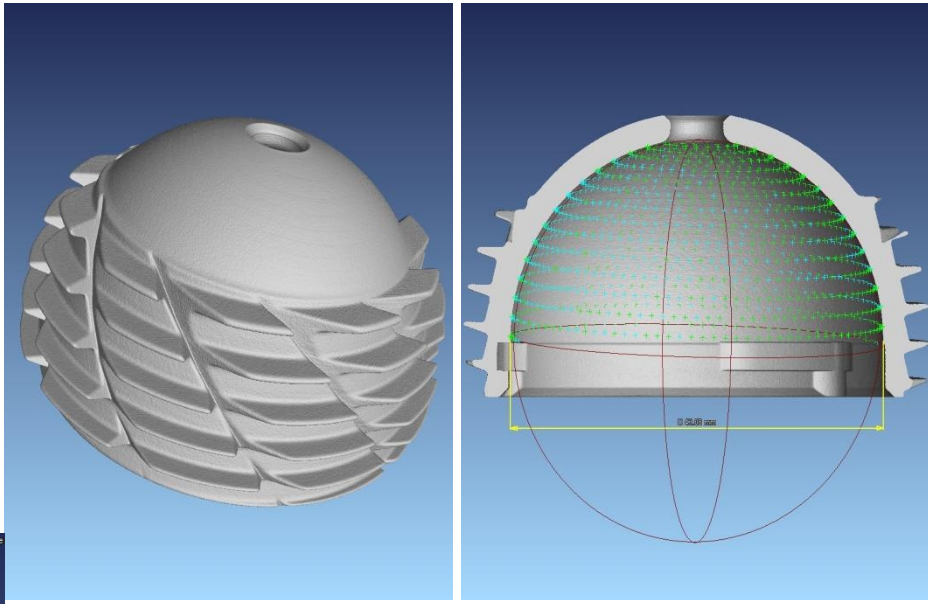
# |x-ray v|tome|x L 300 Dual tube System
## (Unique in Ireland)

# Knee cap Implants

Nominal Comparison

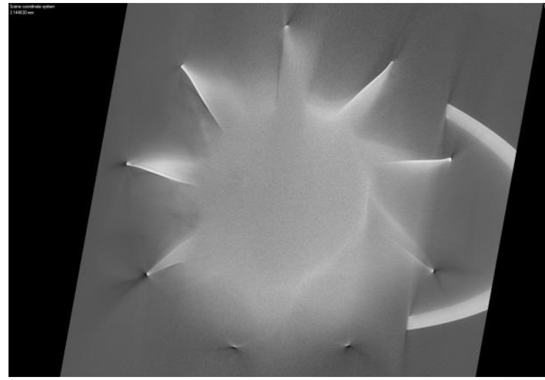
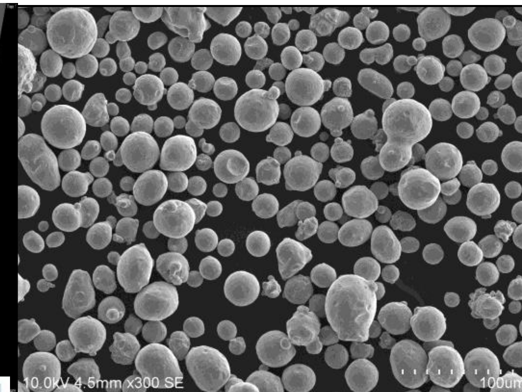


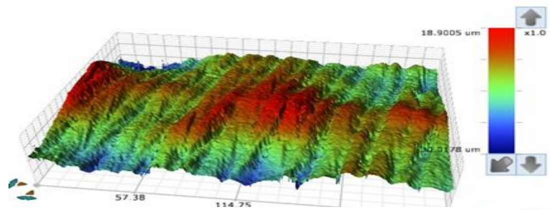



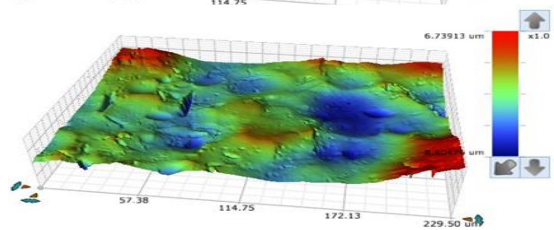
Metrology Inspection

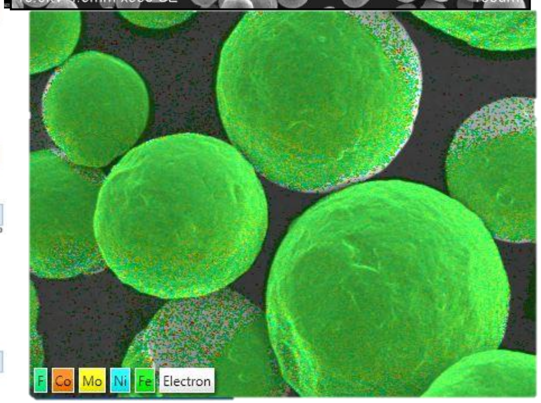
# Other Techniques for Validation of AM

- SEM-EDX (Morphology and Elemental analysis)
- White Light Interferometry (Ra )
- Micro-section and Optical Microscopy
- Mechanical property evaluation (Tensile strength/Harndess)





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# SEAM's Ongoing AM related Projects Topics

- **Micro Laser Sintering of Implants and Industrial Components**
- **Building controlled porous structures in wide ranging materials**
- **Develop methodologies for material consistency and process repeatability**
- **Design of Microwave Components using AM techniques**

# SEAM Foresight Research Topics in AM

- **Correlating Structure Property Relationship in materials processed through AM –Ph.D Topic -position available**
- **Understanding and mitigating metrology challenges in AM - Ph.D position available**
- **Understanding process methodologies for building high impact Light weight structures (lattice structures)**
- **Development of next generation techniques for measurement of complex AM products**

# Thank You All from SEAM Team


**Delivering Real solutions for Real Industry Problems**