Additive Manufacturing:

Global trends and South African opportunities

2017
• **Additive manufacturing (AM)** is defined by ASTM as the "process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies.”
<table>
<thead>
<tr>
<th>AM Technologies</th>
<th>Prototypes, moulds for castings, Jewelry Industry</th>
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</thead>
<tbody>
<tr>
<td>Vat Polymerisation</td>
<td>Sand, Ceramics – Moulds for Castings Metals – Parts Plastics – Creative industries, Prototypes</td>
</tr>
<tr>
<td>Material Jetting</td>
<td>Prototypes,</td>
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<td>Binder Jetting</td>
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RAPDASA

RAPID PRODUCT DEVELOPMENT ASSOCIATION OF SOUTH AFRICA
<table>
<thead>
<tr>
<th>AM Technologies</th>
<th>Tooling, direct part production, consumer goods</th>
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<tbody>
<tr>
<td><strong>Material Extrusion</strong></td>
<td><img src="image1.png" alt="Image" /></td>
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<tr>
<td><strong>Powder fusion</strong></td>
<td>Tooling, Direct part production, Medical, Aerospace,</td>
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<tr>
<td><strong>Sheet lamination</strong></td>
<td><img src="image2.png" alt="Image" /></td>
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<tr>
<td><strong>Direct Energy Deposition</strong></td>
<td>Direct part production, refurbishment and repair</td>
</tr>
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<td><strong>RAPDASA</strong></td>
<td><img src="image3.png" alt="Image" /></td>
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<tr>
<td>Additive Manufacturing</td>
<td>Traditional Manufacturing</td>
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<tr>
<td>-----------------------------------------------</td>
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</tr>
<tr>
<td>Design Complexity / Freedom</td>
<td>Mass Production</td>
</tr>
<tr>
<td>Part consolidation</td>
<td>Choice of Materials</td>
</tr>
<tr>
<td>Reduced Wastage</td>
<td>Large Parts</td>
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<td>Light weighting</td>
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<td>Reduced need for tooling</td>
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<tr>
<td>Speed to Market</td>
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<tr>
<td>Reduced / simplified supply chains</td>
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</table>
AM and the paths of new business opportunities

Path III - Product Evolution
- Customisation to customer requirements
- Increase product functionality / performance
- Zero cost of increased complexity

Path IV - Business Model Evolution
- Mass customisation
- Manufacturing at point of use
- Supply chain disintermediation
- Customer empowerment

Path I – Stasis
- Design and Rapid Prototyping
- Production and custom tooling
- Supplementary capability
- Low rate production / no changeover

Path II - Supply chain evolution
- Manufacturing closer to point of use
- Responsiveness and flexibility
- Management of demand certainty
- Reduction of required inventory

Source: Deloitte University Press
4th Industrial revolution

- Based on cyber-physical systems
- Brought 3D printing, big data

3.0 1969
- Based on electronics and information technologies to further automate production
- Brought mainframe computers, personal computing, and the internet

2.0 1870
- Based on mass production enabled by electrical energy and division of labour
- Brought light bulbs, telephones, and the assembly line

1.0 1784
- Based on mechanical production equipment driven by water and steam power
- Brought mechanical innovations, such as the steam engine, cotton spinning, and railroads

Global Agenda Council on the Future of Manufacturing
Whiteshield partners framing
The goal of 'Industry 4.0' is the intelligent factory which is characterized by adaptability, efficiency and a full digital integration.
AM industry in 2016

Source: Wohlers Report 2017
AM for final part production (2016)
Hype cycle for 3D printing 2015

Source: Gartner (July 2015)
Global AM market is expected to grow significantly until 2020 – Growth rates of up to 40% per year expected by researchers

Global AM market

> Compared to the machine tool market, the 2014 metal AM system market is still small at less than 1%

> For the period 2004 to 2014, the overall AM market showed an annual growth rate (CAGR) of approx. 20%, while from 2010 to 2014 the growth rate (CAGR) was higher than 30%

> Based on different actual estimates the market is expected to multiply by factor two to seven until 2020

957 metal AM machines sold in 2016.
- 18.4% increase from 2015, and 73% increase from 2014
- Concept laser: 40% growth since 2014 with 156 machines in 2016
- SLM Solutions: 67% growth since 2014 with 104 machines in 2016
- ARCAM: 60 machines in 2015
Challenges

• Repeatability of the process
• Reproducibility between machines
• Qualification assurance
  • Mechanical properties (incl porosity)
  • Surface finish
  • Accuracy
• Speed and throughput
  • Including size restrictions
• Cost
  • Cost of machine and materials
  • Unit cost calculations
What is the status in South Africa
South Africa
Additive Manufacturing Landscape
2015 (Nov)

- Total Number of AM Systems
- F3DPs (< $5,000)
- High End Systems (>$ 5,000)

2016: +/- 4400
2017: +/- 5600
OUR MISSION

RAPDASA is a non-profit organisation that aims to be a platform to connect academics, industry partners and companies in the field of new product development, with a focus on Additive Manufacturing (AM) (3D printing).

www.rapdasa.org
Laser Additive Manufacturing Network

**University of Johannesburg**
- Metal casting Technology station
- Metal AM processes

**CSIR**
- Metal Additive Manufacturing (AM)
- Aerospace, Tooling and Infrastructure refurbishment

**CSIR & Aerosud**
- High speed large area Metal AM
- Aerospace alloys; Design for AM

**WITS University**
- Centre for Hard Materials
- Metallurgical processes

**Vaal University of Technology**
- Largely Plastics and Polymer AM
- Tooling and Consumer products
- I2P lab Training

**North West Univ**
- Material Safety
- Design, Polymer AM
- Platinum AM

**Stellenbosch University**
- Metal applications, focus on tooling design and improvement
- I2P lab, Design for AM, μCT scanning

**Central University of Technology**
- Metal and non-metal AM
- Medical implants; Aerospace applications
- ISO 13485 accreditation
- Tooling and general manufacturing

**University Cape Town**
- Metallurgy
Home grown technologies
12 Service Providers

3-D Printing Systems SA
Machine Resellers, Software and Related Technologies

Contact Person: Erwin von Maltitz
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Website Address: www.3dprintingsystems.co.za

3D Solids Additive Manufacturing Technology
Design, Machine Resellers, Manufacturing

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Air Filter Engineering SA
Design, Machine Resellers

Contact Person: Thane Manureik
E-mail Address: airfilter@mweb.co.za

Anything Worx
Consulting, Machine Resellers, Manufacturing

CAD House CC
CONFORMAL COOLING SOLUTIONS
HIGH PRESSURE DIE CASTING CORE
The team produced a custom-made titanium implant for a 32-year-old female patient with ossifying fibroma, a slow-growing tumour causing the expansion of her lower jaw. They resected the tumour and restored the function and appearance of the mouth and jaw. The operation was made possible through a partnership of Central University of Technology, Free State with Belgian company Materialise, Technimark, Stellenbosch University and the CSIR.

Acknowledgements
Dr Kobus Hoek
Dr Riaan Liebenberg
Dr Philip Jonsson

Materialise

CRPM

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Polyurethane Heart Valve

- AM Ti6Al4V sewing ring
- Polyurethane valve leaflets
Current Under-Graduate AM Activities at NWU

• Prosthesis Development - 3D Printed / Carbon Fibre Hybrid
Current Post-Graduate AM Activities at NWU

• Jonker Sail Planes are making use of AM for prototyping work, specifically inside the cockpit.

• End use parts are also being investigated. HIPS, ULTEM & Carbon reinforced nylon is the main design material considered.
CSIR - Turbine blade Refurbishment program

- Technology development for Eskom steam turbines:
  - Blade tenon rebuild
  - Leading edge erosion repair
  - Turbine journal repair
• Pressure Die Cast Tool Insert
  • Aluminium LM24
  • High Volume
  • Continuous Use
  • Tight Fit >0.02mm

• Manufactured Component Info
  • Tool Steel 1.2709
  • Porosity 0.23% Transverse, 0.18% Longitudinal
  • Hardness 38 HRC printed
  • Machinability Excellent, chip formation good
  • Grinding Clean
  • Hand Finishing
    • Finish time 3 Hrs
  • Post aging 5 Hrs @ 500 °C, 54 HRC
  • Warping, not measurable

9200 cycles

Machine Used
• SLM 280
• 400w
• 30 µm Layer Thickness

Printed Finish
Opportunities for 3D printing in South Africa
AM Roadmap
Terms of reference - DST

March 2013

• “The primary purpose of the Project is to develop an implementation framework to guide public and private sector investment in AM research, development and innovation (RDI) in South Africa for the period 2014-2023.”

• “Included in the implementation framework will be a set of prioritised and detailed actionable plans (in 2 to 4 niche areas) to take advantage of high-priority opportunities to contribute towards South Africa’s socio-economic imperatives.”
Methodology

- Desk research
  - International Roadmaps
  - International Opportunities

- Identification of Local opportunities
  - Expert panels
  - National Workshops

- Local Capabilities
  - Surveys

- Identification of Priority Focus Areas

- Definition of Activities to support the Focus Areas
## Opportunities

- **Local R&D expertise**
- **Aerospace industry**
  - Material resource base
  - Established Aerospace manufacturing industry - Interest from international OEMs
  - Opportunity for low volume high complexity parts
- **Medical and Dental**
  - Opportunities for customisation
  - Turnaround time
  - Reduction in recuperation time
- **Traditional manufacturing**
  - Tooling (tooling performance improvements)
  - Accelerated product development cycles
  - High complexity tooling (Patterns for investment casting)
  - Reverse engineering
  - Refurbishment
The SA Ti Strategy

The Aim of the SA Ti Strategy is to establish:

- Small integrated Ti industry
- Large pigment industry based on SA technology
- The TiCl4 production
- World Class primary Ti production
- **Ti powder fabrication industry**
- World class Ti ingot/Billet production
- World class Ti Mill products plant
- Growing Ti fabrication Industry

- SA is the 2nd largest global producer of Titanium minerals with a share of 23% of the world deposits
- The Plan is to establish a Vibrant Ti Industry
- SA must be an active player in the entire Ti value chain
Opportunity identification and prioritisation

- Attractiveness (need, value & potential)
  - Low
  - Med
  - High

- Fit (Capability, National objectives & Likelihood of realisation)
  - Low
  - Med
  - High

Opportunities identified through national workshops
Opportunities identified by evaluation of local capabilities
Opportunities identified by evaluation of international trends

Identified Opportunities

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South African AM Road map – Priority Focus Areas

<table>
<thead>
<tr>
<th>Use of AM for production of medical and dental implants</th>
<th>Qualified AM parts for medical and aerospace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of parts for the Aerospace and military markets based on current customers and collaboration agreements with OEM's</td>
<td>AM for Impact in traditional manufacturing sectors</td>
</tr>
<tr>
<td>Improve efficiency of traditional manufacturing sectors through tooling development and improved product development cycles</td>
<td>New AM Materials and technologies</td>
</tr>
<tr>
<td>Refurbishment of previously unserviceable parts for the local industry by means of powder deposition technology</td>
<td></td>
</tr>
<tr>
<td>Development of Additive Manufacturing systems</td>
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<tr>
<td>Development of Materials for AM</td>
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<tr>
<td>Development of new AM technologies</td>
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<tr>
<td>Development of an AM based SMME industry in SA based on/ strengthened by AM technology</td>
<td>SMME Development and support</td>
</tr>
<tr>
<td>* Prosthetics, Dental, Hearing aids, Jewellery, Creative Arts</td>
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</tr>
</tbody>
</table>

Enabling capability development:
- Design and design optimisation
- Pre-processing (data)
- Process monitoring and control
- Post-processing
- Testing and analysis
- Dimensional verification and reverse engineering
- Simulation and modelling

Enabling education system:
- Promotion and awareness

Education system:
- Promotion and awareness

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# Collaborative Program in Additive Manufacturing

<table>
<thead>
<tr>
<th>Mission and Objectives</th>
<th>Qualification of MAM for Aerospace and Medical applications</th>
<th>Design for AM</th>
<th>Polymer AM</th>
<th>Industry Development</th>
</tr>
</thead>
</table>
| **Establish local competence to produce final Ti6Al4V parts with AM** | - Fundamental understanding of MAM of Ti6Al4V  
- Characterisation of parts after post processing  
- Development of qualification procedures for medical and aerospace | - Establish local design competence for AM-produced parts  
- Establish Design for AM capability at participating HEIs, CSIR  
- Evaluate potential design packages  
- Design projects | - Establish local competence to produce industrial parts in Polymer materials with AM  
- Application in traditional manufacturing sector  
- Process development in high end applications  
- Local developed materials  
- New PAM technology | - Establish support initiatives for industry development and public awareness  
- Pre-industrial platforms  
- Training initiatives  
- Annual seminar for AM  
- RAPDASA support |

| Collaborators | CUT, CSIR NLC, SUN, UCT, VUT, NWU, WITS | NWU, VUT, CUT, CSIR, SUN Aerosud | CUT, NWU VUT, CSIR,  
NWU | CSIR, CUT, VUT, NWU |

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ddebeer@iclix.co.za | Hardus Greyling  
hgreyling@csir.co.za |
Aeroswift: A large area high processing speed AM system
Present limitations of commercial AM systems

- Limited production rate
  - Inefficient laser manipulation
  - Limited energy input
  - Serial processing
- Limited part size
- High Cost
  - Capital cost
  - Production cost
  - Material cost
- Aerospace Qualification
Ti beneficiation

- Sponge
- Ingot
- Billet
- Extensive Machining
- Waste
- 90+% Additive Manufacturing
- <5% Min Machining
- Final Part

South African Development
AeroSwift
South African Capability

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Aeroswift - Objectives

• Design and construct a large area, powder bed AM system, for metallic components:
  o Powder layer manufacturing
  o High speed system for
    ▪ Production of large metal parts
    ▪ High throughput
  o Versatile to support optimisation of parameter field
  o Build volume:
    ▪ 2m x 0.6m x 0.6m
    ▪ Scalable build volume
  o Pre-heating and environmental control
  o Materials that can be accommodated
    ▪ Ti-6Al-4V
    ▪ Stainless Steel alloys
    ▪ Inconel
    ▪ Other metals
Thank you