“Identifying current and future application areas, existing industrial value chains and missing competences in the EU, in the area of additive manufacturing (3D printing)”

IDEA Consult (leader), AIT, VTT (lead partners), CECIMO (sub-contractor)

Report prepared for the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and commissioned by the Executive Agency for SMEs (EASME) in the framework of the Work Programme 2014 of the EU Programme for the Competitiveness of enterprises and SMEs (COSME).

September 2016
1. “Identifying key current and emerging (including future) application areas in the field of AM;

2. Reconstructing the underlying value chains at the regional level by identifying and positioning relevant European players;

3. Identifying missing competences with regard to applications with a promising potential as well as collaboration opportunities to overcome the current and upcoming barriers to AM deployment in their respect.”
1. Patent analysis
2. FP-funded projects analysis
3. Publications/bibliometric analysis
4. Desk Research (incl. Literature Review)

Quantitative and Qualitative Analyses

Task 1: Identification of most promising application areas
Task 2: Identification of the key players along existing value chains
Task 3: Identification of missing competences along the value chain
Task 4: Conclusions and final reporting
## Patent analysis

<table>
<thead>
<tr>
<th>Company</th>
<th>Total No. of published patents</th>
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<tbody>
<tr>
<td>3D Systems Inc</td>
<td>39</td>
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<tr>
<td>Stratasys Inc</td>
<td>37</td>
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<tr>
<td>Massachusetts Inst. Tech</td>
<td>30</td>
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<tr>
<td>Hewlett-Packard Co</td>
<td>26</td>
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<tr>
<td>Hitachi Chem. Co Ltd</td>
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<tr>
<td>Matsushita Electric Works Ltd</td>
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<td>Therics Inc</td>
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<td>Materialise NV</td>
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<td>Objet Ltd</td>
<td>20</td>
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<td>Panasonic Corp</td>
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<td>IBM Corp</td>
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<td>The Boeing Co</td>
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<td>Mimaki Engg Co Ltd</td>
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<td>3Shape A/S</td>
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<tr>
<td>Dainippon Printing Co Ltd</td>
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Source: 3D Printing: Technology Insight Report (2014), Gridlogics Technologies

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<tr>
<td>Rolls-Royce</td>
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<td>Samsung Electronics Co Ltd</td>
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<td>Honeywell International Inc.</td>
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<td>Stratasys Inc</td>
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<td>BAE Systems PLC</td>
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<td>Materialise N.V.</td>
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<td>Alstom Technology Ltd</td>
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<td>GENERAL ELECTRIC COMPANY</td>
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<td>Panasonic Corporation</td>
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<td>DSM IP Assets B.V.</td>
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<td>Hamilton Sundstrand Corporation</td>
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<td>LG Chem, Ltd.</td>
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<td>SNECMA</td>
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</table>

Source: EPO, Calculation by AIT
EU Projects: Participations by country

Source: EUPRO database, CORDIS database, calculation by AIT
EU Projects: Top Organisations

Source: EUPRO database, CORDIS database, calculation by AIT
Main research activities in 3D printing and additive manufacturing

*Source: Web of Science, calculations by AIT*

**Some European companies**

**Selective laser metling:**
- EADS, Eurocoating, Inspire, LayerWise, Bosch, Siemens, SLM

**Biomedical implants:**
- 3D Syst LayerWise, 3T RPD, Avio SpA, Implantcast, LayerWise, Lima Corp, SLM, Simpleware

**Additive manufacturing misc.:**
- Airbus, EADS

**3D Bioprinting:**
- NanotecMARIN
Eye on 10 European AM Value Chains

1. Surgical planning
2. Plastic-based car interior components
3. Metallic structural parts for airplane
4. Inert and hard implants
5. Metal AM for injection Molding
6. Spare parts for machines
7. Lighting and other home decoration products
8. 3D-printed textiles
9. Affordable houses
10. 3D-printed confectionery

About 150 relevant papers reviewed + Desk Researches + used to draft a 1st version of the SAM (12 sectors + misc, 66 apps) + ID of 70 key regions
10 Value chains investigated in-depth (1/2)

Surgical planning

Plastic-based car interior components

Metal AM for injection molding

Metallic structural parts for airplane

Hard and inert implants

Research and Technology Organisations performing research on particular segments and at all levels of the value chain (materials, processes...)

Manufacturing of 3D-Printers

Provision of raw material

Software design

Additive Manufacturing Service Providers

Surgeons, hospitals

Other value chains with which collaborations are starting

Research and Technology Organisations performing research on particular segments and at all levels of the value chain (materials, processes...)

Manufacturing of 3D-Printers

Original Equipment Manufacturers (OEMs)

Car Manufacturers

Additive Manufacturing Service Providers

Other value chains (mainly Aerospace) where collaborations are starting

Research and Technology Organisations performing research on particular segments and at all levels of the value chain (materials, processes...)

Tier 3 Suppliers

Provision of raw materials

Manufacturing of 3D-Printers

Software (CAD/Systems)

Tier 1-2 Suppliers

Integrators

Additive Manufacturing Service Providers

Other value chains (Space, Defence and Automotive)

Research and Technology Organisations performing research on particular segments and at all levels of the value chain (materials, processes...)

Manufacturing of 3D-Printers

Provision of raw material

3D-scanning

Software design

Additive Manufacturing Service Providers

Healthcare consumers, surgeons, hospitals

Other value chains with which collaborations are starting
All the value chain is currently at an early stage of development: no clear supply chain could be identified beyond specific (and/or isolated) cases; However, finishing and post-processing capabilities remain to be developed (surface finish is key to this application area).

Research and Technology Organisations performing research on particular segments and at all levels of the value chain (materials, processes...)

3D-Printed Textiles

- Manufacturing of 3D Printers
- Provision of raw material
- Software design
- Process design

Collaborations with designers and consumer influence

Manufacturing of 3D food printers
- Raw material suppliers
- Food manufacturers
- Retailers
- End user

3D-Printed Confectionary

- Manufacturing of 3D-Printers
- Provision of raw material
- Software design
- AM and other Service Providers

Other value chains (Space, Offshore, Defense) with which collaborations are starting

Affordable Houses

- Research and Technology Organisations performing research on particular segments and at all levels of the value chain (materials, processes...)

- Manufacturing of 3D Printers
- Provision of raw material
- Software design
- AM and other Service Providers
- Architects

Construction sector → End user

Lighting and other home decoration products

- Research and Technology Organisations performing research on particular segments and at all levels of the value chain (materials, processes...)

- Manufacturing of 3D Printers
- Provision of raw material
- Software design
- AM and other Service Providers

Other value chains (Space, Offshore, Defense) with which collaborations are starting

End user

Spare parts for machines

- Research in Universities, Research and Technology Organisations, European/National Projects, and private research labs

- Manufacturing of 3D Printers
- Provision of raw material
- Software design
- Hardware
- Software

Value chains of other sectors/applications

Open source & collaborations (dashed)
Where are we?

Key missing capabilities

1. High-end metal-based material capabilities (transformative capabilities: titanium, aluminum, magnesium);

2. Post-processing segment (Hot Isostatic Pressing = absent; finishing = to be developed).

4 ex. of BARRIERS
• Technical (size)
• Material
• Knowledge and skills
• Post-processing

4 ex. of BARRIERS
• AM Cost
• Competition
• Technical (cooling channels)
• Insufficient demand from OEMs

Europe AM capabilities are mature and (highly) competitive

Competition from USA, Japan, Israel, China

New areas to emerge: new materials, new tech, new business models, etc.
Selected key insights

- Fragmented landscape:
  - **West**: Bavaria, Baden-Wurttemberg but also North Rhine-Westphalia, Ile-de-France, Rhône-Alpes, Auvergne, United Kingdom, Piemonte, Lombardy, Ireland Emilia-Romagna, Sweden, Finland, Norway, South Netherlands, Flanders, Wallonia, Upper Austria, Asturias, Cataluña
  - **East**: Poland, Slovenia, Croatia, Slovakia, and the Czech Republic

- Status
  - Importance of (large) lead-users
  - Nascent disruption (various maturity levels)
  - Emerging/future applications
  - Potential for cross-regional collaboration

**Collaboration opportunities: examples**

- **Across value chains**: Space, Defense, Automotive
  - **Along value chain**: GKN, Google, etc.

- **Across value chains**: all other manufacturing value chains (Auto, etc.) through demand/supply
  - **Along value chain**: collaborations of Mold Makers with RTOs, service providers and printer manufacturers

- **Across value chains**: smart textiles, health, security, car upholstery, fashion, etc.
  - **Along value chain**: designers & OEMs

- **Across value chains**: healthcare, packaging, etc.
  - **Along value chain**: Research centres and food industry
Policy implications regarding main themes such as:

1. Human Resources (skills, info., etc.)
2. Technology (RTDI areas, IPR, standardisation, etc.)
3. Missing or under-developed capabilities
4. Market uptake and latest TRL stages
5. Demand side
Policy implications

• **HR**
  • **Skills + multi-disciplinary curricula** (CAD, materials, management, etc.).
    • EU Member States, EU coordinates.
  • **Awareness raising** (engineers, technicians, R&D and company managers, consumers and end-users).
    • EU to streamline

• **Tech**
  • **R&D support** (incl. experiments and prototyping) to all areas (size of parts, efficiency, etc.), collaborative to the extent possible.
    • Regional, national and European government levels.
    • **Combination of subtractive and additive methods** as a key development field
  • **Streamline all standardization and certification efforts**
    • EU
  • **EU Fab Labs** to be **used as test beds**.
    • Regions, MS and EU
  • **IPR enforcement.**
    • EU and MS

- Biodegradable materials
- Composite materials
- Diagnostics and sensing
- Digital Design / CAD
- Hybrid manufacturing
- Large parts printing
- Material feedstock
- Materials explosivity
- Materials toxicity
- Metal material properties
- Processes
- AM efficiency
- Health impacts
- Multi-material printing
- Quality monitoring and control
- Recycled materials
- Cellulose fibres
- Software development
- Etc.
Policy implications

• Initiate/develop missing capabilities (all levels)
  • Facilitate the access to critical materials (titanium, aluminum, magnesium, etc.) and related transformative capabilities:
    • Market intelligence;
    • Business development conditions;
    • Capacity development through co-investment (in transformative processes for instance);
    • Support to the qualification and standardization of the materials;
    • Urban mining.
  • Develop
    • Finishing / Hot Isostatic Pressing (metal AM).
    • 1) simulation and 2) testing.
    • New business models, incl. platform-based ones.

• Accelerate AM deployment
  • Support:
    • Cross-regional pilot & demonstration activities (Wire-based and hybrid systems, etc.)
    • joint actions and collaborations (case-by-case/ one-stop-shop(s))
      • EU = network/coordination role
    • Cross-value chain fertilization through emerging collaborations (defense, automotive, space, aeronautics, transports; textiles and others)
      • EU = network/coordination role

• Stimulate demand (through integrators, consumers, etc.)
  • Co-invest in the testing and acquisition of printers.
  • Set up a common repository, streamlined information
    • EU must take the lead
  • Support User platforms (financially, especially in Eastern EU) and Fab Labs
  • Clarify regulation as to scale-up living lab experiments into real commercial products
THANKS !
ANNEXES

Selected examples of regional capabilities and barriers
Regional capabilities: example of the AM structural components for airplanes value chain

• Leading regions include:
  • **Materials**: North Rhine-Westphalia, Flanders, Bavaria, North Holland, Auvergne, Cheshire  
  • **Service providers**: Flanders, Ile-de-France, Burgundy, Baden-Württemberg, Midi-Pyrénées  
  • **Printer manufacturers**: Västergötland, Staffordshire, Schleswig-Holstein, Bavaria (!)  
  • **RTOs**: Sør-Trøndelag, North Rhine-Westphalia, Hamburg - Low Saxony, Bavaria, Hesse, Rhône-Alpes, South Holland, Ile-de-France, Veneto, Emilia-Romagna, Cranfield, Sheffield and Manchester  
  • **Tier suppliers**: Nord-Pas-de-Calais-Picardie, Piemonte/(Liguria), Ile-de-France, Piemonte  
  • **Integrators**: Midi-Pyrénées, Piemonte, Bavaria, Northern Ireland, Rhône-Alpes, Ile-de-France and Masovian Voivodeship

• Missing or under-developed capabilities:  
  • Powder supply of aluminum and titanium  
  • Hot isostatic processing  
  • To a larger extent post-processing, finishing and post-printing treatment  
  • NDT (Non Destructive Testing) techniques  
  • Wire-based technologies: 1) absence of commercial systems and 2) software to enable building of parts
Regional capabilities: example of the AM Injection Molding value chain

• Leading regions include:
  • **Software**: Flanders, Bavaria, Baden-Württemberg, Central Region, Scotland
  • **Materials**: North Rhine-Westphalia, North Rhine-Westphalia, Flanders, Skåne, Cheshire
  • **Printer manufacturers**: Warwickshire, Staffordshire, Schleswig-Holstein, Bavaria, Baden-Württemberg, Auvergne
  • **Mold makers**: North Rhine-Westphalia, All EU regions.
  • **Service providers**: Flanders, Scotland, Bavaria, Rhineland-Palatinate, Northern Ireland, Rhône Alpes, Ile-de-France
  • **End-users**: Jutland, North Rhine-Westphalia, Bavaria, Baden-Wurttemberg, Rhône-Alpes, and All other mold users (potentially all EU regions)
  • **RTOs**: Wallonia, Rhône-Alpes, Leiria, Uusimaa, Moravia, Sør-Trøndelag, Bavaria, Hesse, South Holland, Ile-de-France, North Rhine-Westphalia, Baden-Württemberg, Zürich, Flanders, Franche-Comté

• Missing or under-developed capabilities:
  • Printing capabilities (buy printers)
  • Powder supply: titanium and aluminum.
Barriers: 2 value chain examples

**Structural Components for Airplanes**

Rising competition from composite materials; heavy regulations; lengthy development plans; the lack of knowledge and skills; the need for common standards and further characterization of AM materials and processes; missing knowledge (about health and security implications of AM); scalability issues; poor quality and surface finishing; the lack of detection, monitoring and control of surfaces; the lack of transformation capabilities in Europe and the availability of high-class, passivated clean powders, including aluminum, magnesium and titanium; the lack of streamlined information and insufficient awareness.

**Injection Molding**

Printers and powders remain expensive (mainly for SMEs) but also faces issues such as: skills availability; growing demand toward AM system manufacturers; cultural conservatism; lack of AM awareness; lack of demonstration activities; lack of multidisciplinary curricula; AM technical limitations (cleaning of cooling channels, printing of large molds, precision and surface finishing, etc.); insufficient qualification and certification of AM materials and processes; transformative capabilities in the field of metal powders; players standing as bottlenecks in the field of metal powders; fear of having companies’ designs stolen; development of internal AM capabilities in client companies; little bargaining power of SMEs; international competition coming from plastics and composite materials.