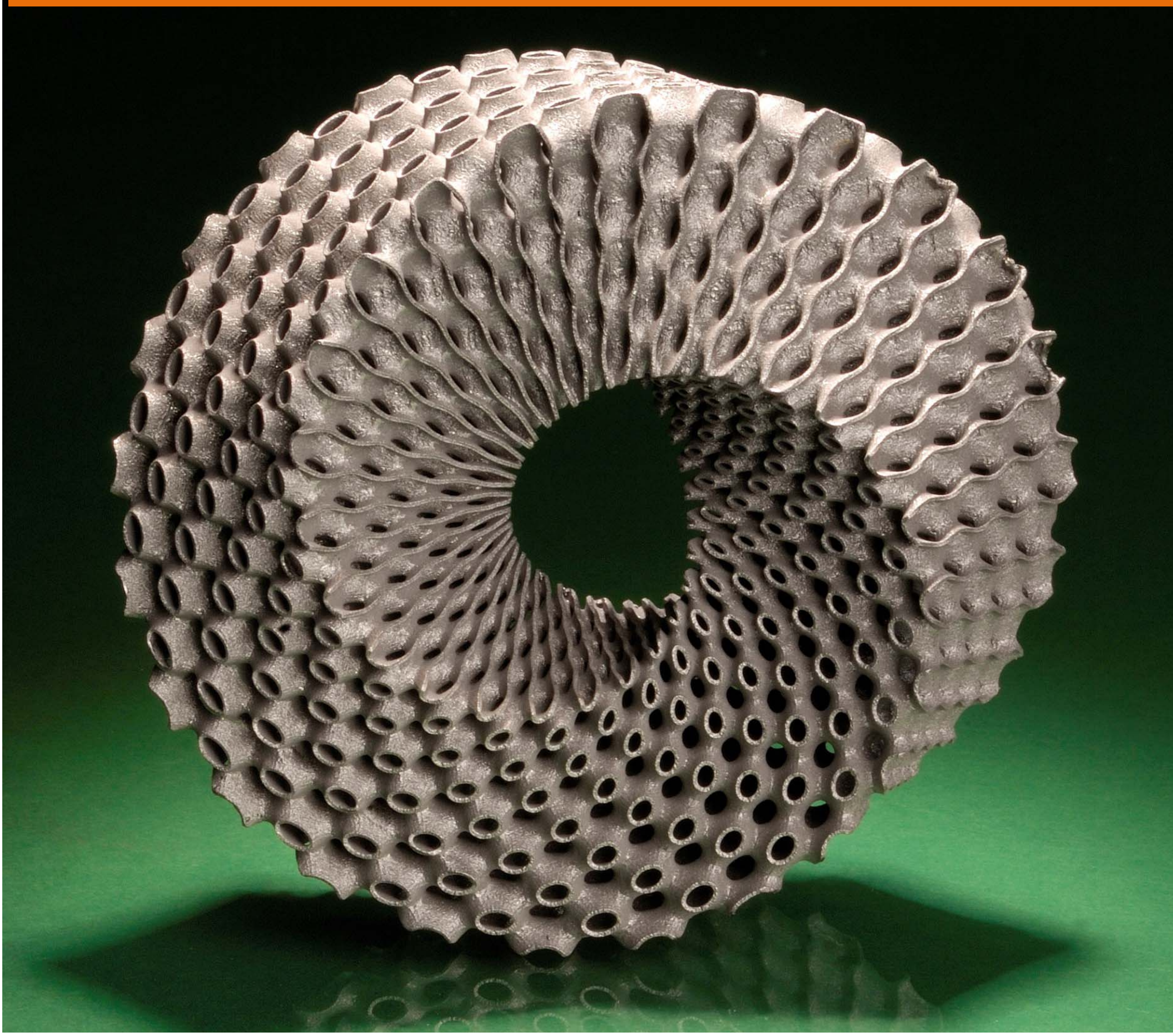
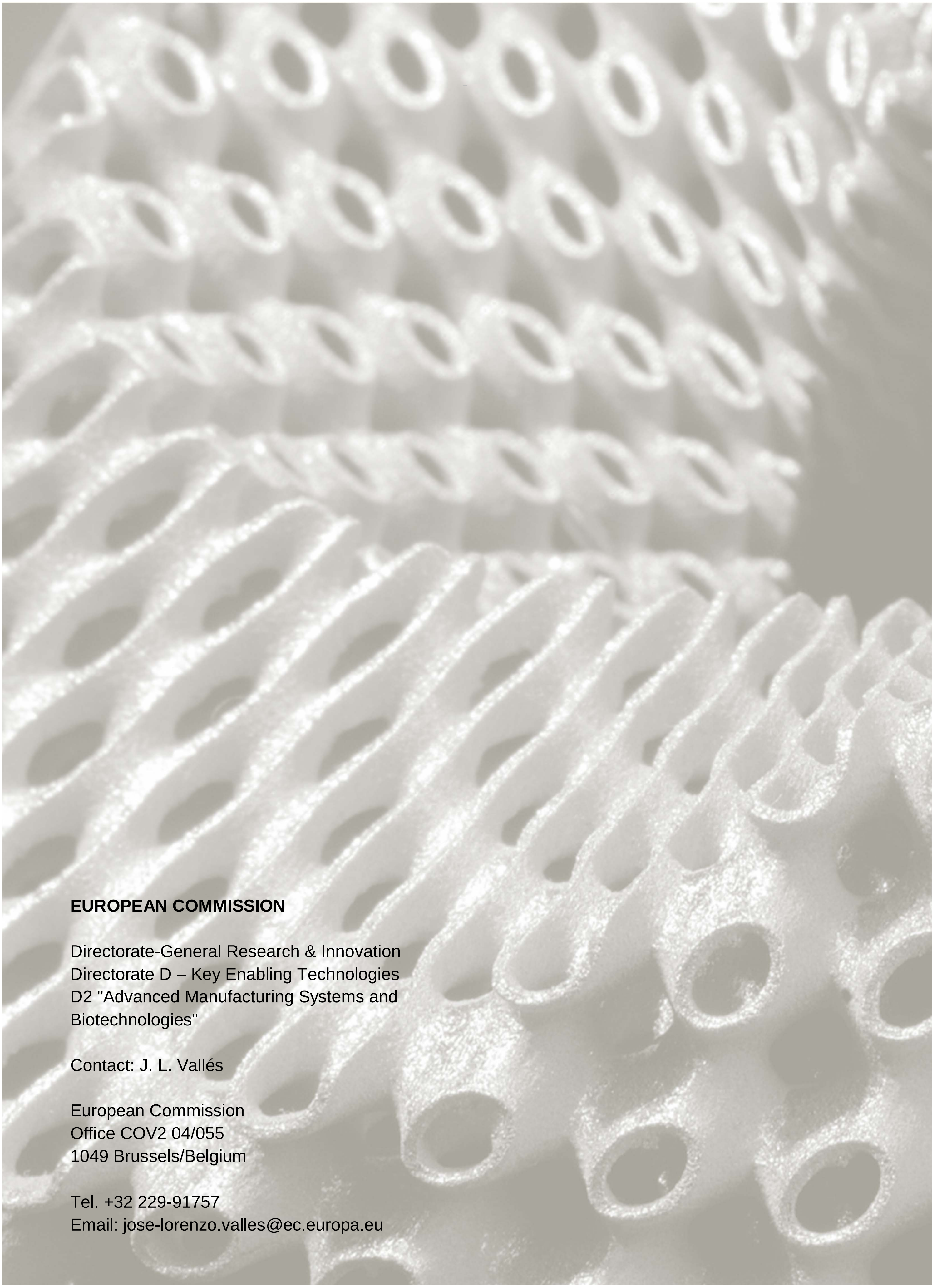
European Commission

Additive Manufacturing in FP7 and Horizon 2020

Report from the EC Workshop on Additive Manufacturing held on 18 June 2014





EUROPEAN COMMISSION

Directorate-General Research & Innovation
Directorate D – Key Enabling Technologies
D2 "Advanced Manufacturing Systems and Biotechnologies"

Contact: J. L. Vallés

European Commission
Office COV2 04/055
1049 Brussels/Belgium

Tel. +32 229-91757
Email: jose-lorenzo.valles@ec.europa.eu

ADDITIVE MANUFACTURING IN FP7 AND HORIZON 2020

REPORT FROM THE EC WORKSHOP ON ADDITIVE MANUFACTURING HELD ON 18 JUNE 2014

LEGAL NOTICE

Welcome from the Director for Key Enabling Technologies

DG Research and Innovation - European Commission

Additive Manufacturing (AM), including 3D-Printing, is one of the potential game changers that, for some applications, has already reached a tipping point of maturity. These days, we are already witnessing the growing enthusiasm and an increased adoption of these technologies.

AM could disrupt the manufacturing value chain, allowing a shift from mass production to full customisation. This is why it is essential that this technology is welcomed and developed in a positive light in order to keep the European economy at the forefront of innovation.

AM has received European Commission (EC) funding since the first Framework Programme (FP), during 1984-1987. The following FPs (from 1988 till 2013) ensured continuous support from different EC services and different funding programmes. In FP7 (2007-2013) more than 60 successful projects on AM technologies were funded, with over €160 million in EC funding and a total budget of around €225 million.

The research and technological development supported by European funding was important for the growth of AM technologies in Europe and Horizon 2020 will bring new opportunities. Nevertheless, and despite the EC support, European companies are facing these days a tough business environment. The strong investments of the US and China in the field of AM are overtaking in just a few years the accumulated EC funding from the FPs. Other countries, like Israel, Singapore, Korea, Japan and South Africa are also seriously investing in AM to face this global competition.

The aim of the workshop was to understand the needs of the AM sector and to discuss how the current barriers to further development of AM technologies could be removed. There was a special emphasis on the impact of potential policy measures at the EU level which could enhance the competitiveness of the AM sector. Thanks to its potential to boost new business opportunities in the market, AM would also foster the European economy at large.

Ms Clara de la TORRE

TABLE OF CONTENTS

EXECUTIVE SUMMARY..1

PART 1: ADDITIVE MANUFACTURING

1. Introduction 5

2. Background 5

3. Additive Manufacturing Technologies 5

4. Global Perspective 9

5. European Investment..10

6. Additive Manufacturing within the European Commission..12

PART 2: THE EC WORKSHOP ON ADDITIVE MANUFACTURING

7. Scope of the Workshop 14

8. Opening Session..15

9. Session 1: European Industrial Roadmaps for AM..15

10. Session 2: Policy Perspectives for AM 22

11. Session 3: EU Projects – Impact of AM innovation on European Competitiveness........24

12. Session 4: Roundtable on priorities for further development of technologies, equipment and materials in AM..31

13. Session 5: Roundtable on policy measures and implementation 35

PART 3: KEY FINDINGS AND CONCLUSIONS

14. Key findings and Recommendations to the EC..39

ANNEX I: Agenda of the Workshop

ANNEX II: Speakers and Panellists Details

ANNEX III: Fact Sheets of Projects Presented

ANNEX IV: List of Participants and Organisations

ANNEX V: References and Links

ACRONYMS

AM	Additive Manufacturing
CAD	3D Computer-Aided Design
DG	Directorate General
EC	European Commission
ETP	European Technology Platform
EU	European Union
FoF	Factories of the Future
FP	Framework Programme
GDP	Gross Domestic Product
IP	Intellectual Property
JRC	Joint Research Centre
KETs	Key Enabling Technologies
NMP	Materials and new production technologies
PPP	Public Private Partnership
SRA	Strategic Research Agenda

EXECUTIVE SUMMARY

Background

This report summarises the first dedicated Workshop held by the European Commission (EC) on Additive Manufacturing (AM). AM (which includes 3D-Printing) is not a new phenomenon, but it is currently receiving considerable interest on a global scale and important investments at international level are taking place.

The purpose of the workshop was to reach a better understanding of the needs of the AM sector beyond the technological developments and to evaluate how the current barriers could be removed for further development of the AM technologies.

Additive Manufacturing

AM refers to a group of technologies that build physical objects directly from 3D Computer-Aided Design (CAD) data. AM adds different materials, layer-by-layer, to form component parts or products. This approach provides a number of advantages, including un-rivalled geometric freedom of design, near 100% material utilisation, and short lead times.

AM gives the designers the ability to quickly turn concepts into 3D models or 3D prototypes, opening up shapes that were impossible to produce before. AM also enables full customisation, which is a real shift from today´s mass production and where the European Union (EU) faces tough competition from developing countries.

AM has the potential to offer significant benefits in a number of industrial sectors including the environmental perspective where future manufacturing will be increasingly measured on its environmental footprint.

Additive Manufacturing in the European Commission

The first European Framework Programme (1984-1987) already funded projects related to the AM technologies, support that continued with the subsequent programmes. The number of projects related to AM requested in the different Call for proposals has been growing constantly since FP1, with an impressive increase during the last years of FP7. Only in FP7, the EC funded more than 60 successful projects in AM, with a total amount of EU contribution of over €160million and a total budget of €225millon.

In Horizon 2020, AM mainly falls within the Key Enabling Technologies (KETs) area under the Industrial Leadership pillar, but certainly playing as well an important role in the Societal Challenges. The Factories of the Future (FoF) Public Private Partnership (PPP) will remain the main actor in AM within the KETs, and its activities will be primarily developed through the relevant industrial roadmaps, in collaboration with the stakeholders.

The EC has also has also started to address some policy aspects related to AM challenges. AM, including 3D-Printing, has been highlighted in the Industrial Policy Communication [1] from 2012, in the Industrial Landscape Vision 2025[2] and by the EC Task Force for Advanced Manufacturing Technologies for Clean Production [3].

AM in Manufacturing

The EC is strongly supporting the goal of 20% of the total EU Gross Domestic Product (GDP) coming from manufacturing, face to the current 15%. Manufacturing is a top priority for European industrial policy and recently the European Council has called for an industrial renaissance. EC President Jean-Claude Juncker also underlined the importance of a strong and high-performing industrial base and the need to stimulate investment in new production technologies. During his confirmation hearing at the European Parliament, Commissioner Mr. Carlos Moedas explicitly mentioned 3D-Printing in the framework of Industrial Leadership.

AM Technologies will have a tremendous impact on industrial and consumer areas in the coming years. For instance, AM can provide a wide array of goods, maximising production flexibility and minimising waste and the use of resources. This has already been seen in specific applications e.g. aerospace and medical fields. Furthermore, AM can increase local production, with more goods manufactured close to their point of consumption, which in turn can strengthen regional economies and entrepreneurship. AM can also foster innovative manufacturing in Europe, bringing outsourced jobs back, and open up new business opportunities for SMEs.

The Global picture

Despite the EC support, in the global picture the competitiveness of the European companies is threatened by the recent developments and the important investments of the US and China in the field of AM, which in just a few years are overtaking the accumulated EC funding from the FPs. Many other countries, such as Israel, Singapore, Korea, Japan and South Africa are strongly investing in the last years in Additive Manufacturing technologies.

From the competitiveness perspective, European companies are still strong in some areas, such as printing with metals, but this position requires high levels of continuous innovation, especially where competitors are fast approaching. However, there are other areas that are comparatively less developed where the technology transfer and adoption is not functional, leading to a slow uptake of the results.

EC Workshop on Additive Manufacturing

It will take a lot more than just pure technology development to generate wealth creation and the workshop aimed to highlight and discuss some of the more fundamental aspects that need to be addressed in order to take advantage of this promising technology.

The workshop helped to identify the needs and barriers that the AM sector is facing today. There was a special emphasis on the impact of potential policy measures at the EU level which could enhance the competitiveness of the AM sector and could remove the current barriers.

Key Conclusions and Recommendations

During the workshop, the need of an integrated and strategic approach in Europe and a common vision for AM was repeatedly highlighted. There is an important urge in linking the wide range of applications, disciplines, manufacturing sectors and countries.

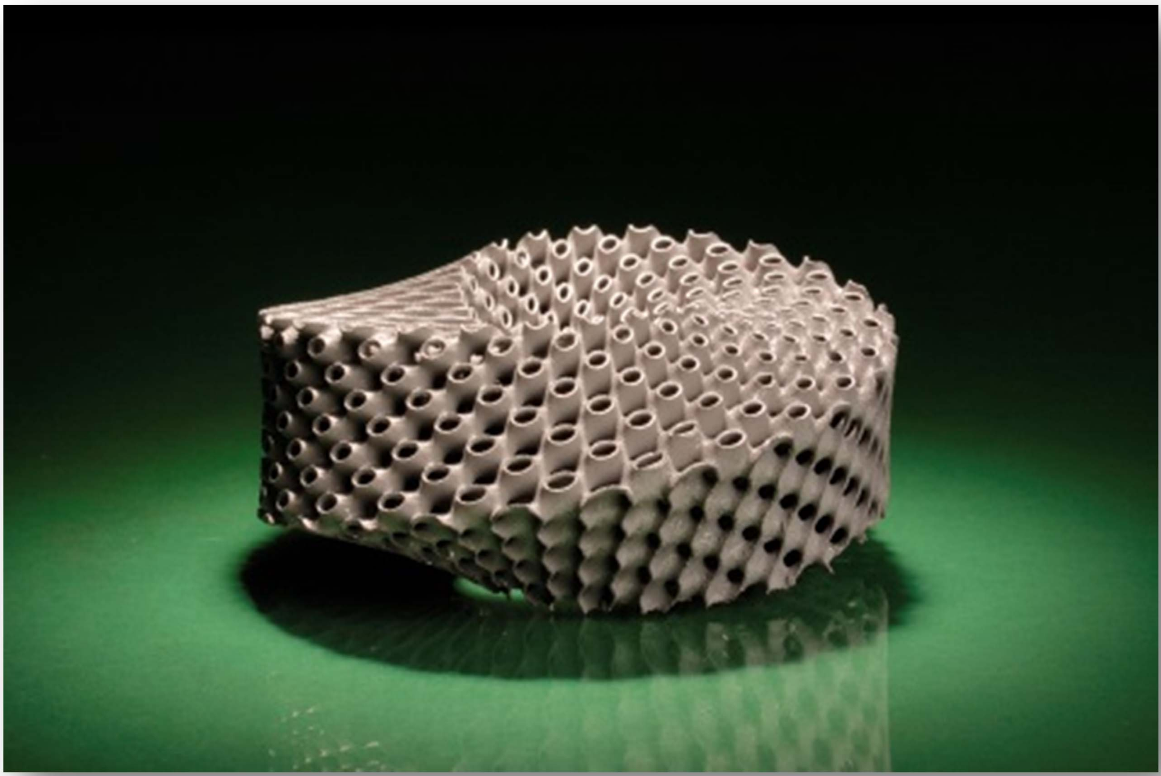
It was pointed out that the EC could play an essential role as a facilitator, by fostering a European network of manufacturing competence, thus helping to accelerate the take-up and the time to market for new applications.

Specific recommendations were provided in different key areas:

- Technological Challenges
- Standardisation, Qualification and Certification
- IP, copyright, patent protection and liability
- Training and Education
- EU Initiatives and Policy Measures

PART 1:

Additive Manufacturing



1. Introduction

This report summarises the first dedicated workshop held by the European Commission (EC) on Additive Manufacturing (AM). It was organised by the Advanced Manufacturing Systems and Biotechnologies (D2) Unit from the Key Enabling Technologies (KETs) Directorate D. The workshop included representatives from other Commission Services (DG Connect, DG Enterprise and Industry and the Joint Research Centre (JRC)) and a group of highly relevant stakeholders in Europe related to AM, representing the whole value chain.

The report focuses on outlining the discussions that took place during the workshop, with emphasis being placed on the wider societal, legal and economic implications of AM technologies, including a policy level perspective. A brief summary of the AM technology and the significant developments that have taken place during the last years on a European and Global scale is also presented.

2. Background

Manufacturing has been highlighted as one of the key enablers for sustainable economic growth, creating competitiveness and long-term jobs. As an Advanced Manufacturing technology, AM has been identified as a key priority for manufacturing. This is because AM, often referred to with the more specific term 3D-Printing, is an innovative technology with the potential to transform the global manufacturing industry and European economies.

The AM industry had an impressive growth during 2013: The revenue for products and services worldwide grew by 34.9%, up to $3.7 billion. The current trend indicates that the AM industry will stand at more than $7 billion by 2016[4] and if the demand continues, by 2020 the estimated volume stands at $11 billion and up to $105 billion if the barriers are removed. This is particularly significant since the European economy has the potential to gain from this rising trend and will be able to capture competitive advantage, particularly over the countries that are just developing competencies in AM.

3. Additive Manufacturing Technologies

3.1. Terminology

Additive Manufacturing refers to a group of technologies that build physical objects directly from 3D Computer-Aided Design (CAD) data. AM adds liquid, sheet, wire or other powdered materials to form component parts or products, usually in a layer-by-layer process (e.g. 3D-Printing) as opposed to subtractive manufacturing methodologies.

‘Rapid Prototyping’ was the earliest approach for AM in the 80s. However, the progress in the field has taken the technology far beyond ‘prototyping’. Many other terms have been or are still used to describe this group of technologies e.g. Freeform Fabrication; Additive Layer Manufacturing; Rapid Manufacturing; Constructive Manufacturing; Direct Digital Manufacture.

3D-Printing, a term brought about in the 90s, has been widely used since then and has become a widespread term for low-cost 3D home printing and some of the larger commercial 3D printing systems. The term ‘Additive Manufacturing’ was later introduced and has taken the fore for describing the technology overall, and more specifically for industrial applications and professional high-end equipment and applications. 3D-Printing is identified more with the Consumer Goods and Home Appliances.

Industry, along with the standards organisations, have categorised AM processes in order to provide a transparent understanding of the different types of technologies in use today (Table 1). Examples of the technologies and the materials of use that fall within these process types have also been presented.

Process Type	Technique Definition	Example Technology	Material
Vat Photopolymerisation	Liquid photopolymer in a vat is selectively cured by light-activated polymerisation.	Stereo lithography (SLA), digital light processing (DLP)	Polymers and ceramics
Material Jetting	Droplets of build material are selectively deposited.	3D inkjet printing	Polymers and composites
Binder Jetting	Liquid bonding agent is selectively deposited to join powder materials.	3D inkjet printing	Metals, polymers, and ceramics
Material Extrusion	Material is selectively dispensed through a nozzle or orifice.	Fused deposition modelling (FDM)	Polymers
Powder Bed Fusion	Thermal energy selectively fuses regions of a powder bed.	Selective laser sintering (SLS), Selective laser melting (SLM), electron beam melting (EBM)	Metal, polymer, composites and ceramics
Sheet Lamination	A process in which sheets of material are bonded to form an object.	Ultrasonic Consolidation (UC)	Hybrids, metals and ceramics
Directed Energy Deposition	A process that focused thermal energy and fuses materials by melting as the material is being deposited.	Laser metal deposition (LMD)	Metals and hybrid metals

Table 1: Classification of AM processes. Adapted from ASTM[5], Technology Innovation Needs Analysis[6] and Wohlers Report[4]

3.2. Benefits and Impacts

AM has the ability to offer significant benefits for a wide range of applications, positively impacting on the societal, economic and environmental elements of sustainable development. These include:

- *CAD-to-Part:* AM allows a 3D CAD drawing of a component or shape to be converted directly into a physical part.
- *Design for Customisation:* AM allows users to generate parts with greater customisation, with no additional manufacturing costs, such as extra tooling costs.
- *Design for Function:* AM manufacturing allows the user to design for function rather than for manufacture, for example allowing internal features that would be impossible to produce using conventional manufacturing techniques.
- *Design for Light-weighting:* Novel design and flexible manufacturing enable the production of lightweight structures. For example, parts can be made with hollow or complex lattice structures which retain structural strength but with reduced weight.
- *Material Utilisation:* AM techniques have the potential to approach near zero waste regarding material utilisation. Also scrap generated during the process has the potential to be recycled ready for use again.
- *Less Pollution:* AM techniques do not directly use toxic chemicals in any measurable amount. This is a direct benefit against traditional machining processes.
- *Reduced Time-to Market:* AM has the ability to consolidate several machining steps into a single manufacturing step which will dramatically reduce the overall manufacturing time.
- *Localised manufacturing:* AM enables localised manufacturing which results in job creation, retention and economic growth.

3.3. Industrial Development

AM technologies started more than twenty years ago but public attention has only focused on it in the latest years, mainly owing to the publicity around developments in 3D printing.

This is illustrated by the Gartner Hype Cycle[7] (Figure 1) which demonstrates what the expectations are for technologies to be close to adoption. For instance, up to 2009, AM is not even referenced. Only in 2010, AM appears for the first time with an estimation of 5-10 years to maturity (Figure 2). In 2013, nevertheless we already see that industrial applications appear, such as Enterprise 3D Printing already situated on the 'slope of enlightenment', almost near real production. There are also concepts emerging for 3D scanners and consumer 3D printing, estimated to reach in 5-10 year the 'plateau of productivity', close to mainstream adoption.

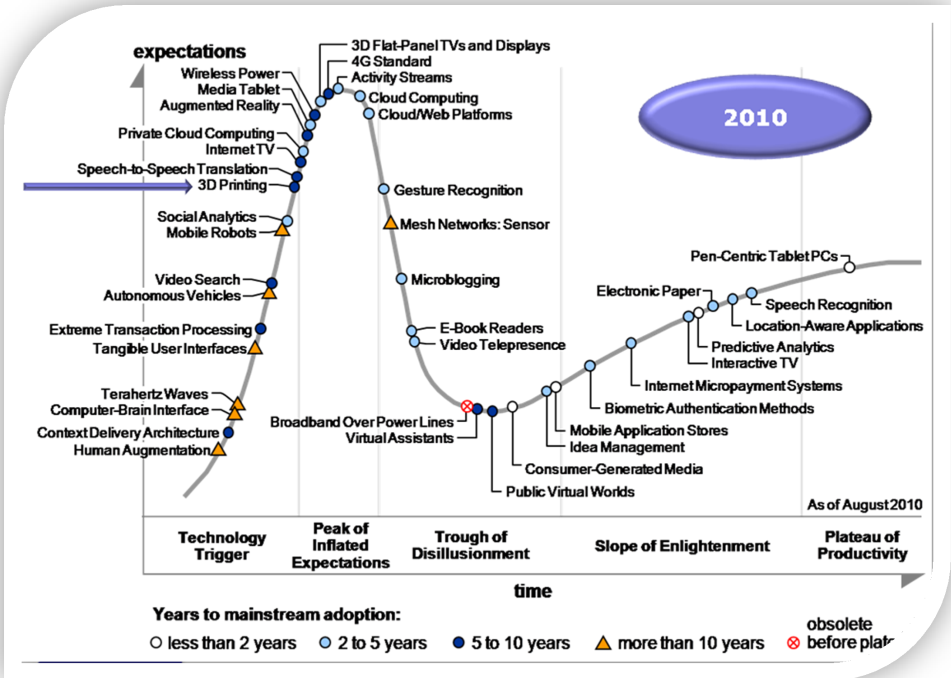


Figure 1: 2010 Gartner Hype Cycle[7]

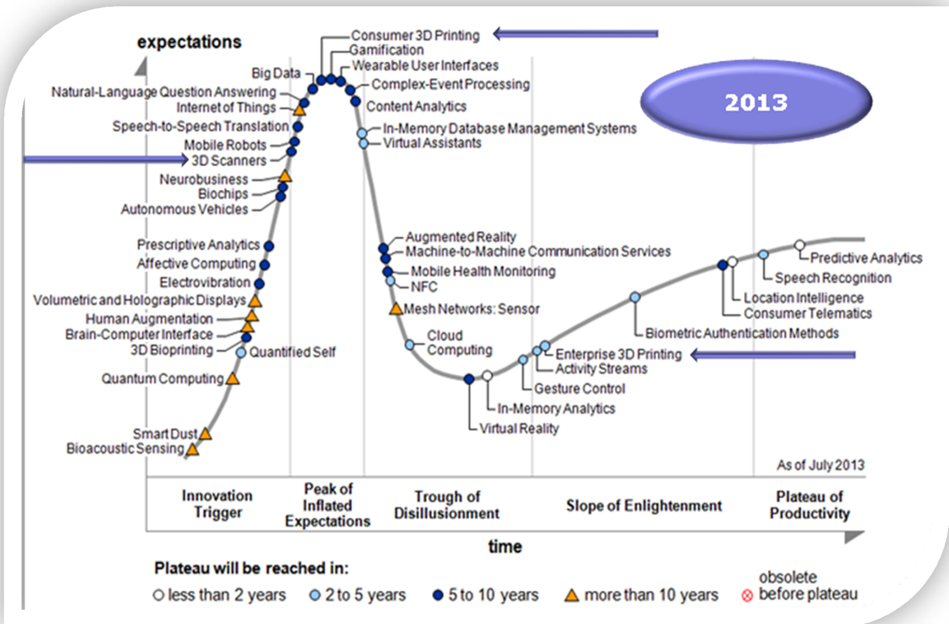


Figure 2: 2013 Gartner Hype Cycle[7]

The Gartner Hype Cycle mainly represents trends to the adoption of a technology. However, AM technologies have already established themselves in some sectors at the level of real production. A survey of over 100 key AM system manufacturers and service providers (representing over 100,000 users and customers) showed that the industrial/business machines are the leading sectors using AM technologies (Figure 3). Immediately follows the consumer products/electronics and motor vehicles sectors. Medical/dental and aerospace sectors are also great users of AM technologies[4].

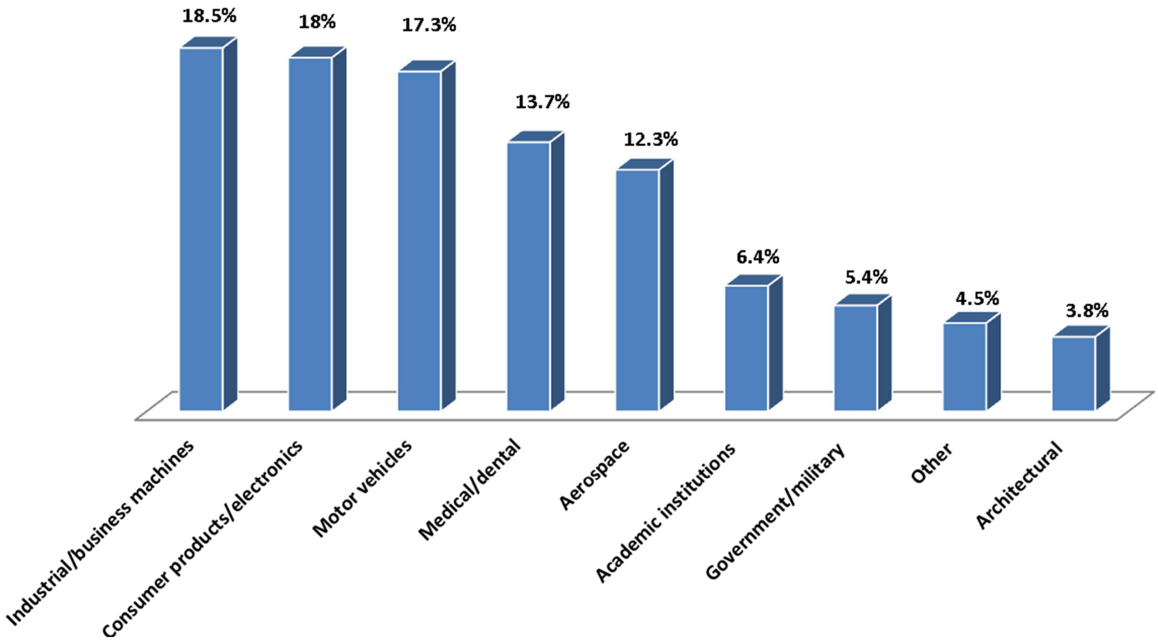


Figure 3: Breakdown of the percentage of industrial sectors using AM[4].

The main characteristics of the manufacturing sectors currently using AM technologies for real production conditions are the following:

a) *Consumer Products*

Within the consumer market there is a large array of products being manufactured by various AM technologies including toys, games, home furnishings, fashion items, sports equipment etc. Artists, jewellers and fashion designers are using AM in a range of ways including to produce one off bespoke pieces.

b) *Electronics*

The electronics industry is using AM to print electronic devices and components. Similarities between AM and direct write technologies can also be made, particularly for the deposition of conductive materials onto conformal surfaces. Inkjet technology can be used to print passive circuit components such as resistors, capacitors and inductors, as well as diodes, and circuit interconnections.

c) *Motor Vehicles*

More and more car manufacturers are using the benefits of AM in the production of concept cars. The process opens a new world of design freedom and allows concept cars to be built faster than with more traditional methods. 3D models are used for everything from concept creation to production planning, allowing design engineers to speed up and improve the development process. The automotive industry has historically used AM as an integral tool in the design process. The fast-paced design cycles in the automotive industry require a rapid prototyping solution that can produce almost any geometry with a variety of material properties, quickly and cost effectively.

d) Medical and Dental

AM techniques have been applied within the medical and dental arena for the creation of assistive, surgical and prosthetic devices, surgical implants, and scaffolds for tissue engineering. For instance, AM allows complex parts to be created specifically for the patient direct from a 3D CAD model generated from a patient's CT or MRI scan. Accurate patient specific implants produced using the 3D scan data can reduce the removal of healthy bone, eliminate the need for bone grafting, promote effective planning of implantation/surgery and shorten the time of anaesthesia. There is also the possibility that the customisation enabled by AM will result in increased implant-life eliminating the need for further surgery.

e) Aerospace

AM is an attractive alternative manufacturing route for the aerospace industry, due primarily to its high material use efficiency and ability to process aerospace grade titanium and nickel alloys. AM is seen as an enabling technology for light-weighting or topology optimisation, because of its capability to create complex structures. This can have the additional benefits of improving performance and reducing waste. AM has also been used for testing of complex or difficult to implement designs, including extensive tests in 'full engine' rigs.

Although we can already see significant usage of AM in particular sectors, there is still a massive potential to further enhance its use and even enter new sectors. However, one of the present problems for AM is that many of the traditional manufacturing sectors are not aware of, or do not fully understand, how they can utilise AM. AM will replace certain manufacturing methods, but not all of them while it has the added potential to complement many of those it cannot substitute.

4. Global Perspective

Many different countries outside the EU have been raising their awareness of the technology for already several years and in this moment North America is at the forefront in the adoption of AM technologies [4]. However, this adoption is rapidly evolving for many other countries, and for most of them emphasis is now placed on AM being at the core of their national competencies.

Some examples at the Global level about the current investment in AM technologies are:

a) United States of America

In 2012 the National Additive Manufacturing Innovation Institute (NAMII), now known as 'America Makes' funded 22 research projects with $13.5 million public investment and $15 million industry cost share. It has also initiated a number of agency-directed research projects that have received over $7 million in funding[8]. In March 2014 it was announced that the federal government will increase the funding commitment to $50 million [4].

b) Asia

Asian countries are also investing. In fact, 26.4% of all industrial AM systems installed worldwide are in the Asia/Pacific region [4].

In Anhui Province (China), Hefei and Bozhou cities and Xery3D are co-investing ~$245 million over a six year period to develop 3D-Printing.

In April 2014, the Ministry of Economy, Trade and Industry (METI) in **Japan** invested over $36.5 million to launch a new research association to develop metal AM technology.

In March 2013, the **Singapore** government announced it would invest ~$400 million over a five year period in advanced manufacturing technologies. Also, the Nanyang Technological University will build a $30 million AM research centre.

The Ministry of Science and Technology in **Taiwan** has initiated a program to develop 3D-Printing with an annual funding of $2.33 million.

c) <u>South Africa</u>

During 2013, in South Africa over $10 million was spent on AM with 80% of the 1500 systems falling within the personal 3D printer category. South Africa looks set to increase expenditure in the area of AM and exploit particular areas such as medical, dental and aerospace [4].

d) <u>Australia</u>

The Advanced Manufacturing Cooperative Research Centre (AMCRC), a large research initiative in Australia has funded a number of projects based on AM and is leading a consortium to establish a national centre to develop AM which is seeking AU$50 million over a seven year period [4].

5. European Investment

European countries have also developed their national competencies in AM, being responsive to the advancements in the expansion and commercialisation of the AM technologies [4]:

a) <u>Belgium</u>

The Belgium regional government of Flanders has invested in a programme on AM for materials called STREAM (Structural Engineering Materials through AM). The programme involving universities, research centres and industry initiated three funded projects at the beginning of 2014. The projects aim to develop polymer laser sintering and metal selective laser melting. A number of educational initiatives are also assisting in dissemination.

b) <u>France</u>

The French Rapid Prototyping Association has contributed to an increased level of standardisation of AM technologies, at both the national level and through the international standards organisation. New calls for proposals were issued in 2013 where one was purely dedicated to “maker space” labs, and others called for research and development of new technologies and applications.

c) <u>Germany</u>

Germany has an AM strategy through creating links between science and industry. The Direct Manufacturing Research Centre (DMRC), based at the University of Paderborn in Germany is a joint industrial and academia centre aiming to advance AM technologies. DMRC and the German State of North-Rhine-Westphalia have co-invested over €2 million. An additional €3.4 million of project funds were provided by that German State to match additional industry funding, which gave an overall budget of approximately €11 million for the five year plan.

d) <u>Netherlands</u>

In the Netherlands, the product development process has become an essential part of AM technologies. For instance, the Dutch research institute TNO has initiated its Penrose-shared research initiative with a number of key industrial partners with the aim of developing the next generation of AM devices and tools with industrial production in mind.

e) Poland

During 2013, Poland ramped up their awareness of AM and arranged a number of events, lectures and workshops. The industry has since experienced a surge in activity, including funded research to develop 3D printing in Poland. For instance, the Lider project received a $300,000 grant to look at specific applications in the Aerospace industry.

f) Portugal

A research centre of excellence, mainly the Centre for Rapid and Sustainable Production Development (CDRSP) at the Polytechnic Institute of Leiria, organises international conferences focusing on AM. A number of research projects have been funded by the Portuguese Foundation of Science and Technology and the Portuguese Agency for Innovation and the Industry. Also, the Portuguese AM initiative (PAMI) was launched by CDRSP, the University of Coimbra and the CENTIMFE. PAMI will be incorporated as part of the national research infrastructure roadmap.

g) Spain

Many entrepreneurial initiatives have been launched in the development of personal 3D printers, applications and new business models. The Spanish Association for Rapid Manufacturing has launched a joint initiative group, AEI-DIRECTMAN, representing the most relevant actors of AM in Spain.

The private research centres are taking the lead for industrial applications in AM (Ascamm Technology Centre; Metal-Processing Technology Institute AIMME; Technological Centre AITIIP, PRODINTEC) and some Spanish regions are very active and involved in European RIS3 initiatives, such as Andalucía, Aragón, Asturias and Catalonia.

h) Sweden

Research and education are speeding up in Sweden, with concentrated funding for research and development. There are also many Universities in Sweden which are significantly increasing their research and development in the area of AM.

i) United Kingdom

The UK has seen a significant investment in AM in a number of industry sectors. The consumer industry accessed some £2.5million of industry contribution to lever around £7.5million support, automotive contributed £3.5million to lever £6.5million in AM research activities and the Medical sector reported contributions of £3 million to lever £11.5million for AM research based activities. Also, the UK Aerospace industry has invested £13 million in AM research. More recently the UK Government has invested £30 million with an equal industry match for a seven year period for the development of a new aerospace technology. The EPSRC has also provided over £4.0 million for development of AM.

6. Additive Manufacturing supported by the European Commission

Research and innovation activities in AM with funding from the EC have greatly evolved since the first Framework Programme (FP) in the 80s, when basic projects on rapid prototyping involving the laser scanning of polymers were funded. The support of AM has grown much since then, with increasingly larger amounts of funding coming from the different Framework Programmes. The main increase occurred during the last years of FP7, from 2011-2013, and the trend continues with the proposals submitted to the first calls of Horizon 2020.

The majority of the AM projects in FP7 were funded under the area of Nano-sciences, Nanotechnologies, materials and New production technologies (NMP) while many other areas in the Framework Programme also included AM projects.
With around 90 EC funded projects since 1991, a broad range of the AM capabilities and potential was demonstrated in a diverse range of applications and industrial sectors.

The Public Private Partnerships (PPPs), particularly Factories of the Future (FoF), meant an impulse to the AM sector, which found a suitable environment for translating the research results into the real production.

EU policy is only starting now to address the challenges in AM through a number of initiatives, such as the Industrial Policy Communication where 3D Printing is highlighted as a key element for the new Industrial Revolution[1]. The “Industrial Landscape Vision 2025” [2], published in 2013 by the JRC also showed AM as a case study on how Standards will facilitate new production systems by enhancing EU innovation and competitiveness. Another example is the EC Task Force for "Advanced Manufacturing Technologies for Clean Production"[3],where AM/3D-Printing has been widely mentioned as a Key Advanced Manufacturing technology.

PART 2:

The EC Workshop on Additive Manufacturing

7. Scope of the Workshop

The aim of the workshop was to bring together into discussion the most relevant stakeholders in the field of AM with the different services of the EC (DG ENTR, CNECT, JRC, led by DG Research and Innovation). The stakeholders participating represented the whole value chain and included:

- Machinery manufacturers
- Parts manufacturers (service-bureau)
- Material suppliers
- OEMs
- Supply chain manufacturers
- Systems integrators
- SMEs
- Software
- Standardisation
- Research and Technology Organisations
- Universities

The distribution of the over 100 attendees was: 35% industrials, 28% academia, 19% research and technology organisations and 18% EC. The participants represented 12 Member States (DE, UK, ES, FR, NL, BE, IT, DK, SE, AT, PT, IE), 2 Associated Countries (CH and NO), the US and Egypt.

Key items on the agenda included the current State-of-the-Art of AM technologies in Europe and the challenges that European companies will have to face in the coming years, especially due to growing competition from other countries. The workshop had special emphasis on the impact of possible policy measures at the Union level and on the competitiveness of European companies in the coming years.

The Director for Key Enabling Technologies (RTD/D) opened the workshop and several presentations set the scene of AM for the participants. Session 1 showed the industrial roadmaps for AM that the main European Technology Platforms (ETPs) have developed in collaboration with the EC and Session 2 covered the related policy aspects. Session 3 presented different AM success stories selected among European FP7projects. Those sessions prepared the ground for the discussion by providing the key elements that currently challenge Additive Manufacturing.
Sessions 4 and 5 focused on a debate between the invited panellists and the participants. The moderators launched several questions to stimulate the discussion. Session 4 focused on the technological aspects of AM technologies and Session 5 discussed the potential policy measures and actions that could be taken at EU level in order to remove the current barriers in AM.

8. Opening Session

8.1. Welcome address

Clara de la Torre. Director for Key Enabling Technologies, RTD/D

The Director for KETs in DG RTD emphasised the role of AM, including 3D printing, as one of the potential game changers for the European economy.
AM can disrupt the manufacturing value chain and allow for a shift from mass production to full customisation. For this reason, it is essential for this technology to be welcomed and developed in order to keep the European economy at the forefront of innovation, allowing an increase in production on a local basis, strengthening regional economies and bringing outsourced jobs back to Europe.

AM has received significant attention during the last years but the European Commission already funded AM projects since the very first Framework Programme (1984-1987). During FP7 (2007-2013), the more than 60 successful projects based on AM technologies received a total EC funding contribution of over €160 million, with an overall total budget of €225 million. However, despite this support, European companies are still facing a tough business environment which is being further stressed by investments in the US and China in the field of AM. Countries such as Singapore, Korea, Japan and South Africa are seriously investing in the technology as a result of the global implementation of AM technologies.

Under Horizon 2020, Additive Manufacturing, and in particular 3D-Printing, will have a very important role in the KETs and in the PPPs, specifically in the Factories of the Future PPP. AM priorities and challenges will be developed through Industrial Roadmaps in collaboration with the relevant stakeholders.

EU policy has also started to address AM, highlighting 3D-Printing in the Industrial Policy Communication from 2012, in the Industrial Landscape Vision 2025 and by the EC Task Force for Advanced Manufacturing Technologies for Clean Production.

The EC Workshop on Additive Manufacturing is crucial to understand and to discuss how the current barriers could be removed in order to further develop AM technologies. Related potential policy measures at the EU Level which could enhance the competitiveness of the AM sector will also be a specific and important topic for the discussion.

8.2. Additive Manufacturing in FP7 and Horizon 2020

José Lorenzo Vallés. Head of Unit "Advanced Manufacturing Systems and Biotechnologies," RTD/D2

Additive Manufacturing has an enormous potential in the industrial and consumer goods sectors. The European projects in the different Framework Programmes showed the wide range of applications and products that AM can develop. Since the early 90s, a total of 88 projects have been funded by the European Commission (Table 2).
A closer analysis shows that nearly 30% of the projects focused on materials for AM with the remaining 70% evenly split between technology development and applications. In the applications area a variety of fields ranging from health, industry, aerospace, electronics and consumer goods (Table 3) have been covered during the different FPs and Work Programmes.

Table 2: AM related projects by programme funded from FP3 to FP7 (1991-2013)

EC Programme	Number projects
FP3	4
FP4	8
FP5	3
FP6	12
FP7 IDEAS ERC	3
FP7 NMP	34
FP7 ICT	2
FP7 PEOPLE	8
FP7 SME	5
FP7 TRANSPORT	1
FP7 INCO	1
FP7 JTI	5
FP7 KBBE	1
FP7 SIS	1
TOTAL	**88**

Table 3: Additive Manufacturing related projects funded by field from FP3 to FP7 (1991-2013)

Materials 29.6%	Metals	11.3%
	Polymers	7.0%
	Biomaterials	5.6%
	Ceramics	2.8%
	Other materials	2.8%
Technologies 34.5%	Process technologies	23.2%
	Informatics	10.6%
	Standardisation	0.7%
Applications 35.9%	Industrial processes	7.7%
	Health	4.9%
	Bio-printing	4.9%
	Aerospace	3.5%
	Moulds and tools	3.5%
	Micro 3D-Printing	2.8%
	Foot and textile	2.1%
	Consumer goods	1.4%
	Electronics	1.4%
	Skills and education	1.4%
	Microfluidics	0.7%
	Design	0.7%
	Food	0.7%

The Industrial Leadership pillar of Horizon 2020, including the KETs, will certainly play a major role in the development of Additive Manufacturing technologies. One of the main drivers for AM will be the FoF PPP. This partnership primarily develops its activities through industrial roadmaps in collaboration with the most relevant stakeholders. In this way the industry plays a leading role in defining the priorities which will aim to close the gap between technology and manufacturing. Also, as a result of this collaboration, the funded projects will be more oriented towards exploitation and therefore closer to the market in comparison to the previous Framework Programmes. A high

SMEs participation is encouraged in the projects and in this way the expected impact is maximised.

One important challenge identified in Europe is the so called 'Valley of death'. When relevant results are developed in research one of the main barriers to overcome is how to take this product or service to the market. The Leadership in Enabling and Industrial Technologies (LEIT) part in Horizon 2020 is addressing this by implementing a Technology Readiness Level (TRL) approach (Figure 4) for the Work Programmes. In this way, the Calls for Proposals can be better targeted to the specific needs of the different sectors. The FoF PPP is mainly focusing on TRLs 4 to 7. Additive Manufacturing will also have a role in the Societal Challenges of Horizon 2020.

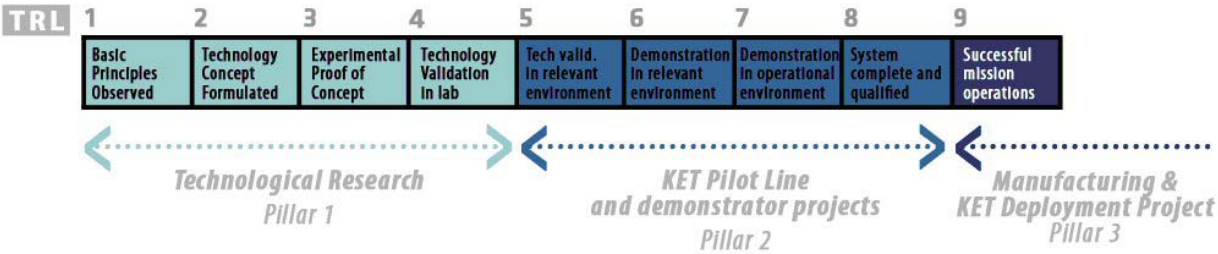


Figure 4: TRL adopted by the EC.

8.3. Additive Manufacturing: The wider societal, legal and economic implication to Europe

Phil Reeves. Managing Director, Econolyst

In the global market of AM, the US is losing its edge to the Asian countries. This fierce competition is one of the main reasons why the US is strongly reinforcing their position in the market and heavily investing in research and innovation in AM. If Asia does succeed, European users would have to buy the technology from the other regions of the world and European suppliers will compete with experienced foreign players. To avoid these pitfalls and to remain competitive against these countries, Europe will need to develop more than just the technology aspects such as software, hardware and materials. A number of wider issues will need to be addressed, such as:

Intellectual Property (IP)

There are many grey areas in AM where IP is concerned. For example, in some cases there are rights to copy and in others there are not. Component parts are also governed by patent and copyright protection. Similarly, there are issues surrounding scanning and how much a modification of the scanned geometry will affect its patent protection. There are as well liability issues concerning the machine, its data and the used material. Equally, when moving towards localised manufacture, there will be questions regarding where the liabilities surrounding the manufactured components are. This raises further questions about how the consumer is protected.

Environmental Considerations

There are some environmental aspects to consider for AM technologies. AM technologies can reduce material consumption, but that does not mean they are zero waste technologies. For example, there are waste streams such as support structures and several issues around materials supply. With polymeric machines there is a need to refresh the material due to limited recycling rates. The idea that the technology is fully 'green and clean' particularly in the manufacturing stage is not right in all the cases.

Infrastructures Management

The Gartner Hype Curves are driven by a belief that objects can be made anywhere and that consumers are engaged in the product design and innovation and therefore involved in the mass personalised production chain. This is true when making phone cases, gifts, dental crowns or even hearing aids, but issues can arise with material limitation, validation and certification, all of which are paramount to growing sectors such as aerospace, automotive and medical. This leads to questions around taxation and cross-border duty because the objects are not moving but the data are. There are also data protection issues, about what happens to the scanned data, how they are used, who owns them, etc.

Legal

AM is an industry where the technology vendors maintain control of their supply chain, but users can dislocate this and source their materials in an open market. Here, competition is an issue. Equally, CE marking and compliance is another aspect to be analysed, since it remains unclear how compliance can be placed on something that someone has made himself.

Technological Challenges

On the broader technical challenges, modelling and simulation is fundamental to AM technology. Software tools allow to simulate the object to be built and to determine whether something is printable or not. Also, AM machines do not stand alone in factories, particularly when involving metal based technologies, where components need to be polished, machined and heat treated. This is where integration requires attention. Equally not everything can be built by AM, and hence the technological limitations need to be fully understood.

9. Session 1: European Industrial Roadmaps for AM

9.1. Factories of the Future PPP: Strategic AM aspects in the Multi-annual Roadmap

Arun Junai. ManuFuture

The mission of the European Technology Platform (ETP) ManuFuture is to propose, develop and implement a strategy based on Research and Innovation, capable of speeding up the rate of industrial transformation to high-added-value products, processes and services, securing high-skills employment and winning a major share of world manufacturing output in the future knowledge-driven economy.

Within the ManuFuture ETP there are currently 1,800 registered members. This membership includes 1,400 SMEs, 230 large organisations, 120 research institutes, 20 industrial associations and 30 governmental bodies.

In 2009, ManuFuture established the European Factories of the Future Research Association (EFFRA) with the objective to promote pre-competitive research on production technologies within the European Research Area. EFFRA engages with the EC in the PPP 'Factories of the Future', an industry-led programme in research and innovation with the aim of launching market-oriented cross-border projects throughout the EU.

The roadmap 'Factories of the Future 2020' identifies the challenges and opportunities in the manufacturing of future products. At the heart of the roadmap are six research and innovation priority domains. The manufacturing challenges and opportunities will be addressed by deploying technologies and enablers.

Additive Manufacturing has been identified as one of the advanced manufacturing processes requiring a clear focus. Domain 1 for Advanced Manufacturing Processes highlights AM as one of the ways to address customisation, improve material efficiency and enable the (flexible) use of substitute materials.

The roadmap also addresses the social, economic and environmental challenges to achieving a sustainable industry. Also in this respect, the introduction of new manufacturing technologies promoting resource efficiency, such as AM and 3D-Printing, are a key priority of the FoF PPP.

9.2. AM Platform: Strategic Research Agenda 2014-2020 and Roadmap for AM standardisation

Amanda Allison. AM Platform

The European Additive Manufacturing Technology Platform (AM Platform) is a sub-platform initiated in 2004 under the ManuFuture Technology Platform and having good cooperation links with DG RTD.D2. The AM platform acts as a focal point where key stakeholders in the field propose and develop activities ultimately for increasing the exploitation of AM. The platform stakeholder representation stands at more than 350 members, based across 26 European countries. The industrial representation is significant and represents 72% of the total membership. The Platform also has good links outside Europe, such as the US (IMS) and the Global Alliance Rapid Prototyping Associations (GARPA).

Industrial engagement is key to the activities of the platform and in supporting the future actions for the successful exploitation of the technology. As a result, the AM Platform has created the AM Strategic Research Agenda (SRA) for Europe 2014-2020[9]. The SRA maps the way forward for addressing not only the technical needs of AM but also the EU grand challenges where AM can assist (Figures 5 and 6).

EC funded projects have generated a significant amount of collaboration and development for AM, which has facilitated a great shift in knowledge and growth amongst AM communities. However, AM has the potential to further facilitate economic growth, generating wealth and jobs. Further industry support is needed especially in standardisation, which is important for improved quality products, processes and services. The EU is one of the global leaders in AM, but it has lost ground to other economies which are investing in the potential of AM. Europe needs to maintain and build on its lead or otherwise is risking to miss out the benefits.

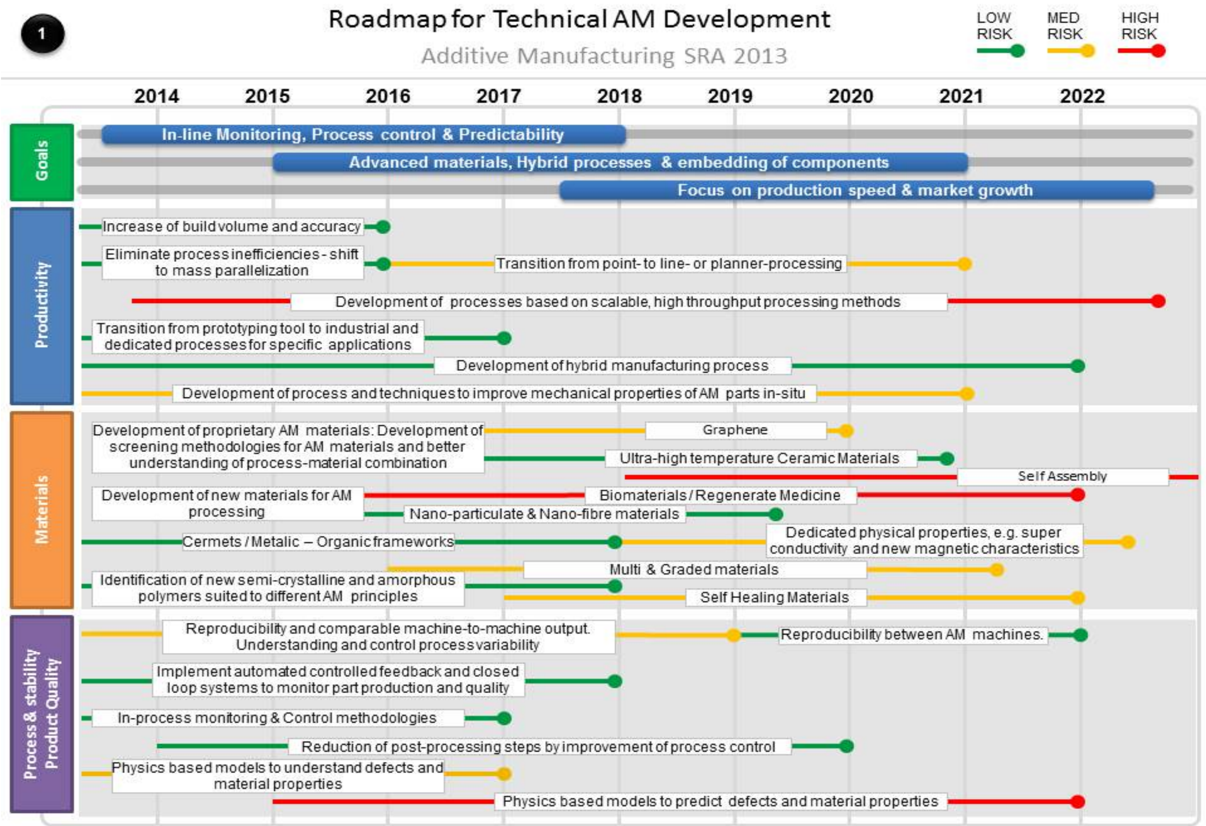


Figure 5: Timeline roadmap for Technical AM development (Images courtesy of AM Platform) [9].

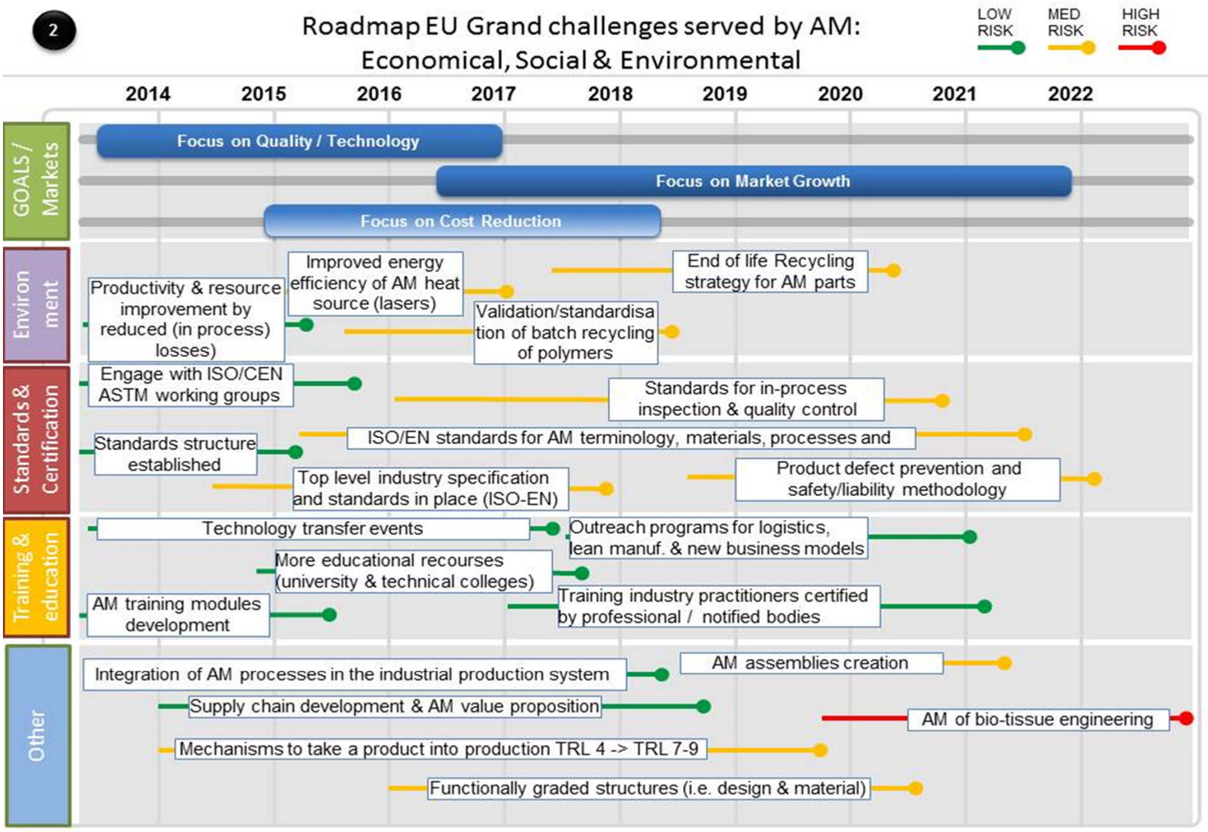


Figure 6: Timeline roadmap for EU grand challenges (Images courtesy of AM Platform)[9].

9.3. EuMAT Platform: New Materials for Additive Manufacturing

Helena Gouveia. EuMAT Platform

EuMaT is the ETP for advancing engineering materials and technologies. The platform was launched in order to assure optimum involvement of industry and other important stakeholders in establishing European research and development priorities in these areas. The platform was initiated in June 2006 and currently has more than 900 registered members of which 23% are from industry.

EuMaT prepared its first SRA in 2006 when the platform was launched and a new SRA is being prepared for launch during October 2014. Within this SRA a special chapter for AM materials will be included. AM is shifting from a pure Rapid Prototyping process to a serious production process offering significant market opportunities for new materials. Most of the materials development work was centred on the use of plastics but there are still a number of weaknesses concerning processes and materials for metal AM. There is a need to understand the basic science of each particular process, the materials microstructure and to develop a comprehensive material property database and testing methodology.

Materials in AM are key for a further development of the technology and EuMaT can contribute to it. The A4M initiative, involving EuMaT and four other ETPs has a strong focus on the materials, in order to ensure the full value chain coverage and to improve this way the speed of innovation implementations in Europe. Because a basic parameter in AM is materials, A4M offer a multidisciplinary approach to provide the support needed for the development of this disruptive technology and bring it to the market.

9.4. Photonics 21 Platform: High Performance Light sources-based Additive Manufacturing

Reinhart Poprawe. Photonics21 Platform

Photonics 21 is a group of 2200 members, half of which are industrial organisations and comprising one third of SMEs. Photonics 21 aims to establish Europe as a leader in the development and deployment of photonics technologies within various application fields (ICT, lighting, industrial manufacturing, life science, safety, education and training).

Photonics 21 functions via a number of working groups. The working group on industrial manufacturing is where most of the activity around AM technologies is based. AM has the potential to extend laser processing capabilities and will allow new and challenging processing applications. In order to understand this concept, there is a need to look at the systematics of conventional production versus production by means of AM technologies. In conventional production there is a decrease in price per object when there is an increase in group sizes. However, when looking at a major product complexity prices usually go up. This is not the case for laser based manufacturing or AM. Over the last five years productivity for laser based manufacturing or AM has been increasing, meaning that higher group sizes are getting more economically interesting. It is now possible for laser costs and efficiencies to be exploited which will bring down the costs by a factor of 10 in the next 5 to 10 years.

10. Session 2: Policy Perspectives for AM

10.1. 3D Printing Revolution - Challenges and Possibilities

Bonifacio García Porras. Head of Unit "Innovation Policy for Growth", ENTR/B3

Manufacturing is a top priority for the European industrial policy and recently the European Council has called for an industrial renaissance. The EC has also presented the goal of 20% of the total EU Gross Domestic Product (GDP) coming from manufacturing from its current value of 15.1%. Although EU industry has proved to be resilient, there is still an important decrease in the amount of jobs and share of manufacturing with regards to GDP that needs to be counteracted.

In 2013 an EC Task Force was set up on Advanced Manufacturing which aimed at fostering the development and adoption of advanced manufacturing for clean production by European industry. As a result, a report on Advanced Manufacturing for Clean Production was presented in March 2014.

This report discusses the technologies that can improve the efficiency and productivity of industry, one of which is AM/3D-Printing. However, there are a number of challenges identified that need to be addressed. There is a need to speed up the commercialisation of the technologies and bridge the gap between research and commercialisation. The debate has to focus on the obstacles that the industry is facing to update these technologies, including the lack of skills, access to finance, understanding of the potential of these technologies and standardisation. The report includes the recommendations by the task force in order to put those technologies forward. One example is the support to industrial clusters that promote these technologies in order to be understood, like the I4MS project by DG CNECT. Another example to promote the acceleration and the update of this technology is Regional funding. The task force has also been cooperating with DG EAC on how to improve the acceleration or elimination of certain types of gaps with regards to skills within these technologies. The Knowledge and Innovation Community (KIC) on added-value manufacturing (AVM) which will be launched in 2016 also aims to address the skills gap. The intention of the task force to move forward is to focus now on how regions can provide funding towards the modernisation of industry.

10.2. Selected perspectives on Additive Manufacturing in the US

Stephan Eelman. Research and Technology Director Germany, Boeing

Although Boeing has mainly focused on polymer based AM, their aircraft programmes to date have resulted in the understanding of both the design elements and the certification of the AM technology. For instance, verification is very important, as prototypes are used in the design phases and in rapid tooling. Adherence to internal qualification and specification is also needed.

In terms of AM processes, Boeing mostly uses powder bed fusion and FDM techniques. In terms of 3D printing, the design process is being accelerated due to multimaterials, different structures and colours which can now be discussed between design teams. However, there are still strict requirements for testing of materials before taking a design with a qualified material from rapid prototyping to 3D manufacturing. A significant amount of engineering and manufacturing requirements for the part itself, in terms of design and post processing, need to be carried out as well.

When looking at materials development, there is a need for even higher performing materials. In this area, a substantial amount of development work is required to understand structural integrity issues such as isotropic properties, stiffness, strength, fatigue and creep behaviour. A common baseline where there is comparability in the tests between different materials and machines is still to be developed.

Finally, there is an open question for the AM industry on how they will address safety and regulation.

10.3. An Industrial Landscape Vision 2025: an opportunity for Additive Manufacturing

Fabiana Scapolo. Head of Sector "Foresight and Horizon Scanning", JRC/A1
Peter Churchill. Advisor for the European Research Area, JRC

A series of Foresight studies were conducted in 2012 and 2013 by the Joint Research Centre (JRC) on the future of standards and standardisation. The 'Industry landscape vision for 2025' report takes a holistic view in understanding the complexity of the industrial system, its inter-linkages and reactions. It also introduces a paradigm shift from the traditional sector-based description of the industrial system to a more function-based representation. Additive Manufacturing and 3D-Printing can play a major role in this transformation.

The studies were based on a panel of over 70 experts from across Europe covering academia, standards organisations and stakeholders from non-governmental organisations, consumers and designers. These studies were performed for DG Enterprise and Industry and aimed to provide policy evidence on standards and standardisation as key elements contributing to industrial innovation policy and competitiveness.

Within these studies, AM is identified as having a especial influence when moving towards more customised goods and services. The foresight studies believe that the service industry will become stronger and products and services will be more interlinked. For example, a single product or service will no longer serve the entire global economy but instead will cover regional, local, and societal needs. ICT will also underpin industry and will lead it towards a digital factory where data will become 'the new oil'. These days, companies are rapidly increasing the amount of data exchanged and are turning them into real business opportunities. These are important elements that will change the business environment in the coming years.

Materials are also a key element for facilitating the adoption of AM. The countries and organisations that currently have an active research on new materials which can substitute rare earths elements will definitely take the advantage. They will also facilitate new technologies and the way forward to enable new industries.

If Europe wants to play a strong role in AM, the EU has to invest and bring AM technologies into the mainstream, training the people with the appropriate programmes which can develop their skills. AM is a challenge for quality and performance in terms of standards but there are also issues on IP and on how to protect IPR that need to be solved. The research and development in these areas will become crucial and will require further investment.

11. Session 3: EU Projects – Impact of AM innovation on European Competitiveness

Session 3 showcased a selection of FP funded projects that represent areas where AM has significant potential for innovation developments that could higly impact the European economy, society and environment.

The areas represented and where Additive Manufacturing is already playing, or will play, a major role in changing the paradigms of production are: Aerospace, Food, Health, Materials, Production Technologies and 3D-modelling software:

- PERFORMANCE FP7 project (Food supply chain). Pieter Debrauwer, TNO
- NANOMASTER FP7 project (Materials). Jeppe Byskov Nielsen, Teknologisk Institut
- REPAIR FP7 project (Aerospace industry). Jens Pottebaum, UPB
- ARTIVASC3D FP7 project (Biomaterials for Health). Arnold Gillner, Fraunhofer
- MANSYS and MERLIN FP7 projects (Production Technologies). Rob Scudamore, TWI
- DIGINOVA FP7 project (Digital Fabrication). Marcel Slot, OCE

Further details of all the projects presented and the impacts they are generating can be found in Annex III.

11.1. Performance

The Performance project is a good example of how AM is positively impacting society through improving quality of life (Figure 7). The main idea of the project is to develop and validate a holistic, personalised food supply chain for frail elderly people in nursing homes, ambient assisted living facilities or at home (served by nursing services). This group of people require careful consideration of the various determinants of their nutritional and health status. As a result of the project an automatic manufacturing and supply of personalised nutrition and specially textured food approach will be delivered.

The project shows the synergies of AM in linking the Industrial Leadership pillar with several of the Societal Challenges: Health, demographic change and wellbeing and Food security.

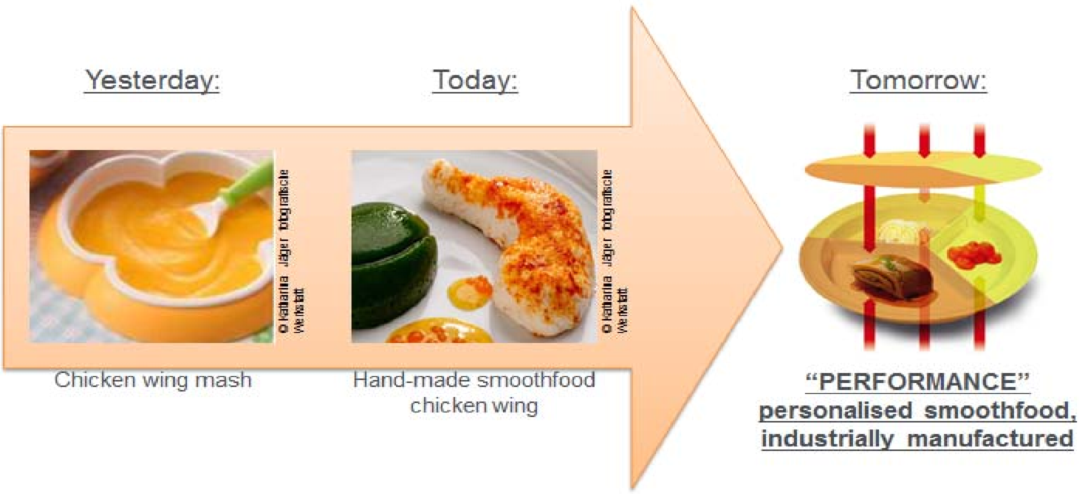


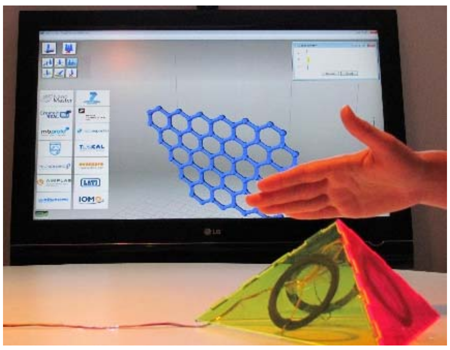
Figure 7: The concept of the Performance Project, working towards 'performance' meals (Image courtesy of the EC funded Performance Project).

11.2. NanoMaster

The NanoMaster project aims to reduce the amount of plastic used to make a component by 50% and hence to reduce component weight by 50% and at the same time imparting electrical and thermal functionality.

This will be achieved by developing the next generation of graphene-reinforced nano-intermediate materials that will be used in existing high-throughput plastic component production processes. The concept for this project is to develop the knowledge-based processing methods required to up-scale the production of graphene, and expand graphite reinforced thermoplastic masterbatches and compounds. The project will develop rapid production at a large scale by integrating into current conventional and AM processes the graphene with reinforced plastic intermediate materials.

Successful development of these materials and processes will have a significant effect on the amount of polymer that needs to be used in a component to meet its performance criteria, and on the ability of plastic mouldings to deliver significantly enhanced functionality.
These breakthroughs will open the door to a vast range of applications that could be exploited throughout Europe and beyond with the subsequent benefits for European competitiveness. They will also help to place European companies in a position to win market share in the rapidly growing markets of the US and Asia-Pacific.



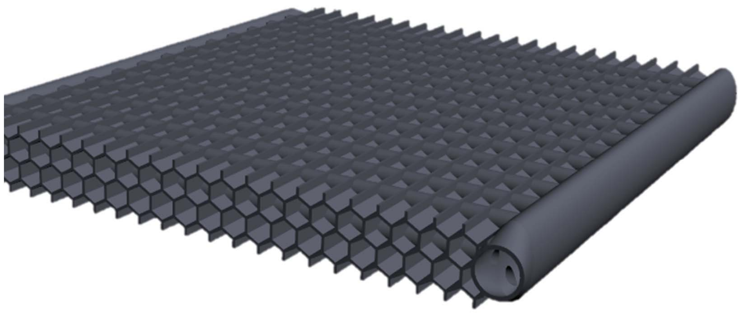


Figure 8: Demostrators of the Nanomaster project (Image courtesy of the EC funded Nanomaster Project).

11.3. REPAIR

The REPAIR project is performing research on future repair and maintenance for the Aerospace industry by integrating direct digital manufacturing. The main objective of the project is to shift the “make” or “buy” decision towards the “make” decision. This will be achieved by the cost reduction in the remake and rework of spare parts and therefore by improving the cost efficiency for maintenance repair in aeronautics and air transport.

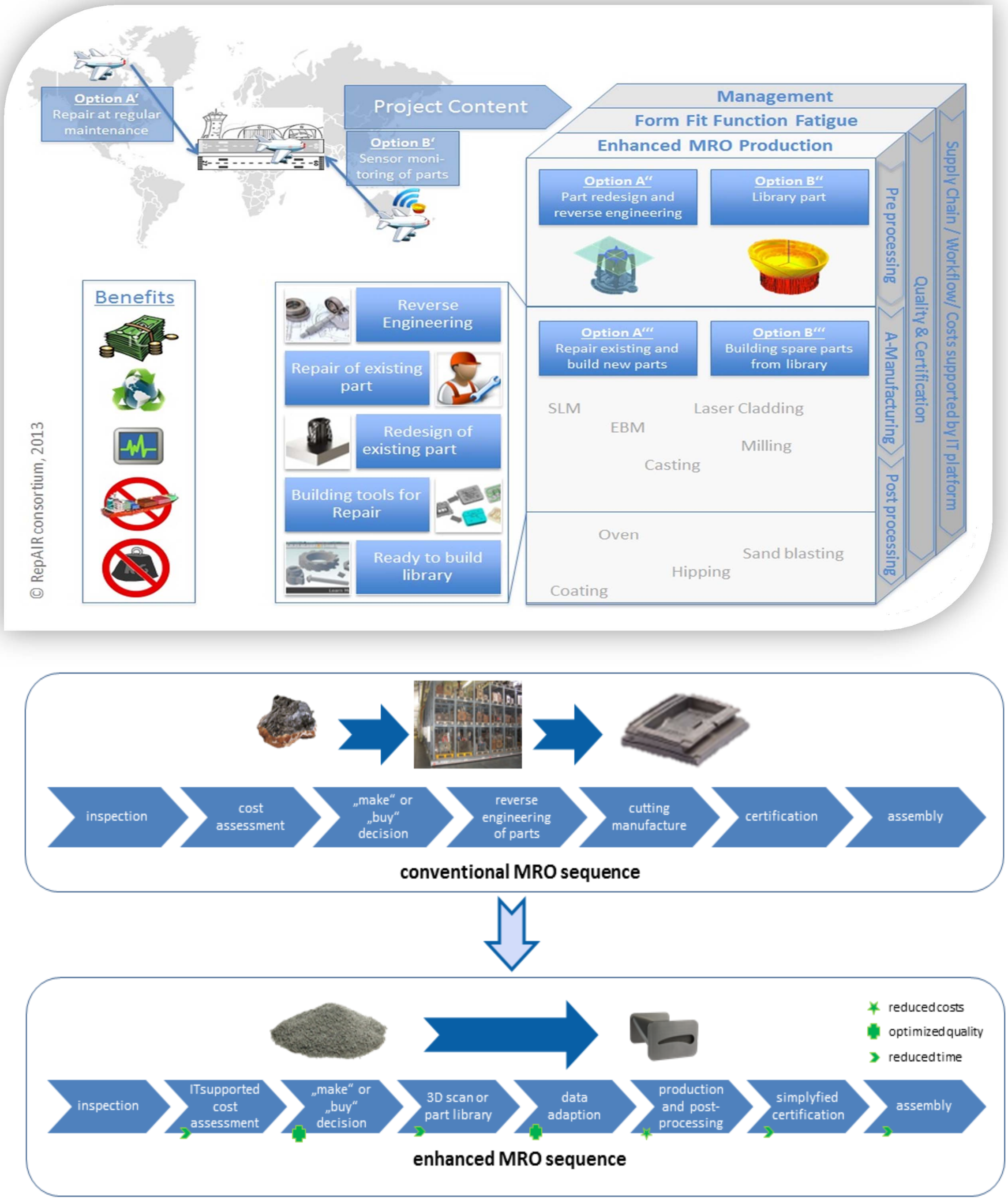


Figure 9: REPAIR project concept (Image courtesy of the EC Funded REPAIR project).

The significant reduction in waste and therefore in the energy produced, will have a considerable impact, especially for the balance of materials. It will also be possible to shorten the entire spare parts supply chain to the simple task of just sending an e-mail. New business models will become sustainable through a higher level of automation and with fewer stages for production. Less personnel costs will subsequently reduce the maintenance, repair, and operational costs.

11.4. ArtiVasc 3D - Artificial vascularized scaffolds for 3D tissue regeneration

The use of bio artificial tissue for regenerative medicine offers great therapeutic potential, but also has to meet high demands with respect to the interaction of the bio artificial devices and natural tissues. Key issues for the successful use of bio artificial tissues as natural tissue replacements are their long term functional stability and biocompatible integration. Up to now, various approaches for the generation of bio artificial tissues have not succeeded due to insufficient nutrition and oxygen supply. Therefore, current tissue engineered products have only been realised for non-vascularised tissues such as cartilage.

The overall objective of ARTIVASC 3D is to develop a synthetic soft tissue graft which can be used in a vast array of clinical applications, including bio artificial vascularised skin in trauma treatment for efficient and scar-free wound healing, vessel replacement, and possibly the development of more complex synthetic biomedical constructs. The ARTIVASC 3D project focuses on the design and implementation of a bio artificial vascularised skin. This synthetic 3D scaffold can be used as an innovative in-vitro skin equivalent for pharmaceutical, cosmetics and chemical substance testing thus contributing to the reduction of expensive and ethically disputed animal testing. ARTIVASC 3D directly contributes to the 3R principle (replacement, reduction, refinement) by providing an option to replace and reduce animal experimentation.

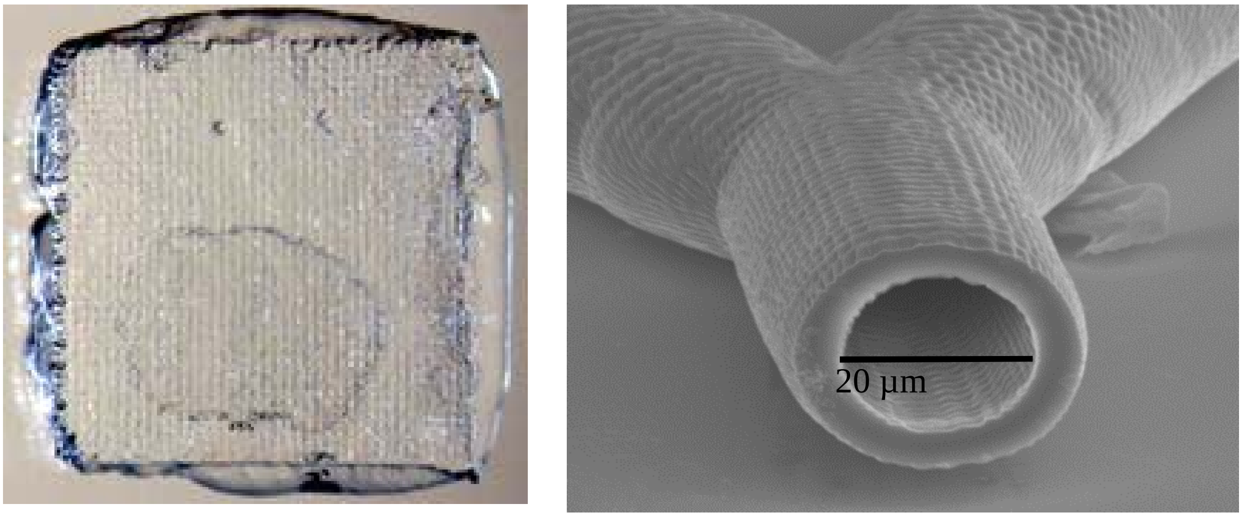


Figure 10: ArtiVasc3D project concept (Image courtesy of the EC Funded project)

11.5. MANSYS - MANufacturing decision and supply chain management SYStem for additive manufacturing

ManSYS aims to develop and demonstrate a set of e-supply chain tools; to enable the mass adoption of Additive Manufacturing (AM). This will allow businesses to identify and determine the suitability of AM for metal products, and subsequently manage the associated supply-chain issues and 'facilitating' open product evolution.

The proposed e-supply chain solution combines all aspects of AM including; multiple build platforms (Laser and Electron-Beam technologies), modelling, post-processing (Machining, Finishing and Heat-Treatment) and 3D scanning techniques. This will give a 'press-button' solution to the production and challenges of new products. The integrated solution will offer a knowledge driven manufacturing process with significant production benefits; customisation, automation, self-management and reduced material usage and waste.

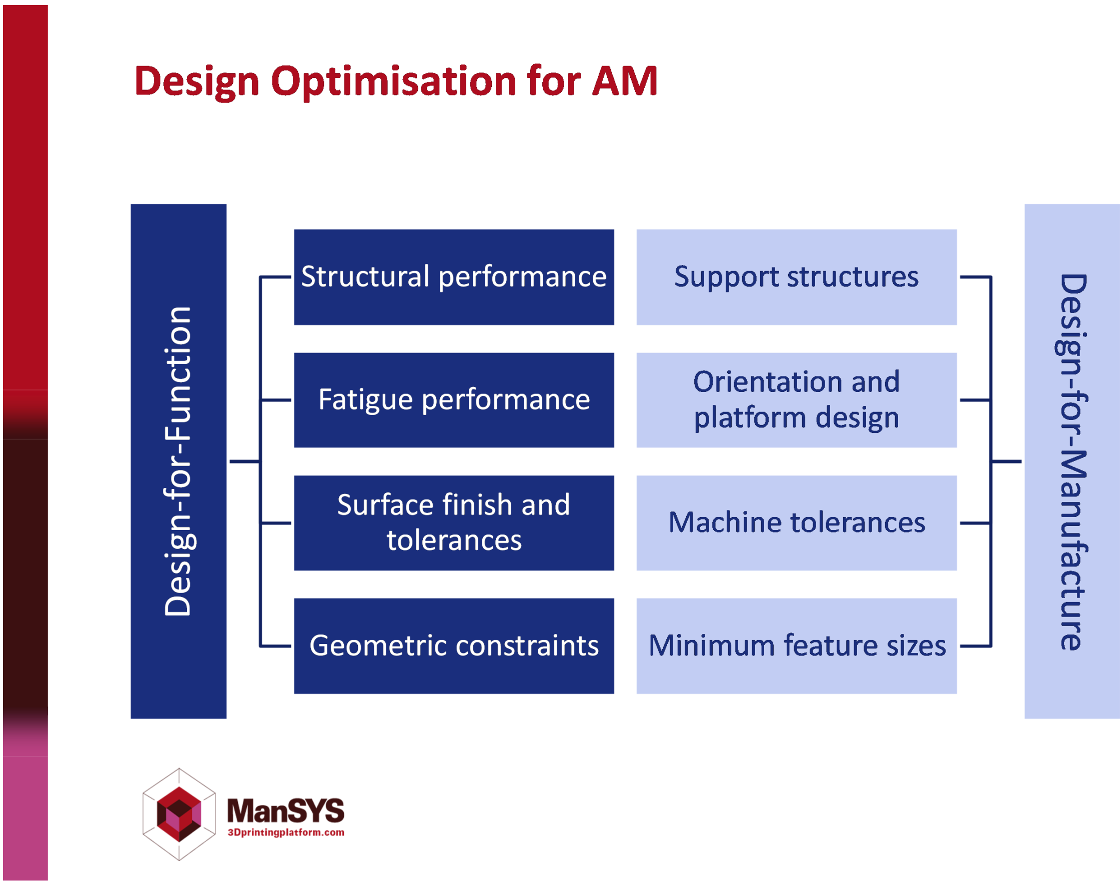


Figure 11: ManSYS project concept (Image courtesy of the EC Funded project

11.6. MERLIN - Development of Aero Engine Component Manufacture using Laser Additive Manufacturing

The MERLIN project aims to reduce the environmental impact of air transport using Additive Manufacturing (AM) techniques in the manufacture of civil aero engines. MERLIN will develop AM techniques, at the level 1 stage, to allow environmental benefits including near 100% material utilisation, no toxic chemical usage and no tooling costs, to impact the manufacture of future aero engine components.

All of these factors will drastically reduce emissions across the life-cycle of the parts. There will also be added in-service benefits because of the design freedom in AM. Light-weighting and the performance improvement of parts will result in reduced fuel consumption and reduced emissions. MERLIN seeks to develop the state-of-the-art by producing higher performance additive manufactured parts in a more productive, consistent, measurable, environmentally friendly and cost effective way.

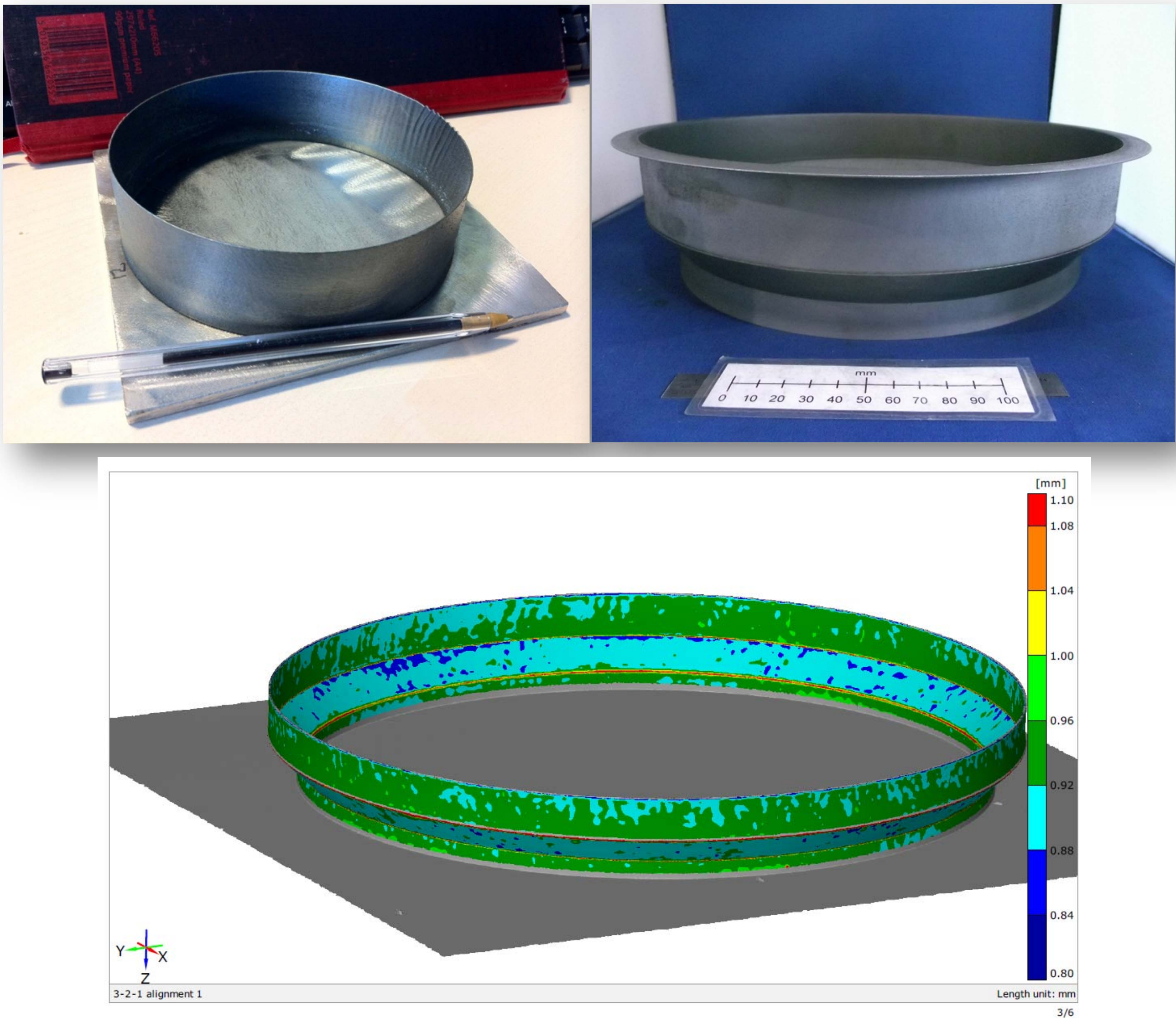
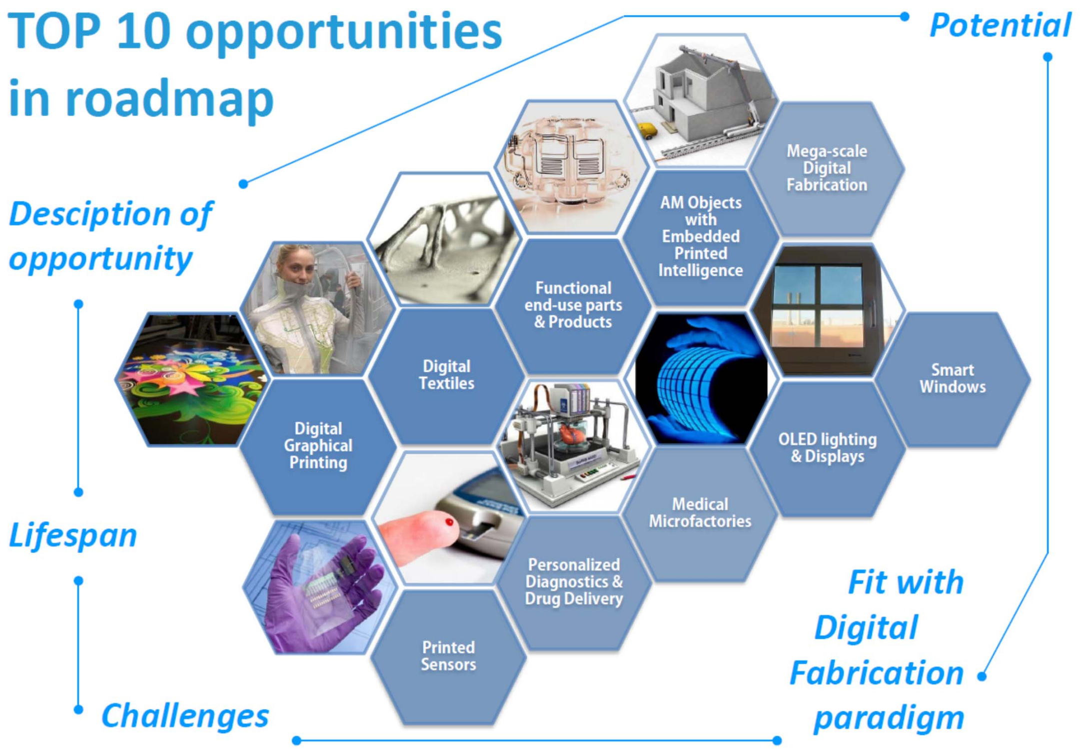


Figure 12: MERLIN 3D structures (Image courtesy of the EC Funded project

11.7 DIGINOVA - Innovation for Digital Fabrication

Most products are produced by means of the established mass production infrastructure. Traditionally, this involves large stocks, high manual labour, large capital investments, high energy use, and long distance transportation. Although many advanced new materials have unique functional properties that hold a great promise for innovation, they often need to meet the criteria and characteristics of this established mass production paradigm. This delays the exploitation of the huge potential of whole new classes of materials. Combined with major societal trends and consumer needs like customization, personalization, on-demand fulfilment and the fact that the world is becoming ever more digital and networked, there is a need for a paradigm shift in manufacturing called Digital Fabrication.

The purpose of the Diginova coordinating work was to determine the current status and assess and promote the expected potential of Digital Fabrication for the future of materials research and manufacturing in Europe, taking the Diginova scope as a starting point. Diginova mapped key material innovation and application domains; identified key technology challenges and new business opportunities. A digital fabrication roadmap describes new business as well as technology drivers, the most promising materials and digital deposition technologies.



12. Session 4: Roundtable on priorities for further development of technologies, equipment and materials in AM

Moderator: **Germán Esteban Muñiz.** Programme Officer, RTD/D2

In this session, a closer look to the main barriers and constraints that AM is currently facing, both in Europe and at global level was explored. Particular focus and attention was given to specific aspects that are preventing an accelerated growth of AM technologies in Europe.

The following experts were on the discussion panel:
Richard Hague. Director, EPSRC
Florian Bechmann. Head of R&D, Concept Laser
Stefan Ritt. Export Sales Marketing Manager, SLM
Bart Van der Schueren. VP Production, Materialise
Andrea Reinhardt. Board Member, MicroTEC

A summary of the questions and the main points raised is given below:

The identification of which technological areas in AM have more potential for economic growth and especially which ones could be the "quick wins" in AM for Europe was the first question addressed to the panellists. It was also important to discuss if Europe should focus its efforts only on AM technologies where we still have the leadership or if instead we should increase the support to technological areas where Europe is already lagging behind. As an alternative strategy, the exploration of new AM technologies was also highlighted.

The different answers could be grouped in the following categories:

MATERIALS

- Material design and its quality are among the main topics that need to be optimised in AM and are not yet fully adapted to the different AM processes.
- Increased understanding of new reliable materials, including better simulation and software, in particular software that allows the simulation on how the product will react after curing or melting with different materials.
- Support to more efficient use of expensive materials, such as titanium for light weight production in aerospace or other important industries where large parts are needed.
- Health and safety issues related to the production of the powders used in AM machines are not well studied yet.
- Recycling of materials and waste disposal need to be addressed, since the growing of AM machines will is expected to quickly grow in the coming years.

PROCESSES

- There is a promising future for combined technologies, such as subtractive methods working together with AM in order to provide an intelligent combination of both, for example by adding post-processing steps to the current AM equipment. However, there are still challenges here to overcome in terms of the data chain. There is also a possibility for combining together several AM technologies in the same equipment. The cost, time and quality issues are still to be assessed for these approaches. Finally, a transition from batch production to continuous production is also a challenge for AM.

- More support towards the industrialisation of AM technologies by the development of new production systems linking AM and traditional technologies and data systems/interfaces. Combining Robotics and AM technologies could be a challenging area.
- In terms of quality control, the manufacturing focus should be on testing, measuring and quality assurance, as well as post processing.
- It is also vital to incorporate the exploration of new processes and encourage new thinking and new innovation.
- Need to develop emerging approaches e.g. moving to the micro-scale or even nano-scale dimensions; processes for new materials and also combining functional materials in the same device (conductive and insulating materials) for functional components.
- Within the consumer and electronics industry there is a need for highly integrated systems and AM has the potential to offer further breakthroughs.
- Process repeatability, speed and productivity are all still key in the up-scaling of AM.
- Ink-jetting is a scalable technology and has potential for economic growth. Europe is drawing very little attention to it in comparison to other countries e.g. Japan.
- Technical developments that have focussed on 2D can be translated into 3D more easily than starting from a brand new approach.

STANDARDISATION AND REGULATION

- There is a lack of standardisation efforts in the coordination and alignment with existing EU and US efforts.
- There is a limited development of standards. Many research programmes could have procedures on deliverables which could be transferred to standardisation to help the development of AM.
- The medical regulations and consumer protection rights have an effect in the innovation and development in AM and this need to be studied into detail. For example, in the medical sector there are critical and 'hopeless' patients that could be easily treated with AM solutions but due to legislation it takes a long time to have a product certified.

APPLICATIONS

- Difference between the Additive Manufacturing technologies, which are mainly identified with the Industrial applications and 3D-Printing, more linked to the Home Appliances and Consumer Goods.
- The automotive, aerospace, medical, dental and research and development services have great potential for immediate economic growth and therefore we could identify them as the "quick wins". For example, in aerospace, the extremely complex and low-volume production parts have a fast growing demand. For small and mid-sized volume, automotive is also a significant area for growth for AM.
- Aerospace and turbo machinery has a large demand for more applications using AM technologies. Many of the large Original Equipment Manufacturers (OEMs) in the AM market are now already equipped with AM machines, but there is still a lot of work to be done in terms of validation and testing of the applications.
- The medical market has been a big driver in terms of economic growth for AM. The population is growing so there is a need for more implants and personalized goods. This field represents as well an enormous potential for the SMEs.

SKILLS

- Support to training of the designers in how they can optimise the design for benefits in reducing costs, energy, materials, etc. Knowledge needs to be brought to the customer in order to get the right parts to be produced.
- The last hype of AM was inspired by a bottom-up movement, including crowd funding for home desktop machines in the US, but there are many makers and hacker spaces running in Europe too. The Fab-lab concept and machines can be used for training, education and qualification matters.
- In different sectors, industrial, medical, consumer goods, there currently are many 'thinkers', 'makers' and craftsman who are using computers to design and develop new products. AM technologies, including 3D-Printing are enablers for these entrepreneurs that want to do business. Here is a potential growth for the European economy.

Another important aspect raised by the moderator was the impact that AM technologies could have on the SMEs, the main employers in Europe. It is frequently said that SMEs could be one of the main beneficiaries of the adoption of AM. Therefore, we need to focus also on what we can do to facilitate their access to AM and the barriers that they find to develop their businesses.

The mains points highlighted were the following:

- There is a need to raise awareness among the SMEs about the benefits of AM, since many of these companies do not have access to specialized forums or big AM industrial events.
- Research projects on AM focused in SMEs are very important, especially since there is a high risk involved when developing new processes. Their role as developers and as end-users should be enhanced.
- More open access will be of benefit to SMEs. In the past a lot of patents were filed so that aspect locked a lot of companies out. Most of the patents related to AM are now expiring and therefore we can expect a big increase of companies making use of AM.
- The current decrease in AM machine costs are also opening up more opportunities and accessibility to the technology for SMEs. Nevertheless, the more capable AM machines are still too expensive.
- Bring more 'best practice' cases forward and showing more widely why AM can reduce costs for the SMEs.
- For an SME the needed investment to adopt AM technologies remains very high, e.g. traning of their staff, changes on their production lines, etc.

Additive Manufacturing has a big potential in many industrial sectors, by replacing or complementing the traditional manufacturing methods. Despite the opportunity that AM represents and while the consumer market is rapidly growing, there is a resistance in the industry for the up-take of AM. In this direction, it is important to take steps that can create awareness of AM technologies in the Europe. In order to create the demand for this technology we need to identify where are the gaps and constraints that are preventing the uptake of AM by the industry.

The panellists shared the following opinions on that aspect:

- There is a lack of knowledge of what AM can offer rather than a lack of awareness. True up-take of AM needs to be driven by the decision makers at the companies and by the engineers and designers working in the production chain.
- Two approaches are promising to increase awareness: A top down approach in terms of communication through conferences, events, etc.; a bottom up approach where the aim is to create success stories, for instance showing the customer the benefits of AM.
- Young people that are willing to work in technical and engineering based industries are hard to find. From a political point of view there is a need to make the industry more interesting and using attractive technologies like Additive Manufacturing for advertisement can increase this interest.
- The mind-set in terms of development and production from subtractive processes to AM needs to start at University level.

13. Session 5: Roundtable on policy measures and implementation

Moderator: **Andrea Gentili.** Deputy HoU, RTD/D2

In this session, a closer look at the possible implications of AM on EU policies was discussed. Within the EC there is a need to think about legislation which is capable of not only protecting the citizen but at the same time capturing the potential of new technologies for the benefit of Europe.

The following experts were on the discussion panel:
Paula Queipo. Director External Relations, PRODINTEC
Phil Reeves. Managing Director, Econolyst
Franz-Josef Villmer. Deputy Rector, HS OWL
Claus Emmelmann. CEO, Laser Zentrum Nord
Dirk Beernaert. Advisor, DG CNECT

A summary of the questions and the main points raised is given below:

The future technological developments in AM need to be accompanied by initiatives and/or policy measures at EU level that will increase the competitiveness of the AM sector. This approach will create jobs and will bring economic benefits for Europe if we are able to develop a European strategy on the AM technologies. Member States and the Regions will also play a crucial role in developing this approach, since AM brings closer to the individual the production of goods and products.
Europe needs to identify the specific areas that should, or should not, be further regulated at EU level and how we can stimulate and remove the current barriers that AM faces today.

The main reflections from the discussion can be summarized in the following points:

POLICY

- A clear statement from the EU and the Member States from the top level will give a definitive push for Additive Manufacturing. AM will become part of large EU programmes and will certainly increase the competitiveness of European companies in this field at the global level. The role and support from the regions to the role of AM in competitiveness and regional growth will also become crucial.
- Smart specialisation will also bring clear opportunities to AM at the regional scale. The localisation of manufacturing that AM implies can bring back industries and jobs to the regions.
- In order to demonstrate the strengths of AM, Technology Transfer Centres with a dedicated industrial focus need to be supported by the regions. Once this infrastructure has been set up, there will be a need for regional and EC funding for the projects.
- EC funding of AM projects with a focus on industry will be crucial, since the success stories can then be communicated all across European countries. This approach will also increase the awareness and understanding of the technology.
- There should be cross-cutting integrating activities running throughout H2020 that link the Industrial Leadership together with the Social Challenges.
- We also need to support the convergence of personal and professional AM. The momentum from media attention should be kept at that level in order to support this convergence. In parallel, support to entrepreneurship on the professional and personal level will increase the chances of success for these new business models.

- In this direction and in order to overcome the through of disillusionment shown in the Gartner Hype Cycle, we need initiatives that could bring Consumer 3D-Printing to the Plateau of Productivity. Competence centres that help with designing for the customers can be a starting point.
- AM processes should not be thought of as isolated technology. We need to consider how to integrate these new technologies into traditional industrial processes.
- We need to pay special attention to the "Business to Customer" and the "Customer to Customer" relationships. An integrated approach will be key for bringing the technology to the market.

INNOVATION

- Innovation is focused on the individuals in AM, therefore giving support for ideas generation like "maker communities" will make Europe more competitive face to the US and Asian countries.
- Additive Manufacturing enables innovation and creativity. These concepts need to be transferred to the industries which still focus on their conventional competencies and fear a loss of their investments. We need to break down the threshold of fear by showing success stories and how they can work.
- Additive Manufacturing creates New Business Models that are the result of the freedom in design and the shortening of the production steps.

REGULATION

- Consideration of regulation and standardisation which can hamper innovation. In the industrial market there are different sectors with different needs. We need to prevent that new regulations will act as a barrier, so regulators and policy makers need to firstly understand the AM technologies.
- Most of the current regulation applies to AM (e.g. Machinery and the Low Voltage Directives). There is no need for major and specific regulations for AM but probably the update of some of them.
- An exception would be the medical sector, where legislation and regulations need to be reviewed to make sure that implants and other medical devices and products created with AM are appropriately manufactured.
- AM is about stimulating innovation and one of the major issues for small businesses is harmonisation and IP law. There are lots of patents governing the use of these technologies for downstream applications.
- IP is very different to copyright since there is no copyright on objects. Copyright in the music industry is "dead" and similarly in AM it will not survive. The key point is the use of the reverse aspect of copyright which is the open source use.
- Products produced in another European country and shipped throughout Europe have problems with VAT since this is not harmonised within the EU. It is complicated for entrepreneurs to use 3D printing to produce goods and sell them throughout Europe.
- We need to differentiate between personal and professional Additive Manufacturing technologies. On the personal level the freedom in design has to be maximised and the support of 3D playgrounds is very important but there is also the need for a clear framework for taxes, logistics, and for the entire supply chain. On the professional level we still need to support the

certification of materials, end products and CE marking, possibly implying some new regulations.

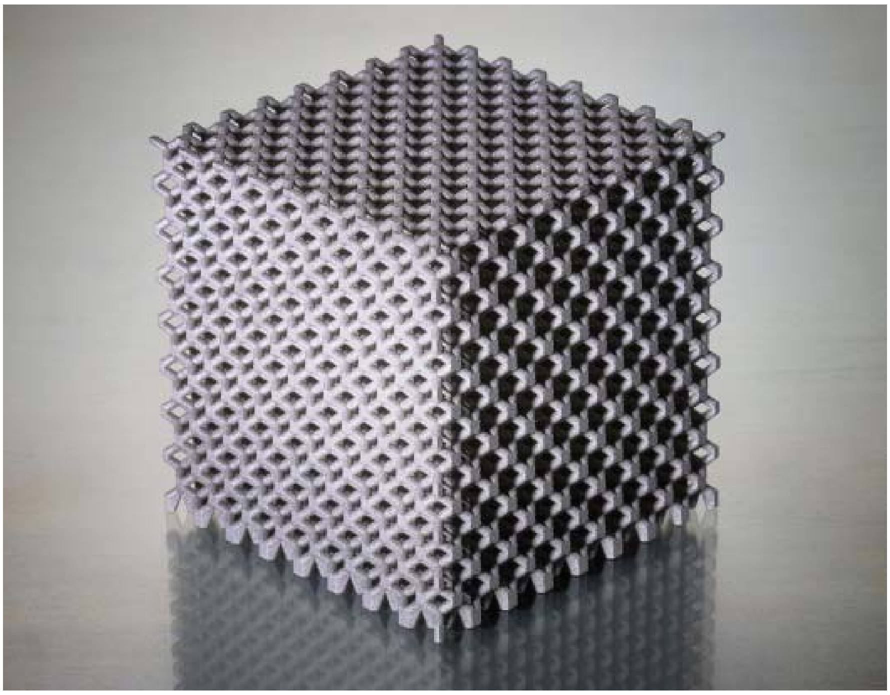
- The "Consumer to Consumer" society will grow and the exchange of goods produced via 3D-Printing will become a social activity. Makers cannot be legislated against and therefore there is a need to look at the platforms that they are using to take products to the market. The biggest issue for the AM industry is the generation of mistrust because of a non-controlled environment at the Consumer Goods level.

SKILLS AND TRAINING

- Training for technicians at machines, engineering design, software, engineers and managers that are currently working in the industrial sectors is paramount in order to bridge the valley of death for these technologies. By doing this, a growing number of skilled people will be able to bring inventions to the market.
- There is a need for education in two areas: First, starting with newcomers and developing new curriculum for schools and universities so students develop knowledge about AM technologies; Secondly, providing centres, places for industry where they can develop ideas and business and professional can also recycle their expertise.
- The AVM KIC to be established in 2016 should address the Additive Manufacturing challenges.

PART 3:

Key Findings and Conclusions



14. Key Findings and Recommendations to the EC

Today, European AM stakeholders and EU Member States act in a fragmented manner, with gaps and inefficiencies in linking the wide range of applications, disciplines, manufacturing sectors and countries concerned. Europe needs a strategic approach and a common vision for AM.

The EC has an essential role to play as a facilitator by fostering a European network of manufacturing competence that will accelerate the take-up and the time to market for new applications.

EU specific policy measures and the continuation of the EC support under Horizon 2020 would provide a clear support to the development of AM and could drive Europe to gain competitive advantage in the global economy.

As a summary from the different sessions, we could highlight the following recommendations. They are the result of the highly valuable input of the group of 100 experts which gathered for this EC Workshop on Additive Manufacturing:

Technological Challenges

- Different needs from AM industrial sectors and 3D-Printing applications.
- Modelling and simulation development.
- Development and testing of materials for higher performing materials with additional isotropic properties, increased stiffness's and strength, and creep behaviour.
- Engineering and manufacturing requirements for the part itself, in terms of design and post processing.
- A more common baseline for comparability in tests between different materials and machines.
- Increased understanding of new reliable materials including better simulation and software, particularly software that allows the simulation of how the product will react after curing or melting with different materials.
- Development of highly integrated and combined technologies, such as subtractive with AM and AM to AM.
- Focussing on the industrialisation of AM technologies (e.g. development of new production systems with linked AM and traditional technologies and data systems/interfaces).
- Developing emerging approaches e.g. moving to the micro-scale or even nano-scale dimensions and also new materials and combining functional materials in the same device (e.g. conductive and insulating materials) for functional components.
- Further understanding of the business and supply chain benefits.
- Process stability, capability and productivity.
- Further development of AM technologies with improved material consumption.
- More efficient use of expensive materials, such as titanium for light weight production in aerospace or other industries.
- Integration of entire process chains, data management (single source), in process / in line quality control and management.

Standardisation, Regulation, Qualification and Certification

- Guidelines and rules for CE marking and compliance of the components manufactured by AM technologies.
- Improve legislation for product certification.
- Focusing efforts of the manufacturing process on quality control (testing, measuring, quality assurance), as well as post processing.
- Material quality which is optimised and adapted to the process.
- Standardisation efforts that are coordinated and aligned with existing EU and US efforts.
- Consideration of regulation and standardisation which can hamper innovation.
- IP, copyright, patent protection and liability engagement with the customer.
- Health and safety about the production of materials and processes.

Training and Education

- Exposing the technology to the widest possible set of innovators, and new industries while encouraging existing industries.
- Training of the designers in how they can optimise the design for benefits in reducing weight, costs, etc.
- Bringing more ‘best practice’ cases forward and showing more actively why AM can provide benefit.
- Facilitating the education of people and SMEs in the adoption of new technologies and providing access by clear rules in future research and development programmes e.g. stronger role of SMEs as end users and extending the industrial sector.
- Establish technology transfer centres which have dedicated industrial focus and that are supported by the regions.
- Educating at all levels from primary schools to capture the imagination of the public.
- Communication through conferences, events etc.
- Use fab-lab machines for training and education.
- Grow and support existing networks, and support connections between them.
- There is a need to look at the business to customer or customer to customer relationship.
- Address the total concept in an integrated way to bring the technology to market.
- Cross-cutting integrating activities running throughout Horizon 2020.
- Skills/training at all levels from practical technicians to more academic researches and managers
- Training in all multidisciplinary aspects of AM including engineering design, software, materials processing, materials supply, post processing, heat treatment, non-destructive testing and final finishing.

EU Initiatives and Policy Measures

- A clear statement from the EU and the member states at the top level regarding approaches for AM.
- Development of taxation and cross-border duty surrounding data and its protection.
- Development of IP rules and guidelines for patent and copyright protection.
- Address liability issues for how the consumer is to be protected.
- More open access to benefit SMEs. Decreasing machine costs to open up more opportunities and accessibility to the technology for SMEs. Setup of an SME specific research and development programme.
- There is a need to support entrepreneurship on the professional and personal level.
- Address issues over cross-border VAT.
- Fostering Innovations and support to SMEs in the AM sector.
- On the industrial level there is a need for certification of materials, end products, and CE marking, which needs to be regulated.
- Other possible areas for policy actions may include: research in materials science for diversification, environmental aspects; low cost AM machines; new business models; standardisation.

ANNEX I

Agenda of the EC Additive Manufacturing Workshop

EC Workshop on Additive Manufacturing

18 June 2014

Centre Albert Borschette. Room AB-2D

Rue Froissart, 36. 1040 Brussels, Belgium

08:30 – 09:00 Registration and welcome coffee

09:00 – 10:00 **Opening session**

Welcome address

Clara de la Torre. Director for Key Enabling Technologies, RTD/D

Additive Manufacturing in FP7 and Horizon 2020

José Lorenzo Vallés. Head of Unit "Advanced Manufacturing Systems and Biotechnologies", RTD/D2

Additive Manufacturing: The wider societal, legal and economic implication to Europe

Phil Reeves. Managing Director, Econolyst

10:00 – 11:00 **Session 1. European Industrial Roadmaps for Additive Manufacturing**

Factories of the Future PPP: Strategic AM aspects in the Multi-annual Roadmap

Arun Junai. Manufuture

AM Platform: Strategic Research Agenda 2014-2020 and Roadmap for AM standardisation

Amanda Allison. AM Platform

EuMAT Platform: New Materials for Additive Manufacturing

Helena Gouveia. EuMAT Platform

Photonics 21 Platform: High Performance Light sources-based Additive Manufacturing

Reinhart Poprawe. Photonics21 Platform

11:00 – 11:30 Coffee Break

11:30 – 12:30 Session 2. Policy Perspectives for Additive Manufacturing: Priorities and current barriers

3D Printing Revolution- Challenges and Possibilities

Bonifacio García Porras. Head of Unit "Innovation Policy for Growth", ENTR/B3

Selected perspectives on Additive Manufacturing at the US

Stephan Eelman. Research and Technology Director Germany, Boeing

An Industrial Landscape Vision 2025: an opportunity for Additive Manufacturing

Peter Churchill. Advisor for the European Research Area, JRC

Fabiana Scapolo. Head of Sector "Foresight and Horizon Scanning", JRC/A1

12:30 – 13:30 Lunch

13:30 – 15:00 Session 3. EU Projects: Impact of AM Innovation on European Competitiveness

REPAIR FP7 project (Aerospace industry). **Jens Pottebaum**, UPB

PERFORMANCE FP7 project (Food supply chain). **Pieter Debrauwer**, TNO

ARTIVASC3D FP7 project (Biomaterials for Health). **Arnold Gillner**, Fraunhofer

NANOMASTER FP7 project (Materials). **Jeppe Byskov Nielsen**, Teknologisk Institut

MANSYS FP7 project (Production Technologies). **Rob Scudamore**, TWI

DIGINOVA FP7 project (Digital Fabrication). **Marcel Slot, OCE**

15:00 – 16:00 **Session 4. Roundtable on Priorities for further development of Technologies, Equipment and Materials in AM**

Moderator: **Germán Esteban Muñiz**. Programme Officer, RTD/D2

Panel Discussion: **Richard Hague**. Director, EPSRC

Florian Bechmann. Head of R&D, Concept Laser

Stefan Ritt. Export Sales Marketing Manager, SLM

Bart Van der Schueren. VP Production, Materialise

Andrea Reinhardt. Board Member, MicroTEC

16:00 – 16:30 Coffee Break

16:30 – 17:30 **Session 5. Roundtable on Policy Measures and Implementation**

Moderator: **Andrea Gentili.** Deputy HoU, RTD/D2

Panel Discussion: **Paula Queipo**. Director External Relations, PRODINTEC

Phil Reeves. Managing Director, Econolyst

Franz-Josef Villmer. Deputy Rector, HS OWL

Claus Emmelmann. CEO Laser Zentrum Nord

Dirk Beernaert. Advisor CNECT

17:30 – 17:45 Conclusions and Closure of the meeting

18:00 – 19:00 Networking Cocktail

Rapporteur for the event: **Rob Scudamore**. Group Manager, TWI

Contact point: **Germán Esteban Muñiz**. Programme Officer, RTD/D2

ANNEX II

Speakers and Panellists Details

Clara de la Torre
Director for Key Enabling Technologies, RTD/D

Since 1 January 2014, Clara de la Torre has been the Director responsible for "Key Enabling Technologies" in the Directorate-General for Research & Innovation, European Commission. Previously she was the Director responsible for "Research and Innovation". From 2008 to 2010, she was the Director responsible for "Inter-institutional and legal matters related to the Framework Programme" also at the European Commission.

After a couple of years in the private sector, her professional career has mainly focussed on research policy where she started her activities at the European Commission in 1987. Clara de la Torre has a degree in Economics and Business Administration from the Universidad Autónoma of Madrid.

José Lorenzo Vallés
Head of Unit "Advanced Manufacturing Systems and Biotechnologies", RTD/D2

Graduated in Physics and Chemistry. Ph. D. in Physics from the University of Barcelona (E). Postdoctoral research in Computational Physics during four years at Courant Institute of New York University and the University of Minnesota (USA). Associate Professor of Condensed Matter Physics at the University of Barcelona (at present under special leave).

Since joining the European Commission in 1991, he first worked at the Institute for Advanced Materials (NL), then as S&T Counsellor at the EC Delegation in China, and finally he moved in 1999 to DG Research and Innovation in Brussels, where he has been Head of the Materials Unit, Head of the New Forms of Production Unit, and is now Head of the Advanced Manufacturing Systems and Biotechnologies Unit.

Phil Reeves
Managing Director, Econolyst

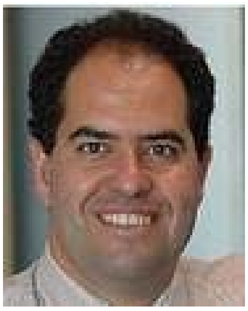
Dr Phil Reeves is the managing director of Econolyst Ltd, a global Additive Manufacturing & 3D Printing consultancy & research firm working across Europe, North America, the Middle East, Far East & Africa. Phil has worked in the field of Additive Manufacturing for over 20-years having gained a PhD in the subject from Nottingham University in the mid 1990's. Since this time, Phil has worked in a number of AM related roles including R&D, business development and corporate strategy, before establishing Econolyst in 2003.

Arun Junai
ManufutureBachelor of Engineering in Metallurgy (1971) and Masters in Nuclear Metallurgy (1972). Since 2011 Arun Junai has been the EU Manager at TNO Industrial Innovation and previously coordinator of EU research programmes. Arun has been involved in setting up and executing EU Research projects under the FPs and national research projects. As coordinator of the ManuFuture ETP with the technology sub-platforms and other ETPs Arun has an established network within the EC and European Associations.

Amanda Allison AM Platform Amanda Allison (FdEng) is a Senior Project Leader for the Joining Technology and Additive Manufacturing Group at TWI Ltd. She has extensive experience in the development of European Initiatives - including committee member role for both the Joining and Additive Manufacturing Technology Sub-Platforms and lead writer for the latest strategic research agendas. Co-ordinating the support of the Group Collaborative approach Amanda is also involved in proposal writing, concept development, partner engagement and submission management. Amanda also has experience in supporting large technology driven European and UK projects including the implementation of exploitation and dissemination best practice. Supporting the Joining Group, Amanda also extends her skills to group corporate activities such as risk management planning, coordinating studentships, corporate data analysis, and technology resource assessment.	

	**Helena Gouveia** EuMAT Platform Helena Gouveia has a Diploma in Metallurgical Engineering from the IST – Technical University of Lisbon, in Portugal (1980). Ph.D. in Laser Welding from the Cranfield University, in England, UK (1994). She is a Senior Researcher in the fields of materials and production technologies, being responsible for the coordination of several national and European research projects. She has several papers and communications in scientific meetings. She is currently in the Business Development Unit at ISQ, responsible for the Innovation and Development.

Reinhart Poprawe Photonics21 Platform Expertise in laser applications and laser development and plasma technology. Reinhart Poprawe has been Honorary Professor of Tsinghua University, Beijing in March 2014, President of the Laser Institute of America LIA January 2012 - December 2012, and won the Innovation Award of Northrine Westfalia in 2011. He has been the Vice-president for RWTH University from 2005 to 2008, Director of Fraunhofer Institute for Laser technology and Head of University Chair for Laser technology, RWTH Aachen from 1996 to 2005. He has also been the Managing Director of Thyssen Laser-Technik GmbH Aachen from 1989 to 1996, Dept. Head at Fraunhofer Institute for Laser technology from 1985 to 1989 and Assistant at Technical University Darmstadt (PhD 1984).	

	**Bonifacio García Porras** Head of Unit “Innovation Policy for Growth”, ENTR/B3 Bonifacio García Porras entered the EC in 2000 where he worked on the liberalization of energy markets. In 2003, he joined the Cabinet of Vice-President Loyola de Palacio and subsequently the Cabinet of Commissioner Andris Piebalgs until 2010, where he had the opportunity to work on the energy and climate change legislative package. Bonifacio had been a practising EC lawyer for seven years prior to joining the European Commission, having studied at the College of Europe (Law) from 1992 to 1993 (Charles IV Promotion).

Stephan Eelman
Research and Technology Director Germany, Boeing

Since 2010 Stephan Eelman has been the Research and Technology Director for Boeing in Germany. He is responsible for the coordination and management of R&T related activities to explore and develop new technologies with German suppliers, universities and research institutes. Within this scope, he addresses special attention to the Boeing co-founded Direct Manufacturing Research Centre at the University of Paderborn in order to progress the company's involvements here in Additive Manufacturing.

Stephan holds a Diplom-Ingenieur degree in Mechanical Engineering with a specialisation in Aerospace Engineering from the TU in Munich. Stephan started his career in January 2009 as Deputy Director of the Engineering and Programs Department at Boeing Research and Technology Europe (BR&T-E) in Madrid.

Peter Churchill
Advisor for the European Research Area, JRC

Peter Churchill is by training an environmental scientist who has worked in academia, industry and public service. For the past 25 years he has worked for the European Commission's Directorate General Joint Research Centre, first as a scientist, and since 1996 as a manager of scientific and administrative Units.

He currently works as the Adviser for Scientific Policy at the JRC's headquarters. His current interests include the research and innovation policy, the future of manufacturing industry, and standardisation.

Fabiana Scapolo
Head of Sector "Foresight and Horizon Scanning", JRC/A1

Fabiana Scapolo has been working at the European Commission Directorate General Joint Research Centre (JRC) since 1999. From May 2008 since September 2011, she worked in the Work Programme and Strategy Unit of the Joint Research Centre where she was in the development of the new JRC Strategy for the period 2010-2020, and on the development and monitoring of JRC's work programmes. Previously she was working at JRC-Institute for Prospective and Technological Studies in Seville (Spain) where she was responsible of the Foresight activities. She has been working on several projects aiming at reinforcing the position of the JRC-IPTS as a centre for Foresight at European and international level. She is interested in the advancement of the application of Foresight as an instrument for policy-making formulation.

Jens Pottebaum
UPB

Dr.-Ing. Jens Pottebaum is senior researcher and deputy of Prof. Dr.-Ing. Rainer Koch at the University of Paderborn, Germany (research group ‚Computer application and integration in design and planning – C.I.K.' and 'Direct Manufacturing Research Centre' in the department for Mechanical Engineering). Jens Pottebaum studied mechanical engineering and computer science at the University of Paderborn. In 2011 he received the doctor's degree for his research on the Optimisation of application oriented learning by knowledge identification. His research deals with the application and applicability of Information and Communication Technology (ICT) for civil protection and mechanical engineering.

Pieter Debrauwer
TNO

Pieter Debrauwer studied aerospace engineering at the Technical University in Delft.

Since 2008 Pieter has been working at TNO as project manager involved in the field of 3D food printing. An example project is the EC funded project Performance, in which personalised nutrient for elderly people is being developed, and the Enthalpy project, where energy and water is saved in the dairy industry.

Arnold Gillner
Fraunhofer

Dr. Arnold Gillner, studied Physics at the University of Darmstadt and has a PHD in Mechanical Engineering from the RWTH Aachen (1994). Since 1985 he works as a scientist at the Fraunhofer-Institut for Laser Technology. Starting in 1992 he developed the department for Micro Technology at ILT and from 2010 he has headed the department of Ablation and Joining. He is developing industrial laser processes for macro and micro joining, packaging, micro and nano structuring, polymer applications and Life Science applications. He is heading the board of the Aachen Competence Center for Medical Technology and head of the advisory board of LifeTec Aachen Jülich. He has published more than 100 papers and book chapters in scientific journals and other scientific contributions and holds more than 20 patents on laser processes.

Jeppe Byskov Nielsen
Teknologisk Institut

Dr. Jeppe Skinnerup Byskov is in the AM group at the Danish Technological Institute. He is mainly involved with development projects regarding optimization, industrialization and implementation of AM. Previously involved in the FP7 project “CompoLight” and currently involved in the Danish Innovation Consortium “F-MAT” and the FP7 project “RepAIR”.

He received his PhD (entitled “Short-pulse laser ablation of metals: Fundamentals and applications for micro-mechanical interlocking”) in physics from the University of Aarhus (Denmark) in 2010 (co-financed by the company “Grundfos”). Since then he has been working at the Danish Technological Institute as a technology developer and project manager.

Robert Scudamore
TWI

Dr Robert Scudamore joined TWI in 2000 following a PhD in Materials Science and Engineering from the University of Liverpool. Since then he has been active in the fields of Additive Manufacturing and Joining Technologies, predominantly using lasers. Originally Robert's work involved Laser Metal Deposition of Nickel based superalloys, such as Waspaloy and various Inconel grades, mainly involved in the repair of jet engine components. Since then his group has mainly focused on other metallics such as various grades of titanium and stainless steels, for repair and original part build, mainly for the aerospace sector. Robert is a committee member of the Additive Manufacturing Sub-Platform to ManuFuture, the ManuFuture ISG and the EFFRA Partnership board. In the UK he is Chairman of AM Net, an Association of Laser Users Strategy Industry Group since 2009.

	**Marcel Slot** OCE Marcel Slot is currently director technology planning & partnerships at Océ, headquartered in the Netherlands, which is part of Canon. He studied Physics at Twente University of Technology in the Netherlands and joined Océ in 1990. During the first 14 years of his career, he was involved in technology and product development as a project leader. His focus has been on electrophotography as well as inkjet printing technology, imaging science, and material science. During the past 8 years, he held various management positions, including department manager of research and vice president of development. In his current position Marcel focuses on technology roadmaps, partnerships and open innovation. Marcel was the initiator and coordinator of the Diginova EU FP7 project focussing on Digital Fabrication and its impact on manufacturing in Europe.

Germán Esteban Muñiz Programme Officer, RTD/D2 Germán Esteban Muñiz, a Senior Chemical Engineer, worked for a decade in water treatment, hydraulic infrastructures and discrete and process manufacturing before joining the EC in 2011. He works as Programme Officer at DG Research and Innovation at the Key Enabling Technologies (KETs) Directorate and is in charge of the Additive Manufacturing portfolio. He has managed over €200 million in FP7 EU projects and is an active player in the H2020 PPP FoF and SPIRE. Under H2020, he works at the Industrial Leadership pillar and contributes to the Societal Challenge of Climate Action, Resource Efficiency and Raw Materials under the European Innovation Partnership on Raw Materials (EIP RM). Mr. Esteban is also the EC contact point and responsible for the AM Platform, which has recently launched its Strategic Research Agenda, highlighting priority areas for future development in AM and its roadmap for standardisation.	

	**Richard Hague** Director, EPSRC Richard Hague is Professor of Innovative Manufacturing in the Department of Mechanical, Materials and Manufacturing Engineering at the University of Nottingham, Head of the AM and 3D-Printing Research Group and Director of the EPSRC Centre for Innovative Manufacturing in AM. He has been working in the AM field for 20 years and has a background of leading and managing large multi-disciplinary, multi-partner research projects. Richard's research interests are focused on AM specific processes, materials and design / design systems across a wide spectrum of industrial sectors with a particular interest in design / design systems; current research programmes are focused on the design and production of multifunctional additively manufactured devices. He is also Chair of the International Conference on Additive Manufacturing & 3D Printing and active within the ASTM F42 AM Standards initiative

Florian Bechmann Head of R&D, Concept Laser GmbH Since 2008, Dr.-Ing. Florian Bechmann is the head of R&D at Concept Laser GmbH in Lichtenfels, Germany. He is responsible for developing new laser-melting systems, the corresponding process and material qualifications as well as managing the research projects. After studying materials engineering at the University of Bayreuth, he received in 2008 his industry-sponsored doctor's degree with focus on high-performance materials at the Research & Innovation Center of the BMW Group in Munich.	

Stefan Ritt
Export Sales Marketing Manager, SLM

Dipl. Eng. Stefan Ritt is the Export sales and Marketing Manager at SLM Solutions GmbH, the leading manufacturer of Metal 3 D printing equipment and the first German company at all which went public with an IPO at TECHDAX in Frankfurt this year on 9.May collecting 180 Mio. € from the stock exchange. This shows how dynamic the 3 D printing market is at the moment.

Stefan is involved in this technology on a global scale for 16 years already and acts as the international ambassador for AMUG-USA(Additive manufacturing user group) as well as an international advisor to the SME-USA (Society of manufacturing engineers).

Bart Van der Schueren
VP Production, Materialise

Materialise Executive Vice President Bart Van der Schueren obtained a Master of Science in Mechanical Engineering from the Catholic University of Leuven (Belgium) in 1990. After graduation, he served as a liaison between the university and the newly founded Materialise, and established the basic research activities for the company. After receiving a PhD in Metal Selective Laser Sintering, Bart officially joined Materialise in 1995 and led the development of its service bureau. Over the years, his dedication and expertise enabled the bureau to grow into one of the most prominent Additive Manufacturing facilities in Europe. Today, Bart is focused on production, engineering services and software development, and continues to be a driving force in the AM industry.

Andrea Reinhardt
Board Member, MicroTEC

Andrea Reinhardt started in banking, studied at University Mannheim and is working in leading positions in the field of industrial applications of micro- and nanotechnologies since 1996, at microTEC as part of the shareholder team and management. In 2001 she co-founded NTC. Andrea has worked with customer and EC funded cooperative R&D projects in production, micro and nanotechnologies and has given presentations, published peer reviewed articles (customised series production of MEMS, applied nanotechnologies, diversity, innovation and SMEs as an element of European growth). She is an experienced reviewer of R&D projects at national and European level, supports as founding member of NANOfutures, as member of the board ZIRP and INSCX. Andrea is appointed technology advisory board Rhineland-Palatinate Germany for the period 2010-2015.

Paula Queipo
Director External Relations, PRODINTEC

Dr. Paula Queipo works at PRODINTEC Technology centre. As Director of the External Relations Department she deals with PRODINTEC's business development in advanced manufacturing and industrial design, international project management activities. She belongs to the Management Boards of the EU platforms AM-Platform and NANOfutures. She is chemist and obtained a PhD degree in Materials Science and Technology in 2003 from the University of Oviedo (Spain). She has more than 10 years' experience as researcher in entities such as Abo Akademi, VTT and Technical University of Technology (Finland), University of Leeds (UK), and CSIC and University of Oviedo (Spain).

Andrea Gentili
Deputy HoU, RTD/D2

Andrea Gentili is currently Deputy Head of the Unit D2 "Advanced Manufacturing Systems and Biotechnologies" of the Directorate "Key Enabling Technologies" in DG RTD (Directorate General for Research and Innovation) of the EC. Andrea, a mechanical engineer graduated from the University of Pisa (Italy). In 2001 Andrea joined the EC's Research DG taking the responsibility in the FP6 NMP programme for machining, followed by mechanical engineering, intelligent mechatronics, micro-manufacturing and enabling production systems. Since 2004 he took the responsibility for the setting-up and running the Manufuture ETP and all the horizontal activities with the ETPs related to manufacturing. In January 2009, he was responsible for the Commission of the FoF PPP included in the European Economic Recovery Plan, adopted by the EC in November 2008. Since 2012, he has been strongly involved in setting up eight contractual PPPs within Horizon 2020.

Claus Emmelmann
CEO Laser Zentrum Nord

Prof. Dr.-Ing. Emmelmann is head of the Institute of Laser and System Technologies at Hamburg University of Technology. He performs R&D in the field of laser free form manufacturing, ablation and welding as well as design and analysis of laser components and systems for automotive, shipyard, aircraft, tooling and medical industry. After receiving his Dipl.-Ing. (MSc) degree of mechanical engineering sciences at the University of Hannover in 1986 Claus established the department of production technology of the Laser Zentrum Hannover directed by Professor Dr.-Ing. H.K. Tönshoff. In 1991 he received his Dr.-Ing. (PhD) degree with a thesis on Laser Beam Cutting of Ceramics.

Franz-Josef Villmer
Deputy Rector, HS OWL

Franz-Josef Villmer is professor of Product Development, Innovation Management and Rapid Technologies at the Hochschule OWL University of Applied Sciences. His professional focus is facets of product engineering, development and product innovation processes, especially on project orientation, additive manufacturing and time reduction technologies. At the university, Prof. Villmer was appointed to several positions, e.g. Dean of the Department of Production and Economics and Vice President for Teaching, Studies and Quality Assurance, for several years. Franz-Josef Villmer is a mechanical engineer. He studied and obtained his doctorate in engineering at the Clausthal University of Technology. He has been involved in a wide range of different industries: mechanical and plant engineering, vehicle and service machine industry and finally 1st tier automotive supply industry.

Dirk Beernaert
Advisor CNECT

D. Beernaert studied engineering (University of Ghent – Belgium -1976). Before joining the Commission, he was involved in semiconductor research, prototyping, manufacturing and transfer of technology in innovation. He joined the EC in 1990 where he has been responsible as Head of Unit for research programs in micro and nano-electronics, photonics, and Microsystems under different European FP, dealing with research, innovation and regulatory activities in these fields. In 2008 he was nominated Executive Director at interim to set up the Joint Undertaking ENIAC, the first PPP between Industry, European Member States and the EC in the field of Nano-electronics. Until recently he was responsible for the Unit "Microsystems" dealing with smart integrated systems, Micro and nano-systems, micro-nano-bio-systems, smart integration technologies, advanced manufacturing and the transfer of these technologies into innovation for key applications.

ANNEX III
Fact Sheets of Projects Presented

REPAIR: Future RepAIR and Maintenance for Aerospace industry

Duration: 2013-06-01 to 2016-05-31

Website: www.rep-air.eu

Objective

The Project RepAIR will perform research on future repair and maintenance for the Aerospace industry. Therefore the onsite maintenance and repair of aircraft by integrated direct digital manufacturing is in the focus of this project. The main objective of RepAIR is to shift the “make” or “buy” decision towards the “make” decision by cost reduction in the remake and rework of spare parts and therefore improve cost efficiency for maintenance repair in aeronautics and air transport. A crucial advantage of this technology is the flexible availableness (even at the gate) allowing on-time maintenance. Through a higher level of automation und fewer stages of production, less personal costs are necessary which therefore reduce the MRO costs. These operations require a higher qualification and promote the preservation and expansion of highly qualified workplaces in Europe. Moreover, the storage costs will be significantly reduced. As only the raw material needs to be stored, instead of having to have in stock up to 3.6 million spare parts for the multitude of airplanes and varieties of aircraft manufacturers, less capital is locked up. Additionally, hardly any energy – intensive produced raw material will be wasted or destroyed, but will be used optimally. When looking ahead, with the aid of AM technology, it will be possible to shorten the entire spare parts supply chain to sending an e-mail. The benefit for all those involved, including the environment, is obvious. New business models will become sustainable. Through a higher level of automation und fewer stages of production, less personal costs are necessary which therefore reduce the MRO costs. These operations require a higher qualification and promote the preservation and expansion of highly qualified workplaces in Europe and make them more competitive.

Project Reference: 605779
Total Cost: EUR 5 971 421
EU Contribution: EUR 4 276 277
Programme Acronym: FP7-TRANSPORT
Sub-programme Area: AAT.2013.4-4., AAT.2013.4-3.
Contract Type: Small or medium-scale focused research project

Coordinator: UNIVERSITAET PADERBORN, DEUTSCHLAND

Participants: APR SRL, ITALIA; TEKNOLOGISK INSTITUT, DANMARK; LUFTHANSA TECHNIK AKTIENGESELLSCHAFT, DEUTSCHLAND; AVANTYS ENGINEERING GMBH & CO. KG, DEUTSCHLAND; DANISH AEROTECH AS, DANMARK; THE BOEING COMPANY CORPORATION, UNITED STATES; ASOCIACION DE INVESTIGACION DE LAS INDUSTRIAS METALMECANICAS, AFINES Y CONEXAS, ESPAÑA; O'GAYAR CONSULTING 2009 SL, ESPAÑA, ATOS SPAIN SA, ESPAÑA; CRANFIELD UNIVERSITY, UNITED KINGDOM; SLM SOLUTIONS GMBH, DEUTSCHLAND

PERFORMANCE: Development of Personalised Food using Rapid Manufacturing for the Nutrition of elderly Consumers

Duration: 2012-11-01 to 2015-10-31

Website: www.performance-fp7.eu

Objective

The main idea of the PERFORMANCE project is to develop and validate a holistic, personalized food supply chain for frail elderly in nursing homes, ambient assisted living facilities or at home (served by nursing services). The supply chain in this case will resemble a loop with the elderly consumers forming the initial link (personal preference and needs) and final link (consumption). As a result PERFORMANCE project, an overall concept will be available which allows the automatic manufacturing and supply of personalized, specially textured food for frail elderly.

To answer these questions, the PERFORMANCE concept will cover the whole supply chain from the food producer to the ready-to eat-meal at consumers place (both in nursing facilities and at home). Focus will be put on personalized food for people with mastication and swallowing problems (i.e. not only elderly).

This group presents 5% of the elderly and has special texture requirements for the food preparation. Elderly in general require careful consideration of various determinants of their nutritional and health status. In contrast to younger people, the impact of nutrition on their well-being and health status is way higher in elderly. The nutritional status of elderly is influenced not only through the aging process, the health status (physiological and physical disabilities) but also through psychological (e.g. the way food is prepared), social-economic factors (available income). Therefore, the PERFORMANCE project will mean a great step forward to improve the Quality of Life of the elderly by offering them a complete new personalised nutritional concept able to increase their independency, health status and social life.

Project Reference: 312092
Total Cost: EUR 4 039 934
EU Contribution: EUR 2 997 886
Programme Acronym: FP7-KBBE
Sub-programme Area: KBBE.2012.2.3-04

Coordinator: BIOZOON GMBH, DEUTSCHLAND

Participants: TEKNOLOGISK INSTITUT, DANMARK; NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK – TNO, NEDERLAND; UNIVERSITA DI PISA, ITALIA; ALTEN-WOHN-PFLEGEHEIM CHRISTKONIG, DEUTSCHLAND; DR. STEPHEN WEBB / RTD SERVICES E U, ÖSTERREICH; AMER KARIM, DEUTSCHLAND; SANALOGIC GMBH, DEUTSCHLAND; MARFO B.V, NEDERLAND; DENKSTATT GMBH, ÖSTERREICH; OTB SOLAR B.V., NEDERLAND; HOCHSCHULE WEIHENSTEPHAN-TRIESDORF, DEUTSCHLAND; FEMTO ENGINEERING SRL, ITALIA; DE GROOD INNOVATIONS BV, NEDERLAND

ARTIVASC 3D: Artificial vascularised scaffolds for 3D-tissue-regeneration

Duration: 2011-11-01 to 2015-10-31

Website: www.artivasc.eu

Objective

The use of bioartificial tissue for regenerative medicine offers great therapeutic potential, but also has to meet high demands with respect to the interaction of the bioartificial devices and natural tissues. Key issues for the successful use of bioartifical tissues as natural tissue replacements are their long term functional stability and biocompatible integration. Up to now, various approaches for the generation of bioartificial tissues have not succeeded due to insufficient nutrition and oxygen supply. Therefore, current tissue engineered products have only been realised for non vascularised tissues such as cartilage. ArtiVasc 3D will break new ground and overcome these challenges by providing a micro- and nano-scale based manufacturing and functionalisation technology for the generation of fully vascularised bioartificial tissue that enables entire nutrition and metabolism. The bioartificial vascularised skin engineered in ArtiVasc 3D will, for the first time, allow tissue replacement with optimum properties. ArtiVasc 3D will research and develop an innovative combination of hi-tech engineering such as micro-scale printing, nano-scale multiphoton polymerisation and electro-spinning with biological research on biochemical surface modification and complex cell culture. In a multidisciplinary approach, experts in biomaterial development, cell-matrix interaction, angiogenesis, tissue engineering, simulation, design and fabrication methods work together to generate bioartificial vascularised skin in a fully automated and standardised manufacturing approach. This bioartificial vascularised skin will be of great value in a vast array of clinical treatments, e.g. as a transplant in trauma treatment. In addition, this new bioartificial vascularised skin will be used as an innovative in vitro skin equivalent for pharmaceutical, cosmetics or chemical substance testing, which represents a promising method to reduce expensive, ethically disputed animal testing.

Project Reference: 263416
Total Cost: EUR 10 523 108
EU Contribution: EUR 7 800 000
Programme Acronym: FP7-NMP
Sub-programme Area: NMP.2010.2.3-1
Contract type: Large-scale integrating project

Coordinator: FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V, DEUTSCHLAND

Participants: UNIVERSITAET STUTTGART, DEUTSCHLAND; ALBERT-LUDWIGS-UNIVERSITAET FREIBURG, DEUTSCHLAND; LOUGHBOROUGH UNIVERSITY, UNITED KINGDOM; MEDIZINISCHE UNIVERSITAET WIEN, ÖSTERREICH; BEIERSDORF AG, DEUTSCHLAND; UNITECHNOLOGIES SA, SCHWEIZ/SUISSE/SVIZZERA; UNIVERSITY OF EAST ANGLIA, UNITED KINGDOM; KMS AUTOMATION GMBH, DEUTSCHLAND; VEREIN ZUR FORDERUNG VON INNOVATIONEN DURCH FORSCHUNG ENTWICKLUNG UNDTECHNOLOGIETRANSFER EV, DEUTSCHLAND; GLOBAL CLINICAL TRIALS MANAGEMENT AG, SCHWEIZ/SUISSE/SVIZZERA; AALTO-KORKEAKOULUSAATIO, SUOMI/FINLAND; ARTTIC, FRANCE; BERUFSGENOSSENSCHAFLICHES UNIVERSITAETSKLINIKUM BERGMANNSHEIL GMBH, DEUTSCHLAND; VIMECON GMBH, DEUTSCHLAND; UNIVERSITA DEGLI STUDI DI SALERNO, ITALIA.

NANOMASTER: Graphene based thermoplastic masterbatches for conventional and additive manufacturing processes

Duration: 2011-12-01 to 2015-11-30

Website: www.nanomasterproject.eu

Objective

The aims of the NanoMaster project are to reduce the amount of plastic used to make a component by 50% and hence reduce component weight by 50%, at the same time as imparting electrical and thermal functionality. This will be achieved by developing the next generation of graphene-reinforced nano-intermediate that can be used in existing high-throughput plastic component production processes. Graphene reinforced polymers have been demonstrated at lab scale in both Europe and the USA, and it has been shown that very low loadings of graphene can have a dramatic impact on the mechanical and physical properties of the polymers it is added to. However, industrial compounding processes have only so far been developed in the United States, where Ovation Polymers are already offering graphene thermoplastic masterbatches and compounds based on graphene from XG Sciences.

The concept for this project is to develop the knowledge-based processing methods required to up-scale the production of graphene and expanded graphite reinforced thermoplastic masterbatches and compounds and, ultimately, enables its industrial commercialisation in Europe. The work will focus on developing processes for large scale rapid production of graphene reinforced plastic intermediate materials which can be integrated into current conventional and additive manufacturing processes.

Successful development of these materials and processes will have a significant effect on the amount of polymer that needs to be used in a component to meet its performance criteria, and on the ability of plastic mouldings to delivery significantly enhanced functionality. These breakthroughs will open the door to a vast range of applications enabling the benefits to be exploited throughout Europe and beyond. They will also help to place European companies in a position to exploit the rapidly growing markets in the US and Asia-Pacific.

Project Reference: 285718
Total Cost: EUR 6 339 038
EU Contribution: EUR 4 199 974
Programme Acronym: FP7-NMP
Sub-programme Area: FoF.NMP.2011-6
Contract Type: Large-scale integrating project

Coordinator: NETCOMPOSITES LIMITED, UNITED KINGDOM

Participants: PROMOLDING BV, NEDERLAND; TEKNOLOGISK INSTITUT, DANMARK; ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS – AIMPLAS, ESPAÑA; ROLLS-ROYCE GOODRICH ENGINE CONTROL SYSTEMS LIMITED, UK; MB PROTO SAS, FRANCE; CREATE IT REAL APS, DANMARK; INSTITUTE OF OCCUPATIONAL MEDICINE, UNITED KINGDOM; PHILIPS CONSUMER LIFESTYLE B.V., NEDERLAND; LATI INDUSTRIA TERMOPLASTI SPA, ITALIA; ROCHLING AUTOMOTIVE AG & CO KG, DEUTSCHLAND; TIMCAL SA, SCHWEIZ/SUISSE/SVIZZERA; AVANZARE INNOVACION TECNOLOGICA SL, ESPAÑA

MANSYS: MANufacturing decision and supply chain management SYStem for additive manufacturing

Duration: 2013-07-01 to 2016-06-30

Website: www.mansys.info

Objective

ManSYS aims to develop and demonstrate a set of e-supply chain tools; to enable the mass adoption of Additive Manufacturing (AM). This will allow businesses to identify and determine the suitability of AM for metal products, and subsequently manage the associated supply-chain issues and facilitating open product evolution.

The proposed e-supply chain solution will combine all aspects of AM including; multiple build platforms (Laser and Electron-Beam technologies), modelling, post-processing (Machining, Finishing and Heat-Treatment) and 3D scanning techniques. This will give a press-button solution to the production and challenges of new products. The integrated solution will offer a knowledge driven manufacturing process with significant production benefits; customisation, automation, self-management and reduced material usage and waste.

The integrated approach will be assessed using a range of demonstration scenarios to assess and highlight:

- Cost-Savings: Assessment of parts (including design optimisation) against existing manufacturing methods allowing businesses to decide if AM is an appropriate manufacturing approach.
- Re-action to Customer Need: Demonstrator parts from industry (initially aerospace, and medical) validated by ManSYS end-users, including the ability to allow rapid design variations.
- Robustness of Supply Network: Development of QA/QC procedures and protocols to allow operation at multiple-locations and across multiple-machines. Demonstrating the ability to handle supply-chain interruptions and improve robustness.
- Environmental Assessment: Measure the embedded CO2 of the parts made, including assessment of the ability of AM to optimise part design.

Project Reference: 609172
Total Cost: EUR 4 405 531
EU Contribution: EUR 2 925 000
Programme acronym: FP7-NMP
Sub-programme Area: FoF.NMP.2013-9
Contract Type: Small or medium-scale focused research project

Coordinator: TWI LIMITED, UNITED KINGDOM

Participants: NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK – TNO, NEDERLAND; GE MARMARA TECHNOLOGY CENTER MUHENDISLIK HIZMETLERI LIMITED SIRKETI, TURKEY; WISILDENT SRL, ITALIA; SMITH & NEPHEW UK LIMITED, UK; POLY-SHAPE SAS, FRANCE; LPW TECHNOLOGY LTD, UK; MATERIALISE NV, BELGIQUE-BELGIË; BERENSCHOT GROEP BV, NEDERLAND; TWOCARE SRL, ITALIA; BCT STEUERUNGS UND DV-SYSTEME GMBH, DEUTSCHLAND; ASOCIACION DE INVESTIGACION DE LAS INDUSTRIAS METALMECANICAS, AFINES Y CONEXAS, ESPAÑA

MERLIN: Development of Aero Engine Component Manufacture using Laser Additive Manufacturing

Duration: 2011-01-01 to 2014-12-31

Website: www.merlin-project.eu

Objective

The concept of the MERLIN project is to reduce the environmental impact of air transport using Additive Manufacturing (AM) techniques in the manufacture of civil aero engines. MERLIN will develop AM techniques, at the level 1 stage, to allow environmental benefits including near 100% material utilisation, current buy to fly ratios result in massive amounts of waste, no toxic chemical usage and no tooling costs, to impact the manufacture of future aero engine components. All of these factors will drastically reduce emissions across the life-cycle of the parts. There will also be added in-service benefits because of the design freedom in AM. Light-weighting, and the performance improvement of parts will result in reduced fuel consumption and reduced emissions. MERLIN will seek to develop the state-of-the-art by producing higher performance additive manufactured parts in a more productive, consistent, measurable, environmentally friendly and cost effective way.

The MERLIN consortia have identified areas where a progression of the state-of-the art is needed to take advantage of AM including increasing productivity, design or topology optimisation, powder recycling validation, in-process NDT development and geometrical validation, and high specification materials process development.

Project Reference: 266271
Total Cost: EUR 7 122 572
EU Contribution: EUR 4 886 561
Programme acronym: FP7-AAT-2010-RTD-1
Sub-programme Area: AAT.2010.1.1-2. - Aerostructures
Contract Type: CP-FP - Small or medium-scale focused research project
Coordinator: TWI LIMITED, UNITED KINGDOM

Coordinator: ROLLS-ROYCE PLC, United Kingdom

Participants: ASOCIACION CENTRO DE INVESTIGACION EN TECNOLOGIAS DE UNION LORTEK, Spain; MTU AERO ENGINES GMBH, Germany; WYTWORNIA SPRZETU KOMUNIKACYJNEGO PZL - RZESZOW SA, Poland; INDUSTRIA DE TURBO PROPULSORES S.A., Spain; MTU AERO ENGINES AG, Germany; LPW Technology Ltd, United Kingdom; TURBOMECA SA, France; GKN AEROSPACE SWEDEN AB, Sweden; TWI LIMITED, United Kingdom; FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V, Germany; ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS – ARMINES, France; LORTEK S COOP, Spain; BCT STEUERUNGS UND DV-SYSTEME GMBH, Germany; HOGSKOLAN VAST, Sweden; FREDERICK RESEARCH CENTER, Cyprus

DIGINOVA: Innovation for Digital Fabrication

From 2012-03-01 to 2014-02-28

Website: www.diginova-eu.org

Objective
Most products are produced by means of the established mass production infrastructure. Traditionally, this involves large stocks, high manual labour, large capital investments, high energy use, long distance transportation. Although many advanced new materials have unique functional properties that hold a great promise for innovation, they often need to meet the criteria and characteristics of this established mass production paradigm. This delays the exploitation of the huge potential of whole new classes of materials. Combined with major societal trends and consumer needs like customization, personalization, on-demand fulfilment and the fact that the world is becoming ever more digital and networked, there is a need for a paradigm shift in manufacturing called Digital Fabrication. **Digital Fabrication can be defined as a new kind of industry that uses computer-controlled tools and processes to transform digital designs and materials directly into useful products.** DIGINOVA will establish the current status across material domains and application domains in Europe in order to identify the most promising technology and business propositions for Digital Fabrication. The project consortium will identify and connect main stakeholders through establishment of innovation networks centred on concrete business cases to determine the added value and feasible routes to commercialization. The DIGINOVA consortium has broad research and development experience covering a wide range of materials and applications.

Project reference: 290559
Total cost: EUR 1 703 909
EU contribution: EUR 1 265 785
Programme Acronym: FP7-NMP
Sub-programme Area: NMP.2011.2.3-3
Contract Type: Coordination (or networking) actions

Coordinator: OCE TECHNOLOGIES B.V., NEDERLAND

Participants: FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V, DEUTSCHLAND; NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK – TNO, NEDERLAND; UNIVERSITY OF TEESSIDE, UK; UNIVERSITY OF NEWCASTLE UPON TYNE, UK; THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE, UK; THE UNIVERSITY OF NOTTINGHAM, UK; CENTITVC - CENTRO DE NANOTECNOLOGIA E MATERIAIS TECNICOS FUNCIONAIS E INTELIGENTES ASSOCIACAO, PORTUGAL; SINTEF RAUFOSS MANUFACTURING AS, NORGE; NANOGAP SUB-NM-POWDER SA, ESPAÑA; KEY MANAGEMENT CONSULT B.V., NEDERLAND; LOUGHBOROUGH UNIVERSITY, UK; XAARJET LIMITED, UK; TEKNOLOGIAN TUTKIMUSKESKUS VTT, SUOMI/FINLAND; XENNIA TECHNOLOGY LIMITED, UK; CENTRE FOR PROCESS INNOVATION LIMITED, UK; 3D-MICROMAC AG, DEUTSCHLAND; INNOVATIONLAB GMBH, DEUTSCHLAND; COATEMA COATING MACHINERY GMBH, DEUTSCHLAND; THE UNIVERSITY OF MANCHESTER, UK; OLED TECHNOLOGIES BV, NEDERLAND.

ANNEX IV

List of Participants and Organisations

FIRST NAME	SURNAME	COMPANY
Clara	De La Torre	RTD.D
Jose Lorenzo	Valles	RTD.D2
Andrea	Gentili	RTD.D2
Germán	Esteban Muniz	RTD.D2
Gustav	Winroth	RTD.D2
Erastos	Filos	RTD.D2
Jyrki	Suominen	RTD.D3
Louis Victor	Brill	RTD.D1
Michail	Kyriakopoulos	RTD.H3
Peter	Churchill	JRC
Fabiana	Scapolo	JRC
Bonifacio	Garcia Porras	ENTR
Dirk	Beernaert	CNECT
Amanda	Allison	AM PLATFORM
Helena	Gouveia	ISQ
Andrea	Reinhardt	MICROTEC
Paula	Queipo	PRODINTEC
Patricia	Lopez Vicente	EDA
Catherine	Loubineau	UNM
Virginia	Gotor La Torre	BSHG
Berta	Gonzalvo	AITIIP
Marleen	Rombouts	VITO
Rob	Scudamore	TWI
Frits	Feenstra	TNO
Martin	Schaefer	SIEMENS
Joan	Guasch	ASCAMM
Carsten	Engel	SIRRIS
Antonius	Köster	AK
Claus	Emmelmann	LZN Nord
Arun	Junai	TNO
Fabian	Niesler	NANOSCRIBE
Michael	Thiel	NANOSCRIBE
Andreas	Berkau	CITIM
Luc	Van den Berghe	CEN CENELEC
Marc	van Munster	Xycarb Ceramics BV
Stephan	Eelman	Boeing
Joerg	Lenz	EOS
Sergio	Molina	UNIV CADIZ
Franz-Josef	Villmer	HS OWL
Phil	Reeves	ECONOLYST
Bart	Van der Schueren	Materialise
Stefan	Ritt	SLM Solutions GmbH
Kai	Peters	VDMA
Rainer	Gebhardt	VDMA
Oliver	Refle	FRAUNHOFER
Mauro	Caocci	Cimatec S.R.L
Marcel	Slot	OCE
Onno	Ponfoort	BERENSCHOT
Marco	Cavallaro	SYNESIS
R.A.	Harris	LBORO
Eric	Klemp	DMRC
Jeppe	Skinnerup Byskov	Danish Technological Institute

Roberto	Apestigue	AIRBUS DEFENCE
Joaquin	Blanco	AIRBUS DEFENCE
Richard	Hague	University of Nottingham
Henning	Zeidle	TU CHEMNITZ
Walter	Mattauch	DLR
Klas	Boivie	SINTEF
Khalid Abd	Elghany	CMRDI
Frank	Niklaus	KTH
Arnold	Gillner	FRAUNHOFER
Jürgen	Stampfl	TUWIEN
Jun	Qian	KU LEUVEN
Jan	Deckers	KU LEUVEN
Jens	Pottebaum	UPB
Adrian	Spierings	INSPIRE
Juan Antonio	Arrieta	IDEKO
Paolo	Calefati	Prima Industries
Alberto	Colella	MBN
Javier	Ferrís	IBV UPV
Manfred	Schmid	INSPIRE
A.A.	Poot	UTWENTE
Florian	Bechmann	Concept Laser GmbH
Luis	Portoles	AIMME
Mario	Monzon	UNIVERSIDAD LAS PALMAS GC
Jose Antonio	Dieste	AITIIP
Dante	Pocci	EuMAT
	Wilkens	Photonics21
Jari	Pallari	Peacocks
César	Carrión	AIJU
Philippe	Barré	IMERYS
Andrew	Lynch	ICMR
Jens	Telgkamp	AIRBUS
Gregorio	Cañavate Cruzado	CETEM
Reinhart	Poprawe	Photonics21
Simon	Scott	Renishaw
Neil	Mantle	Rolls Royce
Rainer	Rauh	Airbus
Bo Goran	Andersson	HOGANAS
Axel	Demmer	FRAUNHOFER
Joe	Carruthers	Netcomposites
Pieter	Debrauwer	TNO
Maikel	Beerens	XILLOC
Niclas	Stenberg	SWEREA
Martin	Kage	Heinz Nixdorf Institute
Joren	De Wachter	Jorendewachter
Petr	Pracna	NCP
Michael	DOUKAS	Univ. Patras
Pierre	FIASSE	NCP
Alain	Strowel	UC Louvain
Jochen	Zimmer	INDMATEC

ANNEX VII

References

1. Stronger European Industry for Growth and Economic Recovery. Industrial Policy Communication Update. COM(2012) 582
2. A Manufacturing Industry Vision 2025, European Commission (Joint Research Centre) Foresight study, October 2013.
3. Advancing Manufacturing - Advancing Europe' - Report of the Task Force on Advanced Manufacturing for Clean Production. SWD(2014) 120
4. Wholers, T., & Caffrey, T. (2014). Wholers Report 2014 - 3D Printing and Additive Manufacturing State of the Industry. Wholers Associates.
5. ASTM International. (2012). ASTM F2792 - 12a Standard Terminology for Additive Manufacturing Technologies, ASTM International, West Conshohocken, PA. DOI: 10.1520/F2792-12A
6. Materials KTN. (2012). Shaping our National Compentency in Additive Manufacturing - A Technology Innovation Needs Analysis Conducted by the Additive Manufacturing Special Interest Group for the Technology Strategy Board. Materials KTN.
7. Hype Cycle for 3D Printing, 2014
8. Martin, J., February 28, 2013. Australian Additive Manufacturing Technology and Cooperative Research Roadmap. [Online] Available at: http://amcrc.com.au/aamtsummary.
9. Scudamore, R., & Allison, A. (2014). *Additive Manufacturing Strategic Research Agenda.* Sheffield: Additive Manufacturing Sub-Platform.

Acknowledgements and Editors Notes

Sincere thanks to the participants who took part in the AM workshop, and to the individuals that contributed to this report.

Special thanks are also given to the speakers of the day and the expert panellists that provided their knowledge and views of the industry which, together with the invited EC funded projects, were able to demonstrate the benefits and impacts of AM technology in our society.

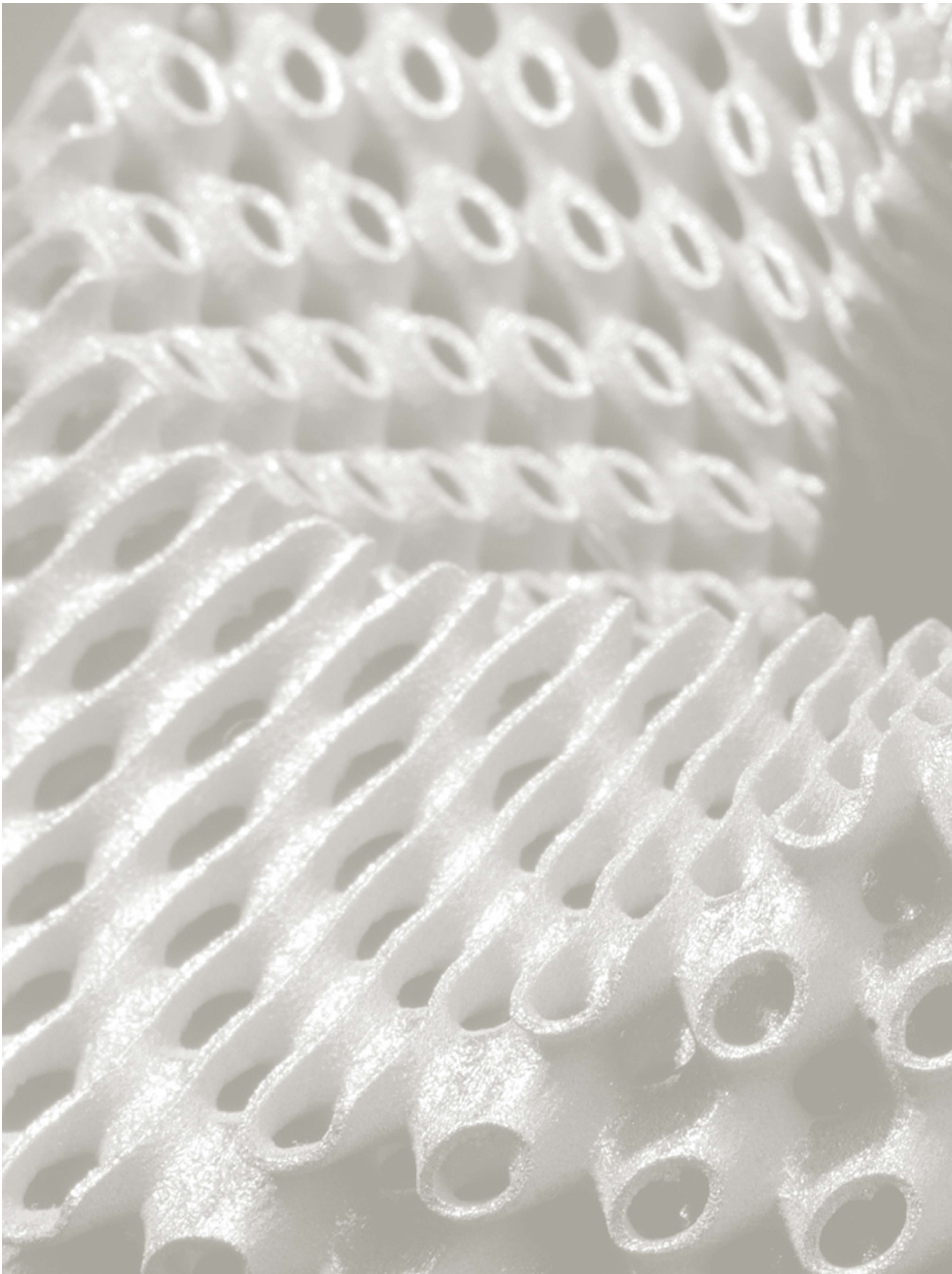
Thanks for the encouraging demonstration of the 3D printing technology provided by Maikel M A Beerens of Xilloc Company. Also to Prodintec Technology Center which 3D-Printed the badges for the event and to Materialise for the items showcased at the workshop.

Thanks to the rapporteur of the event, Mr Rob Scudamore, TWI, and the support of Ms Amanda Allison, TWI, for their contribution to this report.

Particular appreciation for their continued support and development in the field of AM to Ms Clara de la Torre, Director for Key Enabling Technologies; Mr José Lorenzo Vallés, Head of Unit and Mr Andrea Gentili, Deputy Head of Unit from Advanced Manufacturing Systems and Biotechnologies; Germán Esteban Muñiz as the Research Programme Officer responsible for Additive Manufacturing and main contributor to this report and workshop.

The final programme from the workshop including the presentations and recordings of the sessions are all available at:

http://ec.europa.eu/research/industrial_technologies/events_en.html



Additive Manufacturing (AM), including 3D-Printing, is one of the potential game changers that, for some applications, has already reached a tipping point of maturity. These days, we are already witnessing the growing enthusiasm and an increased adoption of these technologies.

AM has received European Commission (EC) funding since the first Framework Programme (FP), during 1984-1987. The following FPs (from 1988 till 2013) ensured continuous support from different EC services and different funding programmes. In FP7 (2007-2013) more than 60 successful projects based on AM technologies were funded, with over €160 million of EC funding and a total budget of around €225 million.

The research and technological development supported by European funding was very important for the growth of the AM technologies in Europe and Horizon 2020 will bring new opportunities. Nevertheless, and despite the EC support, European companies are facing these days a tough business environment.

The aim of the workshop was to understand the needs of the AM sector and to discuss how the current barriers for further development of AM technologies could be removed. There was a special emphasis on the impact of potential policy measures at the EU level which could enhance the competitiveness of the AM sector.