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Introduction

Digital Fabrication has been described as the 'Third Industrial Revolution' (http://www.economist.com/node/21553017).

The use of computer controlled tools and processes to transform digital designs directly into products has significant implications for the structure of manufacturing. New manufacturing norms, based upon distributed manufacturing will develop. New Intellectual Property and legal structures will be required to underpin its development. The Diginova project has already identified the development of well matched combinations of advanced new material deposition tools and materials as a key success factor for Digital Fabrication. This means that Digital Fabrication will need new processes, new fabrication tools and new materials to support its development.

The world of Digital Fabrication is developing rapidly. The multi-disciplinary nature of its development can make it difficult for those interested in the area to keep up-to-date with the latest developments.

For this reason, the Diginova team and its networks are being used to monitor developments in this continuously changing landscape, so that those individuals, groups and organisations that are interested in the technology and its development can get a useful overview of the area.

This report is the first of two of Technology Watch Reports (TWRs) that the project will publish on a regular basis, presenting key information from the relevant trade literature, conferences and exhibitions, the scientific and technological literature and the media. It is not a comprehensive review of all developments. Rather it seeks to keep the reader aware of the major areas of development and the current areas of debate and discussion within the industry.

This first report presents 24 references to developments in Digital Fabrication and it is interesting to 'map' the areas that these reports cover.

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These articles vary from the underpinning systems required to help the technology to develop (e.g. intellectual property and legal systems) to new application areas such as biomaterials. There is already great interest in the technology in countries with a significant manufacturing base, such as Germany and China and it is clear that the area is drawing the attention (and investment) of OEMs from a variety of industries.

Digital Fabrication of Spare Parts

Source of Information	Magazine, internet
Reference	Magazine Make: Winter 2013 (makezine.com) Gallery of scanned objects: http://www.123dapp.com/Gallery/ 3D printing of spare parts: http://www.directspare.eu/project/movie Printing titanium bike parts: http://vimeo.com/47522348
Date	21 January 2013
Key learning Points	A real useful application of 3D printing could become the printing of spare parts. Instead of throwing away a complete product when a small functional part breaks, the part can be replaced by 3-D printed part. This could lead to a huge reduction of waste and required resources. Current stock of spare parts can be reduced too, since parts can be produced when required. Quality of products can increase since during development the reuse of parts (to increase production numbers) is not a big issue any more. Products are allowed to change faster since this does not increase spare parts stock any more. Manufacturers can provide refurbishing services and sell geometry files of spare parts to consumers. For older products these digital descriptions often will not be available. Here the trend of 3D-scanning and uploading of geometry specifications to the cloud comes to help. Note that scanning real-life objects into digital files is the opposite transformation of 3-D printing where geometry files become real objects. The broken parts can be scanned and 'repaired' digitally or downloaded from the cloud when made available by other owners of similar products. One of the biggest technical hurdles is the still inferior quality of 3-D printed products. Rubber parts are for example difficult to print and it is rubber spare parts that are required very often due to short life times. Printed metal parts however are already being used instead of milled parts, for example in titanium bikes.
Breakthroughs	Replacement of milled metal objects by printed metal objects in applications where high strength is required. 3-D scanning is available for everybody.

Use of Digital Fabrication in Printed Electronics

Source of Information	NIP 28 and Digital Fabrication 2012 Conference
Reference	Hakola et al., "Optimizing the Performance of Metal Grid Conductors by Modifying Printing Conditions". NIP 28 and Digital Fabrication 2012 Conference.
Date	9.-13.9.2012, Toronto, Canada
Key learning Points	Printed metal grid conductors for light-emitting electrochemical cell (LEC) devices can be fabricated by industrial inkjet printing. Inkjet processing will yield devices with sufficient performance when critical parameters such as layer thickness and roughness are optimized.

Digital Fabrication in Fashion

Source of Information	Internet article
Reference	http://www.core77.com/blog/digital_fabrication/digital_fabrication_and_fashion_intersect_at_paris_fashion_week_24243.asp
Date	23. Jan 13
Key learning Points	Digital Fabrication and textiles intersect Materialise have teamed up with fashion designer Iris van Herpen to create some unusual clothes for Paris Fashion Week, featuring 2 prototype dresses. The first was a cape and skirt created with the help of MIT Media Lab's Neri Oxman and 3D printed by Stratasys. The second, created with the help of Austrian architect Julia Koerner, was laser sintered by Materialise. The 3D printed skirt and cape were produced using Stratasys' unique Objet Connex multi-material 3D printing technology, which allows a variety of material properties to be printed in a single build. This allowed both hard and soft materials to be incorporated within the design, crucial to the movement and texture of the piece. While the designs are conceptual, van Herpen feels digitally manufactured clothes in the future are a certainty. "I believe it will only be a matter of time," she explains, "before we see the clothing we wear today produced with this technology, and it's because it's such a different way of manufacturing, adding layer-by-layer, it will be a great source of inspiration for new ideas." says Julia Koener

Legal and Intellectual Property issues in Digital Fabrication

Source of Information	http://www.publicknowledge.org/files/docs/3DPrintingPaperPublicKnowledge.pdf
Reference	It Will Be Awesome if They Don't Screw it Up: 3D Printing, Intellectual Property, and the Fight Over the Next Great Disruptive Technology, Michael Weinberg
Date	Nov 10, 2012
Key learning Points	Whitepaper on the Intellectual Property of 3D Printing
Breakthroughs	How to handle Patents, Copyrights and Trademarks of 3D printed parts.
Comments	Creative Common document from Michael Weinberg, staff attorney with Public Knowledge.

Source of Information	Internet
Reference	http://www.dezeen.com/2012/12/09/legal-issues-threaten-rise-of-3d-printing/
Date	21.01.2013
Key learning Points	The 3D printing revolution could be hampered by copyright claims and legal challenges as the emerging technology matures, an expert has warned.
Breakthroughs	Possible legal issues over copyright and responsibility of accident claims
Comments	legal minefield

Printed Houses

Source of Information	Internet
Reference	http://www.dezeen.com/2013/01/20/dutch-architects-to-use-3d-printer-to-build-a-house/
Date	21.01.2013
Key learning Points	Dutch architecture studio Universe Architecture is planning to construct a house with a 3D printer for the first time
Breakthroughs	3D printing website 3ders.org quoted Ruijssenaars as "It will be the first 3D printed building in the world. I hope it can be opened to the public when it's finished."

Source of Information	The Guardian article
Reference	http://www.guardian.co.uk/artanddesign/architecture-design-blog/2013/jan/22/first-3d-printed-house-janjaap-ruijssenaars
Date	22. Jan 13
Key learning Points	Designs unveiled for first 3D printed house. Developed by Italian engineer Enrico Dini, the printer uses the same stereolithography principles as smaller printers, only scaled up, using sand fused together with a chemical binding agent.
Breakthroughs	The key reason for using digital printing is for freedom of design.

Source of Information	Internet, Book
Reference	http://www.stonespray.com/ http://www.thecreatorsproject.com/blog/istone-spray-projecti-a-robot-that-turns-sand-into-3d-printed-architecture http://www.engadget.com/2012/08/05/stone-spray-research-project-wants-to-print-bridges-with-sand/ http://www.theverge.com/2012/8/5/3220003/stone-spray-project-3d-printer-sandcastles
Date	August 2012
Key learning Points	"A research project Stone Spray done by Anna Kulik, Inder Shergill and Petr Novikov in the Institute for Advanced Architecture of Catalonia in the year 2012. The goal of the project was to research the field of additive manufacturing in architecture and to propose a new eco-friendly, efficient and interesting system to print architecture in 3D. As a result a robot and series of samples were created. Also a book describing the project was published."
Breakthroughs	Allow the construction on uneven ground and reducing the risk of accidents on hand labor. Projecting archeology for easy and faster representation. Leaving architects with freedom of creations.

Company investments in Digital Fabrication

Source of Information	Internet
Reference	http://www.dezeen.com/2013/01/18/nokia-releases-files-for-3d-printing-lumia-820-mobile-phone-cases/
Date	18.01.2013
Key learning Points	Mobile phone maker Nokia has released open-source files that will let Lumia 820 smartphone users 3D print their own customised case.
Breakthroughs	John Kneeland, community and developing marketing manager at Nokia, explained the move in a blog post: "We are going to release 3D templates, case specs, recommended materials and best practices – everything someone versed in 3D printing needs to print their own custom Lumia 820 case," he wrote. "In doing this, Nokia has become the first major phone company to begin embracing the 3D printing community and its incredible potential."

Source of Information	Internet: Economist, Schumpeter
Reference	http://www.economist.com/blogs/schumpeter/2012/11/additive-manufacturing
Date	November 22nd, 2012
Key learning Points	GE Aviation buys Morris Technologies, who employ a number of 3D printing technologies (Direct Metal Laser Sintering (DMLS), Electron Beam Melting (EBM), Polyjet Connex 500 3D Printer, Stereo Lithography). Among the components that Morris Technologies plans to print will be some used in the LEAP jet engine, which is being developed by CFM International, a joint venture between GE Aviation and Snecma of France. The LEAP engine is scheduled to enter service in the next few years on a number of short-haul airliners. More than 4,000 engines have already been ordered. With regard to Diginova, this is yet more confirmation that Additive Manufacture is being taken very seriously by the manufacturing sector and that it will be employed to produce safety critical devices with high performance standards. GE is buying Morris Technologies (which includes a sister company, Rapid Quality Manufacturing) for an undisclosed sum. GE sees the purchase as an investment in an important new manufacturing technology. “Our ability to develop state of the art manufacturing processes for emerging materials and complex design geometry is critical to our future,” said Colleen Athans, general manager of GE Aviation’s supply-chain operations.
Breakthroughs	Not so much a breakthrough, but a confirmation of the economic importance of the technology and a demonstration of how it is maturing.
Comments	Yet more evidence of investment in the technology as part of a 'third industrial revolution', with the end user employing the technology in a high performance, safety critical application.

Digital Fabrication in China

Source of Information	Internet
Reference	http://www.3ders.org/articles/20130121-china-looks-to-3d-printing-related-stocks-surge.html
Date	January 21st, 2013
Key learning Points	China is not just cheap labor but also a high tech powerhouse. China seems to take 3D printing / digital fabrication seriously.
Breakthroughs	China has shown that it can lead in new industries (e.g. photo-voltaic panels, wind energy). Should it decide to invest in 3D printing and given the financial and human resources they have, this could have a huge impact for the 3D printing industry.
Comments	China already has numerous 3D printer manufacturers, however largely unknown to us (?).

Source of Information	Internet
Reference	http://www.3ders.org/articles/20130118-3-meter-long-titanium-airplane-part-3d-printed-in-one-piece.html
Date	January 18th, 2013
Key learning Points	China already investigates Laser Additive Manufacturing focusing on metals since 1995.
Breakthroughs	Producing 3 m long titanium airplane parts for commercial application within a few years places this research center at the forefront of 3D printing of metal parts.
Comments	China's 3D printing industry and research centers are a force to be reckoned with.

Source of Information	Internet
Reference	http://inhabitat.com/autodesk-and-organovo-team-up-to-3d-print-living-human-tissue/
Date	21.01.2013
Key learning Points	Autodesk and Organovo Team Up to 3D Print Living Human Tissue
Breakthroughs	New software specifically to design and print living tissue

Source of Information	BBC News Website
Reference	http://www.bbc.co.uk/news/technology-20972018
Date	21st January, 2013
Key learning Points	Modern Meadow is a US startup, whose CTO Gabor Forgacs is a professor at the University of Missouri.
Breakthroughs	The company is using additive printing to print biomaterial. The article states that they have a development product that is effectively 'printed meat', although the prototype is not ready for consumption. The excitement seems to be around the potential for creating meat and meat-based products without the environmental impact of livestock farming. The article talks about bioprinting, its limitations and uses the example of printing a hamburger with the current technology. Such a burger would cost around £200k, but prices would be expected to fall!
Comments	The report somewhat sensationalizes the prospects of printing meat. However, this does illustrate the use of additive printing with bio-based materials and it generally publicizes the benefits of additive printing.

Source of Information	Internet
Reference	http://www.oxfordkneegroup.com/3d-printing-in-orthopaedics/
Date	23.01.2013
Key learning Points	A scan of the patients' knee is made into a 3D representation with computer assisted design. The instruments are then made to fit the individual knee (bespoke) by utilizing 3D printing technology
Breakthroughs	bespoke patient care

General Reviews of Digital Fabrication and relevant Tradeshows

Source of Information	Article in Der Spiegel: "Technology May Bring New Industrial Revolution"
Reference	http://www.spiegel.de/international/business/3d-printing-technology-poised-for-new-industrial-revolution-a-874833.html
Date	4 January 2013
Key learning Points	Nice overview with some interesting numbers about sales and market.

Source of Information	internet
Reference	http://www.economist.com/topics/digital-fabrication
Date	11.01.2013
Key learning Points	There is a lot of focus on digital fabrication and developments are going very fast.
Breakthroughs	More and more businesses open up shops for printing 3D designs. Also designs are shared and adapted by other people.
Comments	This is a new business model, where you pay for the design is paying for the product.

Source of Information	Tradeshow Euromold 2012, Frankfurt, Germany
Reference	http://www.3ders.org/articles/20121128-euromold-the-3d-bioplotter-from-envisiontec.html
Date	27. Nov 12
Key learning Points	Commercial printers become available for printing bio-materials. This seems to be a professional system targeted to do research on printing implants and potentially produce implants for actual use in a human body.
Breakthroughs	Automatic tool changing system with 5 dispensing heads. This enables multi material implants. The availability of such printers can give a huge boost to 3D printing research for human applications.
Comments	Developments in the field of human implants may go faster than is commonly known?

Source of Information	Tradeshow Euromold 2012, Frankfurt, Germany
Reference	http://objet.com/company/press-releases/objet-launches-objet1000-euromold
Date	November 27th, 2012
Key learning Points	Increasing the build size of the Objet Connex 500 (500x400x200 mm^3) to that of the Objet 1000 (1000x800x500 mm^3) shows the scalability that inkjet technology has to offer. Inkjet also enables multi-material printing and digital materials.
Breakthroughs	Increasing the build volume by a factor of ten, Objet opens up new applications and reduces assembly work. The large build size combined with the wide range of materials, including digital materials. Also the Objet 1000 can print up to 14 different material properties into one single model. This gives possibilities that have yet to be discovered.
Comments	Objet also has high temperature materials that are used to make injection moulds: 3D Printed Injection Moulding Tool (PIMT): http://objet.com/sites/default/files/pdfs/injection_molding.pdf

Source of Information	Tradeshow Euromold 2012, Nov 2012, Frankfurt, Germany
Reference	http://3dprintingindustry.com/2012/12/05/supersized-industrial-3d-printing-in-metal/ http://www.ipmd.net/news/002008.html http://voxelfab.com/blog/2012/11/euromold-2012-go-big-or-go-home-connex-1000-and-concept-laser-1000r/ http://www.3ders.org/articles/20121205-3d-printing-metal-in-an-xxl-format-for-the-carmaker-daimler.html
Date	27th November 2012 the Concept Laser X-line 1000R was revealed to the public at Euromold.
Key learning Points	3D printer manufacturer Concept Laser, Research institute Fraunhofer ILT and automobile manufacturer Daimler A.G. teamed up to develop a production Laser Curing (similar to Selective Laser Melting) printer that opens up whole new possibilities for large metal parts to be produced.
Breakthroughs	The X line 1000R has the largest build volume for SLM printers to date: 630 mm × 400 mm × 500 mm. The rotating build bed - when the build at one side is over, a new build could continue on the opposite side increases the productivity. The large build size and increase in productivity (both print speed due to powerful kW-range laser as well as workflow) may open up a range of new applications and types of products that can be metal printed.
Comments	It might be that laser sintering of metal parts evolves faster than laser sintering of plastic parts. Possibly this has to do with engineering alloys being available and because it may have more potential to the powerful aerospace and automobile industry than plastic laser sintering.

Source of Information	internet
Reference	http://www.core77.com/blog/digital_fabrication/voxeljet_concept_the_first_continuous_3d_printer_22762.asp
Date	26 June, 2012
Key learning Points	Focus developments in digital fabrication not only on materials and deposition method, but also on system design!
Breakthroughs	No real technological breakthrough. More a drastic system design change, that enables 'continuous feed 3-D printing
Comments	nice example of a way to use current technology in another way to expand the application range

Source of Information	Internet
Reference	http://www.guardian.co.uk/artanddesign/architecture-design-blog/2013/jan/15/filabot-home-3d-printing-recycle
Date	21.01.2013
Key learning Points	Recycling
Breakthroughs	Recycling old plastic, reducing waste and wasted parts
Comments	Increased green-ness

Source of Information	Internet
Reference	http://www.newscientist.com/blogs/onepercent/2013/01/irobots-3d-printer-patent.html
Date	24.01.2013
Key learning Points	Robot-assisted 3D printer aids march of the machines
Breakthroughs	The Bedford, Massachusetts, firm has filed a US patent on a way to rid 3D printers of the need for humans, allowing robots to do all the post-printing work to make a complete product
Comments	Fully automated 3D printing, cleaning and assembly

Source of Information	The Economist article - Print me a jet engine
Reference	http://www.economist.com/blogs/schumpeter/2012/11/additive-manufacturing
Date	22. Nov 12
Key learning Points	GE Aviation, part of the world's biggest manufacturing group, bought a privately owned company called Morris Technologies, who are heavily involved in 3D printing and invested in technology to print parts for jet engines. It suggests how seriously companies are taking 3D printing, and that the technology is also good enough to make production items too, as opposed to just making prototypes.
Comments	product innovation will increasingly go hand-in-hand with manufacturing innovation

Source of Information	Internet
Reference	http://imieurope.com/blog/sii-printek-launches-continuous-flow-printhead/
Date	1st Feb 2013
Key learning Points	SII Printek launches continuous flow printhead which is targeted for ceramic, textile and other digital fabrication applications. SII Printek 's product announcement is the 512 JetFlow printhead with 512 nozzles in 2 rows, a native resolution of 180 dpi, drop volumes variable between 20-150 pl, and drop frequencies in excess of 36 kHz. Oil, solvent aqueous and UV inks can be used.
Breakthroughs	Industrial printhead technology available