MaRS Market Insights

Layer–by–Layer: Opportunities in 3D printing

Technology trends, growth drivers and the emergence of innovative applications in 3D printing

MaRS is a member of

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Content Leads and Authors

Claudio Munoz, Senior Industry Analyst, MaRS Market Intelligence
Christina Kim, Information Specialist, MaRS Market Intelligence
Lucas Armstrong, Junior Industry Analyst, MaRS Market Intelligence

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Dr. Axel Guenther, Professor, Department of Mechanical and Industrial Engineering, University of Toronto
Michelle McBane, Director, MaRS Investment Accelerator Fund, MaRS Discovery District
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Derek Quenneville, Director, Site 3 coLaboratory
Fanny Sie, Project Manager, Physical Sciences/Medical Devices, MaRS Innovation
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1. Introduction

Additive Manufacturing (AM) is a manufacturing process that deposits materials layer-by-layer to build a tangible product. The most common, and the most popular currently, is 3D printing. AM is claimed to have triggered a third industrial revolution because the technology presents new and expanding technical, economical and social impacts (Economist, 2012). Particularly, the increased accessibility to 3D printing capabilities has allowed mass customization to become more widespread in industries such as healthcare and consumer markets.

Since the advent of mass production in the early 20th century, consumers' demands have been met by producing large numbers of goods in significantly less time than ever before. While production time and price decreased, they did so at the expense of customization. AM makes it possible to offer customers options to personalize the products and goods they are purchasing, from custom-made prosthetics to a personalized smartphone case.

The importance of customization cannot be understated. Researchers agree that customization will continue to grow as a major trend across industries. J.P. Gownder, vice president and principal analyst for infrastructure and operations professionals for Forrester, says that while "mass customization has long been the next big thing in product strategy ... changes in customer-facing technology are opening up new opportunities for product strategists to bring customers into product design, creating both customer loyalty and higher margins" (Forrester, 2011, p. 12). Marina Wall of the Heinz Nixdorf Institute at the University of Paderborn also contends that, "individuality or mass customization are important trends driving change so increased product diversity is important for the future and for meeting individual customer requirements. AM has great potential for freedom of design that can cope with these challenges" (as cited in AM Platform, 2013, p. 29). 3D printing is expected to play a significant role in the future of mass customization.

This report explores the potential impact that this technology may have in various sectors. Through secondary research and conversations with business analysts, investors, members of the 3D printing community, experts and entrepreneurs, we investigated some of the potential market opportunities the technology is unveiling. We also explore sources of capital and nascent business models for those innovators interested in capitalizing on this technology.

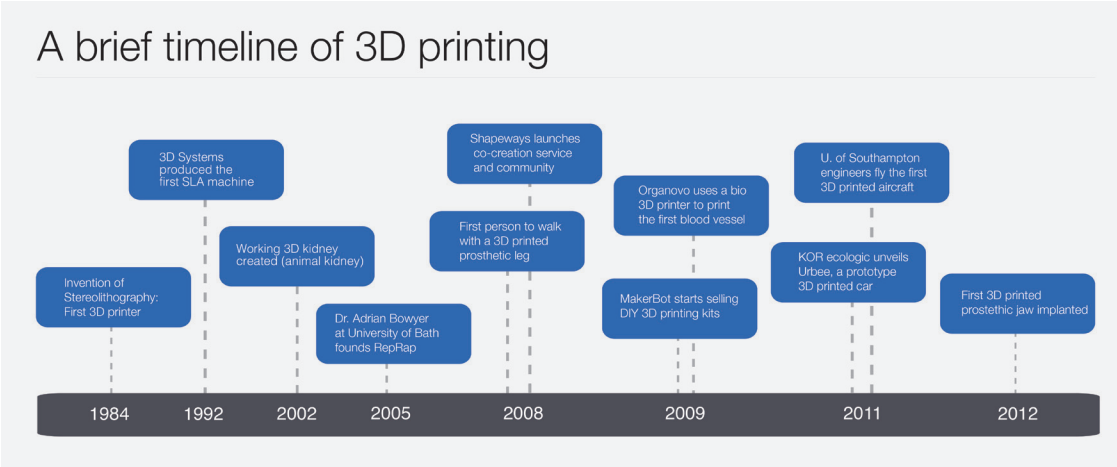
As part of our investigation, we also profile some organizations involved with 3D printing or related markets. These entrepreneurs are actively and creatively pushing the limits of 3D technology. For the purposes of this document, the terms 3D printing and additive manufacturing will be used interchangeably.

Industry at a glance

Charles (Chuck) Hull of 3D Systems developed the first working 3D printer in 1984. While 3D printing has been around for almost 30 years, it is still a nascent market with low market share concentration although rapid growth is expected. According to IBISWorld (2013), the industry is growing at a rate that consistently surpasses the overall US economy. Falling costs, technology developments and new applications for 3D printing technology have driven growth in the industry.

Recent hype and buyer interest are also giving rise to software, hardware and service providers that are offering easy-to-use tools, a wider range of materials, and improved product quality. Industry revenue in the US is expected to reach $1.4 billion in the next five years and grow at an annual rate of 12 per cent (IBISWorld, 2013).

Fig. 1. TIMELINE



Technology and key players

There are seven different additive manufacturing processes, as defined by ASTM International. Of the seven, material extrusions lead the market growth due to greater consumer adoption (Gartner Forecast, 2013).

Table 1 summarizes the seven process classifications and technologies that comprise the 3D printer market with selected market participants. This research does not constitute an exhaustive list of developers in any given technology area.

Table 1

Clasification of additive manufacturing processes, adapted from ASTM International (ASTM International, 2012)

Classification	Technology	Description	Materials	Developers (Country)
Binder Jetting	3D Printing Ink-jetting S-Print M-Print	Creates objects by depositing a binding agent to join powdered material.	Metal, Polymer, Ceramic	ExOne (US) VoxelJet (Germany) 3D Systems(US)
Direct Energy Deposition	Direct Metal Deposition Laser Deposition Laser Consolidation Electron Beam Direct Melting	Builds parts by using focused thermal energy to fuse materials as they are deposited on a substrate.	Metal: powder and wire	DM3D (US) NRC-IMI (Canada) Irepa Laser (France) Trumpf (Germany) Sciaky (US)
Material Extrusion	Fused Deposition Modeling	Creates objects by dispensing material through a nozzle to build layers.	Polymer	Stratasys (US) Delta Micro Factory (China) 3D Systems (US)
Material Jetting	Polyjet Ink-jetting Thermojet	Builds parts by depositing small droplets of build material, which are then cured by exposure to light.	Photopolymer, Wax	Stratasys (US) LUXeXcel (Netherlands) 3D Systems (US)
Powder Bed Fusion	Direct Metal Laser Sintering Selective Laser Melting Electron Beam Melting Selective Laser Sintering	Creates objects by using thermal energy to fuse regions of a powder bed.	Metal, Polymer, Ceramic	EOS(Germany) Renishaw (UK) Phenix Systems (France) Matsuura Machinery (Japan) ARCAM (Sweden) 3D Systems (US)
Sheet Lamination	Ultrasonic Consolidation Laminated Object Manufacture	Builds parts by trimming sheets of material and binding them together in layers.	Hybrids, Metallic, Ceramic	Fabrisonic (US) CAM-LEM (US)
VAT Photopolymerisation	Stereolithography Digital Light Processing	Builds parts by using light to selectively cure layers of material in a vat of photopolymer.	Photopolymer, Ceramic	3D Systems (US) EnvisionTEC (Germany) DWS Srl (Italy) Lithoz (Austria)

New applications

Today, 3D printing accounts for only 28 per cent of the total manufacturing sector (Wohlers, 2013), but the market seems destined to explode. Gartner research suggests that 3D printing has already reached an inflection point, and predicts that "the total number of consumer and enterprise 3D printer shipments will grow from 38,002 units in 2012 to 1,083,496 units in 2017, a compound annual growth rate of 95.4 per cent (Gartner, 2013).

While the consumer market is expected to be the main driver of the sector growth, there is also room for innovation in the enterprise market. Most analysts expect that more companies, from large organizations to small and medium-sized enterprises (SMEs), will begin to explore the technology and unravel new business cases. Entrepreneurs are not only focusing on new manufacturing processes, products or verticals but also on other opportunities in the ecosystem, from the recycling of (printed) plastic products, establishment of standards and legal frameworks, to the cataloguing of 3D printing products for consumers.

Based on conversations conducted with several analysts and investors for this report, there is still a gap between what 3D printing technology can do and what it will end up being used for. Thousands of developers, designers and enthusiasts working with the technology continue to stretch the boundaries of applications. The process is challenging and, in most cases, requires sophisticated skills and training.

2. What can you do?

Opportunities at the commercial level

Historically, prototyping has been the most popular application of 3D printing, as part of product development and research and development (R&D) projects. Today, printers and materials have evolved and 3D printers are currently being used to create finished products for niche applications and industries; for example, the latest Boeing 787 Dreamliner has 3D-printed parts (Popular Science, 2013).

According to Deloitte (2013), most of the revenue generated by the 3D printing sector will come from commercial users, as printer makers experience continued price pressure and 3D printers become more affordable. In the past, only large organizations such as 3M, Ford and Microsoft had the capital necessary to invest in 3D printers and explore new business models or product lifecycles: 3M, for example, has used AM to conduct research on new materials and health-related products; Ford has used it to prototype and build cars components; and Microsoft used 3D printers to develop its Kinect in house to avoid media leaks. Thanks to more affordable prices, smaller organizations are increasingly joining in the exploration of applications. Some are even purchasing 3D printers without a pre-defined use and setting up small labs to explore new business opportunities and efficiencies.

Another key driver of 3D printer growth is the expanding set of materials available. Materials are as important to AM as the printers themselves: build materials account for 40 per cent of revenue for this sector and is expected to increase as 3D printing grows (IBISWorld, 2013). Even though polymers are the most common, metals, paper and even organic tissue are becoming available. The development of new composites could allow the industry to explore new product development in sectors such as electronics (from simple motherboards to robots).

Researchers and professionals in 3D printing say that product design is also being transformed by the rise in popularity of 3D printing. Companies can market test new products, making necessary transformations based on customer feedback. They can also print small batches of a product, test different versions and only send to production the one that proved most successful. Instead of mass producing one product, based on limited feedback from focus group participants, companies can now create five products and sell them directly to consumers, letting the market decide which is successful enough for mass production.

Prototyping, customized products and small production runs will keep driving the commercial usage of 3D printers in the short term while new niches develop. The range of enterprise applications for 3D printing varies depending on the sector, but there are three industries that are already experimenting or applying 3D printing that are expected to experience the biggest gains. These sectors are the aerospace, biomedical and consumer markets.

Table 2

Sectors expected to experience the highest growth in 3D printing use

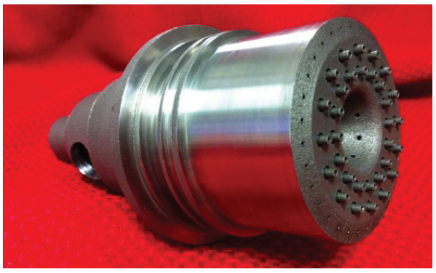
Research firm	Industry 1	Industry 2	Industry 3
Wohlers	Consumer	Automotive	Medical / Dental
Gartner	Consumer	Industrial	Manufacturing
IBISWorld	Aerospace	Medical	Consumer
Frost & Sullivan	Aerospace	Automotive	Medicine
Morgan Stanley	Aerospace	Medical	Consumer

Aerospace

Despite current limitations, particularly with materials and structural integrity, aerospace companies are exploring 3D printing for manufacturing various parts of their products. Boeing has already used the technology to manufacture interior pieces of airplanes while NASA has used it to build rocket engines and parts for satellites. Companies in the sector are actively investing in the technology either by (1) purchasing companies, like GE Aviation did when it acquired Morris Technologies, an engineering firm specializing in advanced fabrication techniques for jet engine production; or (2) investing in partnerships with research centres, like Pratt & Whitney which invested millions in an advanced additive manufacturing centre in collaboration with the University of Connecticut (PricewaterhouseCoopers, 2013).

Aerospace is also one of the most research-intensive sectors using 3D printing. It has used the technology to build demonstration units, used by governments to evaluate functionality and hull design concepts. Research also includes developing complex parts, such as satellites parts or components of NASA's rovers, including flame-retardant vents and housings, camera mounts and large pod doors (Stratasys, 2013). In 2013, Airbus, a leading aircraft manufacturer, announced plans for an airplane that will include 3D-printed components that are significantly lighter but as strong as traditional machined parts (PricewaterhouseCoopers, 2013).

Gallery of noteworthy applications
(See photo credits at the end of this report for image sources)



Health

Researchers and business analysts interviewed for this report identified the medical and healthcare vertical as one of the key industries for new developments, as 3D printing can replicate the human form more accurately than traditional manufacturing techniques. Hearing aids, orthopedics and dental implants are the most common medical uses of the technology. IBISWorld (2013) estimates that there are already more than half a million 3D-printed dental implants in patients worldwide. New research in other applications is rapidly expanding in this sector. For example, various organizations are researching the possibility of bioprinting live cells and tissue, such as the University of Toronto's Bio Printer project which is exploring the use of 3D-printed tissue for the treatment of burned patients.

3D printing also allows the production of complex shapes (such as hollow figures) and lightweight parts that can be used to create implants—a growing demand in countries with aging populations. Bone replacements and support structures for growing body parts made by 3D printers are at different stages of research. Another possible application in the medical industry is to use 3D printers to create models of human parts from CT scans or MRI images to assist surgeons during complex surgeries. Designers and engineers are also exploring the development of new and specialized surgical tools made by 3D printers.

Gallery of noteworthy applications
(See photo credits at the end of this report for image sources)

The path towards commercialization of these technologies is complex, long and expensive. One of the key restraints of 3D printing in the health sector is certification of medical implants, a process that can take years and varies according to geographical location (making scaling more complex). Furthermore, some applications require solid streams of funding to develop. Organovo, the world's most popular bioprinting company doubled revenue to $1.2 million from 2010 to 2012, but its losses increased nearly eight-fold to $9.3 million in the same time period (The Guardian, 2013). For example, the University of Toronto's Bio printer project could take between 5 to 7 years to actually reach patients.

Consumers

Various reports predict that 3D printing will experience the biggest growth in the consumer market, even outpacing the enterprise market in the short term. However, the definitive consolidation of the consumer sector depends, among other things, on the irruption of a compelling application that would prompt consumers to embrace the technology, a "killer app" that, in connection with reduced prices, will finally bring the era of self-production into consumer homes. This application (or applications) is expected to likely emerge from the thousands of projects, labs and experiments currently being conducted by makers, hobbyists and enthusiasts who are pushing the limits of the technology. These experiments range from new lower-cost printers like a 3D printer that costs $100 (CBC News, 2013), catalogues of 3D models, computer-aided design (CAD) software, and customized design services (see Hot Pop profile). Many entrepreneurs and professionals interviewed for this report agreed that mass consumption is not yet part of the equation. Even though it is possible to download and print a 3D model, it is not yet clear what types of applications would compel consumers to purchase their own 3D printers. Currently, 3D printers cannot compete with economies of scale or the mass production of some goods. In this context, it is still unclear how 3D printing will affect consumer goods manufacturing.

Gallery of noteworthy applications
(See photo credits at the end of this report for image sources)

It's a maker's world

The makers culture is fostered by tinkers, craftsmen and enthusiasts that engage with technology as part of the do-it-yourself (DIY) culture. Highly motivated, makers are a very eclectic group that includes designers, engineers, developers and graphic artists. In the case of 3D printing, makers are one of the most energized groups of technology adopters and creators. Their work includes printers, like the RepRap community, and 3D artifacts that are distributed through platforms such as Shapeways and Thingiverse among others.

3D printing is not as accessible as it seems, as the technology has not reached a "plug and play" or a "push and print" stage. Printing a 3D object requires data preparation, file modification, setting of the device, pre-heating, build, cooling, support removal and finishing (Wohlers, 2013). As a result, "extreme users"—people with the skills and knowledge to understand the nuances of the process—are largely conducting the exploration of new products, business models and verticals.

Makers are exploring the design, production and consumerization of complex forms that were previously unthinkable due to the limitations of traditional manufacturing (complex forms are expensive to build and therefore avoided; conventionally, an efficiently designed object is one that can also be easily manufactured). Furthermore, makers are creating new business models or conducting the necessary research to bring products to market.

Research not only includes 3D printers and its applications, but also the materials. As the materials available and the refinement of the 3D printing process continue to progress, the types of products that can be built are, arguably, unlimited. In reality, however, there are still restrictions. Materials are complex, thus restricting the type of products that can be printed (for example, electronics that combine plastics and metals). Printing also involves a lengthy process that is prone to errors and often requires the user to print several versions of a product. The lack of simple CAD software also makes the technology only accessible to more advanced users, such as architects and designers familiar with 3D modeling (Morgan Stanley, 2013).

3D printing may change how things are manufactured in the future but cannot replace mass manufacturing, at least not yet. Only usage will determine its evolution. In this sense, 3D printing may undergo an evolution similar to the Internet, a tool originally created to share academic knowledge (D. Southwick, personal communication, October 24, 2013). The discussion is still open. Some experts view 3D printing as a tool that could change manufacturing to its core (Lipson & Kurman, 2013) while others say it is complementary to traditional manufacturing.

A quick peek into Ontario

In Ontario, the maker movement is strong and very active. From the 3D Printers Group in Toronto to the Kwartzlab in Waterloo, makers across the province get together to explore, create and transform artifacts. Libraries are also creating labs and conducting workshops to introduce the technology: The Toronto Public Library is opening two digital hubs (complete with a 3D printer and spaces for game design) at the Toronto Reference Library and the new Fort York location, set to open in 2014. The Ottawa Public Library will also launch a designated area for makers ("makerspace") called IMAGINE SPACE – an American Corner, to encourage hands-on learning and exchange of ideas in pursuit of innovation, including 3D printing, in 2014.

Universities are also exploring the technology, either as academic research projects or in a makerspace fashion. Many Ontario and Quebec universities are committed to research within the 3D printing and AM space, most of which have focused on healthcare or biomedical applications (such as prosthetics). For example, a group of professors at McGill University are using 3D printers to create exact replicas of bones for spinal grafts. Heal.X from OCAD University has developed a new form of casts/splints for broken bones created using 3D printing. These new casts are affordable, waterproof and can be fully customized.

In general, established manufacturers are familiar with the technology and in various cases have adopted it, mostly as a prototyping tool. As part of an ongoing search for competitive advantage, some are exploring potential new benefits from the technology. Recent innovation involves developing different types of advanced manufacturing strategies such as transforming manual processes into highly computerized procedures (a phenomena that's been as impactful as 3D printing).

To compete, many companies are exploring customized production processes, trying to build products faster and with high levels of precision. In this context, business analysts and developers consulted in the preparation of this report believe the technology would have greater impact in consumer segments rather than industrial production. There may be a niche in the construction of customized machinery pieces, but the high costs of printing metals, and its complexity, is currently keeping the technology out of the factories.

In any case, the exploration of new manufacturing processes (not necessarily 3D printing) is tightly connected to core expertise. For example, there is interest in exploring new technology in the development of drilling parts in North Bay and mining technologies in Sudbury, or customized furniture in Northern Ontario. Nonetheless, there seems to be no large technology clusters using AM; manufacturers and researchers are a diverse group. The enabling capacities of the Internet have allowed these groups to share knowledge.

3. Financing 3D printing ideas

Government and industry initiatives

In North America and globally, there are many government and industry initiatives that are sponsoring and financially supporting advanced manufacturing and 3D printing research. Many of these countries, such as Canada, the United States and in the United Kingdom also have national programs that support university-level research, which in turn drives technology advances and startup companies. The following section outlines several examples of initiatives in various countries.

Canada

The Advanced Manufacturing Fund is a new fund delivered by the Federal Economic Development Agency for Southern Ontario (FedDev). The government's Economic Action Plan 2013 proposes to provide $200 million over five years to support the efforts of advanced manufacturers in Ontario in activities that create new and innovative products or production methods.

SMART Prosperity Now Program is administered by Canadian Manufacturers & Exporters (CME) and funded by FedDev. The $18.9 million fund is aimed at helping small and medium-sized manufacturers invest in product and process improvements.

Industrial Research Assistance Program (IRAP) is a new pilot program to be delivered through the National Research Council-Industrial Research Assistance Program (NRC-IRAP) that helps small and medium-sized enterprises access research and business development services at universities, colleges and other non-profit research institutions.

Tax Relief for New Manufacturing Machinery and Equipment is a two-year extension of the government's accelerated capital cost allowance (CCA) that was scheduled to expire at the end of 2013. This extension will help Canada's manufacturing and processing sectors to invest in advanced machinery and equipment.

United States

The National Additive Manufacturing Innovation Institute (NAMII) is a public-private institute for manufacturing innovation in Youngstown, Ohio that helps accelerate AM technologies to the US manufacturing sector. The institute brings together a network of manufacturing firms, universities, community colleges and non-profit organizations from the Ohio-Pennsylvania-West Virginia Tech Belt, and provides $40 million to match $30 million in federal funding for the sector.

United Kingdom

As the UK's innovation agency, the Technology Strategy Board (TSB) has identified high-value manufacturing as one of 13 key priority areas for boosting growth in the UK through innovation. TSB anticipates spending £25 million towards high-value manufacturing industries for research and development, universities and science.

Advanced Manufacturing Supply Chain Initiative (AMSCI) provides funding of £120 million for supporting supply chain investments in equipment, research and development, skills and collaboration.

Research and Development Relief for Corporation Tax gives a taxable credit on research and development expenditure, thereby encouraging greater spending to promote innovation.

Australia

Innovation Voucher Program (IVP) encourages collaboration between small to medium-sized enterprises (SMEs) and research and development organizations to encourage greater innovation within the manufacturing sector. Vouchers up to a value of $50,000 AUS are awarded.

Commercialisation Australia is a government program that offers funding and resources to accelerate the business building process for companies, entrepreneurs and researchers who want to commercialize innovative intellectual property. Funding ranges from $50,000 AUS to $2 million AUS.

Research and Development Tax Incentive program helps businesses offset some of the costs of doing research and development in order to innovate.

Germany

The joint industry and academia Direct Manufacturing Research Centre (DMRC), based at the University of Paderborn in Paderborn, Germany, is a industry-academia initiative that focuses on research that advances AM technologies. The overall funding is Đ11 million over five years.

China

Shanghai International Science & Technology Collaboration funding program is administered by the Shanghai Science and Technology Commission and provides a maximum of $340,000 CDN per project for Shanghai companies that are collaborating with foreign companies.

Investment

3D printing has enjoyed high levels of growth, significant consolidation within the sector (Stratasys recently acquired MakerBot) and more attractive prices for consumers. The winners have been systems manufacturers (3D Systems, Stratasys, ExOne, Arcam, Optomec), suppliers (Concept Laser, Scanlabs, Trumpf), 3D service companies (Solid Concepts, Quickparts) as well as software providers (Autodesk, Dassault Systèmes). These four sectors are currently seeing most of the investment in this space (Morgan Stanley, 2013).

For inventors, researchers or enthusiasts working on new applications, the situation is not as clear, as investors try to distinguish between trends in niche industrial applications and what is happening in the mass market (Morgan Stanley, 2013). The path from research to building an application to commercialization has not been defined. The result is a cautious approach by investors to investing in 3D printing.

It is not new that investors are very cautious in the face of a relatively young, emerging technology, especially if the development could take upwards of 10 years. According to Lipson & Kurman, "if we focus on applications rather than technology, we have a much greater chance of getting this technology adopted" (2013, p. 39). An example of a company that has approached investors as a service organization, rather than as a technology-based platform, is Shapeways, a US company that successfully raised capital from investors such as Lux Capital and Andreessen Horowitz. The company aims to become the "Amazon of 3D printing" (VentureBeat, 2013) through its service focus. Shapeways has been able to create a strong community, a clear service model and factory footprint (VentureBeat, 2013).

Crowdfunding

Despite the lack of funding from venture capitalists, AM projects, particularly those regarding new and cheaper printers, have been able to raise money directly from potential consumers. Extreme users have used crowdfunding websites such as Kickstarter and Indiegogo to raise funding to start development and jump from inventor/explorer to entrepreneur.

According to Wohlers (2013), three of the top 10 all-time Kickstarter technology projects were for 3D printers: Printrbot, RoBo 3D and Form 1. Formlabs, a Massachusetts Institute of Technology (MIT) Media Labs spin-out and maker of the Form 1 3D printer, gathered more funding from different investors after surpassing its Kickstarter funding goal. Three-dimensional scanners are also finding success on crowdfunding sites: Matterform successfully completed an Indiegogo campaign in March 2013. It is the highest funded campaign outside of the US in crowdsourcing history.

4. Viable business models

While AM has been available for a number of decades it has just recently gained widespread recognition and adoption. As this practice has progressed and improved there is a greater opportunity for individuals and companies to invest in the technology. However, 3D printing is still in its adolescence and it has yet to develop a concrete business model to build off. Jorg Lenz of Electro Optical Systems explains that, "as a comparatively young technology, AM already today raises high expectations. Since AM is not just another technology to replace conventional ones but requires a new thinking in entire business models, progress is needed in various elements of such a chain" (as cited in AM Platform, 2013, p. 21). The following section outlines new business models that have emerged from 3D printing.

Prototyping

Prototyping has long been part of the manufacturing process as there has been no substitute to physically having a product in one's hands and testing it before mass production. Traditionally, prototypes have been designed and molded by hand and the process was commonly outsourced overseas. It is a time consuming process, particularly if numerous prototypes are required before the right one is found.

The advent of 3D printing has brought the rise of a new form of prototyping known as rapid prototyping. Three-dimensional printers allow manufacturers to quickly make and alter prototypes on their own or through a company that specializes in rapid prototyping. The ability to design, produce and test products five or 10 times faster enables designers and entrepreneurs much more creative freedom (Lipson & Kurman, 2013). In fact, prototyping has become the leading use of 3D printers globally, with the automobile and aerospace industries leading the way. It is estimated that prototyping is used in 70 per cent of the 3D printing market and earns approximately $2.2 billion annually (Morgan Stanley, 2013).

Mass customization

Mass customization combines aspects of mass production with the ability to personally customize the product. 3D printing technology has had a large impact on mass customization; for example, a customer renovating his or her bathroom could use a 3D printer to completely customize the cupboard handles on a vanity, down to the size, colour and placement. The handles can then be printed off and installed in a matter of hours. While this process is still in its infancy, it may soon become general practice and expected by consumers. Hamid Mughal of Rolls-Royce, an engine company that has experimented with 3D printing, has stated, "product technology is the key to survival, and manufacturing excellence provides one of the biggest opportunities in the future" (as cited in The Economist, 2012).

However, it is also important to forecast and predict how consumers are going to react to different forms of customization. Some consumers may feel overwhelmed when customizing goods or products such as clothing. By anticipating and suggesting popular combinations or clothing designs, the consumer can have a better experience with the customization process. These combinations can be determined through stylistic reasoning or by looking at past consumer purchases. Further predictions can be made based on the knowledge of certain customer demographics. There may be similarities amongst consumers in similar age groups or levels of income.

The idea of collaborative customization is closely related to mass customization. Collaborative customization occurs when a customer articulates precisely what he or she wants from a product to a particular manufacturer. This collaboration allows the manufacturer to customize a product to suit the customers' needs and expectations (HBR, 1997). The increased use of 3D printing has resulted in an increase in collaborative

customization because some levels of personalization would be unfeasible without the technology. The ability to use digital environments to manipulate goods before they are physically produced increases the chances that the customer can receive exactly what they want.

3D printing and the cloud

The combination of 3D printing and the cloud are two major game changers in terms of manufacturing as a service. Manufacturing as a service refers to the ability to deliver on-demand products through a virtual environment. This process allows individual consumers access to untold numbers of products that could otherwise be difficult to obtain. An article on the increasing use of 3D printing from CloudTimes, an international group of experts on cloud computing, sums up the process well: "Imagine if instead of companies manufacturing parts or products in their factories in bulk and selling it to consumers, consumers can instead just buy said parts of products per piece through a company that will create a single one through 3D printing..." (2012).

In the future, it may not make financial sense for companies to keep large inventories of their products. Instead, their entire inventory can be made available on the cloud and printed off when selected by customers. These items can be kept on a digital file until they are needed. This also eliminates the worry of overstock. Currently, this practice has proved especially useful for hard-to-get items or items that are no longer manufactured such as parts for classic cars or motorcycles. Business models that involve 3D printing are changing the landscape of manufacturing around the world. Countries in which manufacturing is faltering could embrace these models to potentially revive their industry.

5. Other considerations

Price

The outcomes that can be achieved with high-end printers ($1.5 million laser deposition systems, for example) differ drastically from those at the lower end (less than $1,000), including surface finish, build size and the ability to use multiple materials and colour. The price of materials also has an impact in the sector. According to Wohlers Associates (as cited in Morgan Stanley, 2013), thermoplastics used in 3D printing may cost as much as $175-250/kg compared to $2-3/kg for plastics used in injection molding.

Software

Software is not necessarily an enabling tool for mass consumption as CAD software requires training and a particular skill set. The creation of 3D content can thus be a daunting exercise for mass consumers. According to Lipson & Kurman (2013), most modelling software was developed for solid modelling (use by engineers and industrial designers) and surface modelling (used for animations and, more recently, video games). Software needs to evolve for companies to be able to model and print complex pieces, such as components of a robot or electronics. There is an opportunity for developers and vendors to create and sell new suites or add-on modules that can provide the necessary capabilities to deal with complex objects for the enterprise market. For the consumer market, there's no clear path, as modelling software has always been expensive and complex, thus constraining adoption. There is a wide open market opportunity for developers and vendors to release easy-to-use and cheaper solutions. Some companies such as Dassault Systèmes (3DVia), and Autodesk (TinkerCAD and 123D) have already begun this process, developing low-end 3D software packages for use by the consumer market.

Legal issues

Legislation always follows innovation, and the process of adapting old laws to new ecosystems is difficult. There are three areas that could shape the future of 3D printing:

Patent enforcement remains difficult, expensive and even contra-productive in open environments such as 3D printing. One of the key enablers of the sector is the open source approach that members of the community have embraced towards experimenting with the new technology. Extreme users share 3D models, software and even 3D printers (see the RepRap community project), constantly iterating each other's work. It is an innovative space that could be hampered by the use of broad patents (see the discussion regarding Stratasys' patent claim to print chocolate in VentureBeats' article, *The latest threat to 3D printing: Stupid, broad patents*, and the work conducted by the Electronic Freedom Foundation). Patent trolls have already attempted to try to make money out of 3D printing. Former Microsoft chief technology officer Nathan Myhrvold's Intellectual Ventures filed a patent on a system of digital rights management that could force anyone who wants to 3D print certain files to pay a licence fee. Similarly, 3D Systems filed a lawsuit against Kickstarter for patent infringement that, if successful, would allow 3D Systems to stop Kickstarter from allowing fundraising for potential competitors (ITechLaw Journal, 2013).

Copyright issues in the 3D printing realm not only include physical objects but also the digital files containing the information needed to print an object. Currently it is possible to scan objects, such as toys, that are protected under copyright law, print them and even sell them without paying royalties. Furthermore, extreme users are also able to design objects that depict or are similar to well-known objects. This raises questions around copyright ownership of the file. For example, when 3D printing is used to create modified figurines from popular television shows (Thrillist, 2012).

Regulation is also an issue in that production of goods cannot be controlled when printed with 3D printers, such as guns, organs or proprietary toys. It is possible to control the input (files, to a certain extent, and materials). In this context, future regulation may affect printer makers (for example, regulation could prohibit mass commercialization of machines that can print organic tissue) rather than files.

Environment

There is the perception that additive manufacturing is less wasteful than other types of manufacturing, such as subtractive manufacturing, because they don't waste material. The environmental impact of 3D printers, however, is not necessarily lower. According to Lipson & Kurman, "per pound of manufactured product, a 3D printer consumes more than 10 times as much electricity as an injection molding machine" (2013, p. 201). If 3D printing was to scale, and consumers ended up printing objects at home, the volume of plastic waste would likely be equal to traditional manufacturing. Plastic toys, whether manufactured in China or printed by a consumer in Ottawa, would both eventually end up in the garbage.

There are potential environmental benefits of 3D printers. Three-dimensional printers can fabricate products on demand, drastically reducing the need for unnecessary stock inventory and replacing it with digital inventories. Depending on usage, 3D printers can be effective recycling machines. For example, students at MIT are conducting research on the use of biodegradable materials (including crabs shells and wood) and Mcor Technologies, an Irish company specializing in 3D printing, is already commercializing a 3D printer that uses recycled paper and water as materials.

6. Last words

The excitement about 3D printing today is centred on the potential new applications for the technology. The technology is expected to grow exponentially and become a new source of productivity and innovation. Aerospace, biomedical and consumer applications are already being developed, with other verticals quickly joining the exploration. Extreme users are constantly pushing the limits of the technology, searching for new products, applications and business models that could transform the technology into a feature of everyday life. This push is filled with challenges and uncertainties; viability of new applications, legal constraints and environmental impact are already being debated.

The initial intention of this report was to introduce the technology to entrepreneurs and to illustrate how a disruptive technology can transform an industry. After extensive research, discussions with experts and interviews with entrepreneurs, two main points emerged: first, there is a big difference between a technology's potential and its actual usage; and second, the utmost impact of 3D printing technology may not happen in a vertical but rather in the process of developing and selling new products.

Although some participants interviewed for this report consider 3D printing a technology with the potential to replace traditional manufacturing in the production of consumer goods, this substitution seems highly unlikely. As with previous technologies, 3D printing would mature in those verticals where there is an advantage to be gained (either by reducing costs or producing highly customized goods). 3D printing can be a great complement for the local manufacturing industry, which is today in search of higher levels of customization and competitiveness.

Furthermore, 3D printing provides designers and tinkers with a new tool and process to solve problems and create new products. Traditionally, limitations of the manufacturing process (such as the construction of some geometrical figures or hollow structures) have constrained designers. In some cases, a well-designed artifact was one that solved a problem effectively and was easy to mass-produce for a competitive price. 3D printing allows the construction of imaginative solutions and artifacts that may not exist otherwise, solving problems in a novel way. This technology can be the answer to problems for which we do not have a solution yet.

Historically, design can be understood as a continuous copy and refinement process—the same way that Apple's iPod resembles Braun's portable radios from the sixties. Thanks to 3D printing, that process can be accelerated or transformed into a collaborative process. Product design can become an open process, where the usage of products can easily inform new iterations of always changing artifacts based on frequent and fast-paced user feedback.

3D printing is a fascinating and exciting technology that requires skill, knowledge and patience. It is not a simplified process or a democratization of manufacturing. It is a new playground for innovators and only the increased use of the technology will determine its evolution and final adoption.

7. Photo Credits

Aerospace – Clockwise from top left

Airbus320 Nacelle hinge (Source: EADS)
Turboprop No Decals (Source: Stratasys)
Rocket Engine Injector – before and after (Source: NASA)
3D Printers operating inside a simulated gravity environment (Source: NASA)

Health – Clockwise from top left

Prosthetic Arm (Source: Samuel Huron)
Printed heart (Source: Kevin Hand, The Body Shop)
Face (Source: IEEE Spectrum)
Direct metal – dentistry (Source: 3D Systems)
Bionic ear (Source: Frank Wojciechowski)
Prosthetic Limb (Source: io9)

Consumers – Clockwise from top left

3D Printed clothing (Source: EdytaZwirecka)
Cubify Guitar (Source: 3D Systems)
3D Printed Sugar – Custom sugar cubes (Source: 3D Systems)
Nike football shoes cleat (Source: Nike)
Auto Tailight (Source: Stratasys)
Urbee – 3D Printed car (Source: Urbee)
3D Printed rabbit figurine (Source: CreativeTools.se – PackshotCreator – Lisebergskanin)
Ted Noten Chanel 001 Gun bag 2011 (Source: Photography: Atelier Ted Noten / Artwork: Atelier Ted Noten)

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Appendix A: Featured Companies

Anubis3D

Tharwat Fouad

Quick Facts

Year founded: 2005
Number of founders: 1
Number of employees: 8
Top industries served: Short production runs and rapid prototyping for automobile, robotics and end-of-arm tooling, mechanical components, electronic enclosures and arts.

Anubis3D
Design for a New Dimension

Anubis 3D is an Ontario-based company working to take 3D printing and 3D prototyping deeper into the manufacturing industry. The company offers quick product development or prototyping with the use of its advanced 3D printers. Anubis is able to design and create very complex mechanical parts and components that otherwise cannot be made economically with most other conventional technology today.

MaRS Market Intelligence interviewed Tharwat Fouad, president of Anubis 3D.

Can you give us some background information about your company?

Anubis Manufacturing Consultants Corporation is an engineering company. We've been around for about eight years. Our focus has been on providing engineering solutions for the food and bulk handling industries. That spans a whole variety of different things, from plant layout and process control to full skidded solutions where a client has a particular problem and they're looking for a solution. We can help customers anywhere around the globe. We're able to plan, create and fabricate the solution into a predefined skid or a constructed platform that could be shipped virtually anywhere in the world and turn keyed into a plant as an immediate solution to a problem.

In your opinion, what distinguishes Anubis 3D from your competitors?

I'd say a few things, one of which is orientation. Our orientation is to support manufacturer requirements. Our technical background enables us to provide input during the design phase to our customers. We bring in years of experience in industrial manufacturing, plant design and quality control to our additive manufacturing side of the business. We can fabricate parts using nylon, a variant hybrid mix of nylon with aluminum, glass or alternatively with carbon fibre. We're able to get parts that are strong, lightweight, durable and, most importantly, functional at a competitive price.

Can you tell us what industries your clients are involved with?

I can say that in general terms we're dealing with companies across Canada and throughout the US. We're dealing extensively with electronics, automotive, robotics and end-of-arm tooling. We're involved with the design community as well as the education and mechanical markets. We've found ourselves involved most recently in the drone and unmanned aerial vehicle (UAV) area.

So you're actively involved with a large number of sectors and industries?

We are quite diversified and our target is to become the additive manufacturing resource for prototyping and short production runs. The Canadian market is slowly growing as different industries learn and realize how additive manufacturing will change how products are made.

Do you find that potential clients are interested in 3D printing and rapid prototyping?

It's not an easy sell. The Canadian market is a conservative one. There are certainly more aggressive markets around the globe that are more embracing of new technologies. We are going to companies whose typical solution for making a particular part is to take a design, send it to China, wait eight weeks for it to be fabricated and then have it shipped to them. This process has been acceptable to them and they've built it into their cost base. However, sometimes things go wrong. For example, a company can have the part come in and it's been damaged or destroyed in transit and they have a commissioning or pitch session in the next couple days. We've had situations similar to this where customers have come to us and we've been able to take their designs, replicate them in the nylon that we're using as our base material and deliver it to them at about 25% of the cost that they are plowing into a Chinese order.

Could you give us a specific example of a client?

We've been working with a company that invented a solution for network cable repair. Network cables have an end network plug that inevitably breaks off through the course of use. Instead of cutting the end off, rewiring the cable and then going through continuity testing for validating whether or not the cable can be used again, he actually invented a little repair piece that slides onto the end of that cable. It's a consumer-priced product that he started with us from a prototype perspective, and he's taken it right through to production batches with us. We're running thousands of pieces at a time for him, from very modest quantities required to validate his design.

What do you think is next in store for 3D printing?

I was at a three-hour seminar that talked about 3D manufacturing and the main question was, "Is there 3D manufacturing?" Absolutely there is—our client base says as much and they speak with their purchase orders. I think it's really just a matter of time before this particular technology is really embraced in North America. In addition, as the manufacturing processes advance, together with the introduction of new materials, more industries will be interested and will use it as mainstream. I envision that what we're going to see coming down the pipe is much more penetration of the steel or the alloy side of the business, which is currently still a niche market due to the high cost of material, equipment and post processing. It's coming, and it's just another radical step that's going to be introduced into the manufacturing environment.

Bioprinting

Axel Guenther

Quick Facts

Year founded: 2012
Team members: 4
Top industries served: Healthcare

UNIVERSITY OF TORONTO

The Bio Printer project at the University of Toronto explores the possibility of printing soft material with the purpose of recreating tissues such as skin. In collaboration with Sunnybrook Hospital, the project explores the potential treatment of burned patients. The technology is significantly faster and less expensive than other international projects and does not require a moving printhead. The project could have global impact in areas as diverse as cell manufacturing, biopharmaceutical drug development and clinical applications.

MaRS Market Intelligence spoke with Axel Guenther, project lead and a professor in the Department of Mechanical and Industrial Engineering at the University of Toronto.

What clinical applications does the technology have?

We are working on the potential treatment of severe burns with Dr. Marc Jeschke, director of the Ross Tilley Burn Centre at Sunnybrook Hospital, Canada's largest burn centre. We place human cells in these printers and thoroughly characterize the printed tissues. We can form living tissues, skin tissues, but we are not yet at the stage where we can put them in actual patients —that will take us some time.

There are other possible applications. There is huge interest in the area of drug development to explore micro-tissues and various types of tissues for different types of screening applications. It's very different than placing cells on a hard surface, plastic or a dish; we could try to place cells within the soft matrix and mimic the organization of different cell types in the tissue.

There's also this recurring, very important need for generating large masses of cells. Our laboratories employ technicians that work very hard to make cells healthy and to grow cells through a largely manual process. We think we can get a small amount of cells to a large amount faster, which could also benefit patients waiting for tissue.

Tell me about the team

The core team is about seven people with different areas of expertise. Dr. Jeschke is a burn surgeon and also a cell biologist at Sunnybrook, looking at the cellular aspects of this work. Phoenix Ba, in my group, has designed and is currently testing the second-generation bioprinter that we will showcase to the public during an event in April 2014. And of course, Lian Leng, a mechanical engineer who did the original work and who initially had to learn the biological aspects of the process and largely learned it through collaborations.

We collaborated with Dr. Milica Radisic's lab (Dr. Radisic is a specialist in heart tissue engineering at the University of Toronto). The first experiments we conducted were with heart cells. As a team, we were able to demonstrate that this technology could be applied to biological cells and it could also scale. We have an ongoing collaboration with Dr. Radisic on heart tissues.

How important is collaboration for biological projects?

It's impossible to develop this technology in a fast, international and competitive environment as a single research group because there are so many aspects. It combines the materials that surround cells; the design, integration and scalable manufacturing of micro-devices that my lab specializes in; and clinical aspects, so that the gadgets that we create in our labs ultimately have the capacity to actually change a patient's life.

We are quite confident that we have all the things we need in place; we have a group of great people working together and getting close to translating the technology into something that may be clinically viable. It takes a lot of time, it takes a lot of money, it takes a lot of energy, and it is an incredible amount of fun.

We also have support from other groups, such as MaRS Innovation, the University of Toronto Connaught Fund, and the University of Toronto's Innovations and Partnerships Office, which help us with securing intellectual property and executing on a path to commercialization. They have been involved with the project since the beginning and we have frequent meetings with them.

Where are you in the path to commercialization?

We believe the technology can soon be applied to the automated formation of 3D human micro-tissues for automated screening experiments. We are currently working with the first- and second-generation systems (prototypes). The second-generation system has additional features and is intended as a system that we can share with other labs for validation. We already have three of the first-generation systems placed in different research laboratories for more than one year: one of them in our lab, another at Sunnybrook and the third in another university. They are fully functional, and people are excited about this technology.

So, how does it work?

As opposed to conventional printers, this prototype makes a sub-strain so you don't feed any 'paper' in there, and you don't print on top of the 'paper'—it actually makes the equivalent of 'paper'. It would be like creating the paper and what you print on it at the same time. The trick is that while printing we can also change properties on demand.

Tissue engineering researchers are still making coarse, polymer, or other materials that are known to be gentle to cells. And they grow cells into these frames. But it takes a lot of time for the cell to crawl in so it's a slow process. Also, cells are going to be on the surface, rather than being distributed all across the material, and it's very difficult to have a well-defined localization of more than one cell type.

We extrude sheets that have a well-defined composition. It doesn't take several days or weeks for cells to migrate into a sheet. We can form these sheets at a rate as high as one square metre per hour. So material formation is not really the rate-limiting step anymore.

What are your main challenges right now?

Time and money. We have many exciting things to work on but we're focused on a few concrete tissues for now for validation. Our bioprinting technology is a technology platform and, in principle, transferrable to different cell and tissue types. We are testing our second-generation system. We will make it available to other laboratories for evaluation and feedback, and will showcase the printer at a 3D bioprinting workshop in April next year.

How would you describe this technology's ecosystem? Have you encountered any legal or regulatory challenges?

I've seen this in different places and it's never easy. Here in Toronto, we are extremely fortunate to have such a high concentration of scientists, engineers and clinicians in very close proximity. And we have exceptionally bright students that we train at the interface between traditional disciplines. This density and proximity is very unique in the world and a wonderful asset.

In terms of infrastructure, compared to many places, we are quite well supported. Much of our work was performed with the help of unique microfabrication technology available at the Centre for Microfluidic Systems in Chemistry and Biology that was set up with generous support from the federal and Ontario governments. But we need to be able to operate at a comparable level in the future. There is openness and an excellent collaborative culture across disciplines as different as materials chemistry, mechanical engineering and physiology.

Hot Pop Factory

Matt Compeau Bi-Ying Miao

Quick Facts

Year founded: 2012
Team members: 3
Top industries served: Creative agencies, architecture and design, public art
Main products: Custom design, corporate 3D printing workshops and events, interaction design

HOT
POP
FACTORY

Hot Pop Factory is a design consultancy that specializes in creative applications of 3D printing, and uses the technology to make physical goods. The company's work ranges from small objects to art installations as well as software programs. Now the company is transitioning into a consultancy, in which they engage with designers and companies to bring brands or products into the 3D printing world.

MaRS Market Intelligence spoke with Bi-Ying Miao, one of the founders of Hot Pop Factory.

Can you give us some background information about your company?

We started experimenting with the technology, working on 3D models. With a background in architecture, we quickly realized the enabling capacities of 3D printing and decided to explore how the technology could be applied to other fields. By using jewelry as a medium, we tried to establish a bridge between the technology and users, as people tend to have a very personal relationship with jewelry. The idea was to explore how the technology could fit into a user's life in a very relevant and personal way.

Can you tell us about your clients and the industries you're involved with?

3D printing is really hot right now, but it's still in its infancy. How it will be applied by different industries is still

in development. The array of different applications can be observed in the partnerships we've made. We have worked with companies in architecture and design, industrial design and jewelry design. We've also worked with set designers, to create replications of their set designs, and creative agencies who are looking for new and exciting ways to present a brand or a novel way to bring a particular product into the 3D printing realm.

Do you have any trouble engaging with clients or selling 3D printing?

3D printing is everywhere. Almost everyone has heard a little bit about it, but we find that a lot of people don't understand the technology in terms of how it applies to their industry. Everybody is looking for the perfect application. Our challenge is relating the technology to existing verticals, with very traditional set of principles, rules or best practices.

There is a big education gap: everybody thinks that you push a button and the machine spits out your design right away. The process is actually not as simple or instantaneous as the word "printing" implies. 3D printing involves access to a 3D printer which has become much more obtainable in recent years. However, it also requires a 3D model or print file to create a physical object. Unlike a word document, the creation of 3D content requires skills that most people don't have. For us, it's part of our architectural background. For industries that have no experience with it, it's hard to integrate 3D printing if they need to create original content. A lot of what we do is communicating this process to clients in an easy-to-digest way. It's at the forefront of our marketing strategy when we design our beginner-friendly 3D printing workshops and when working with clients.

So that's one of the main challenges of adoption?

I think so. I think there is a popular narrative out there about the future of 3D printing, and desktop 3D printers in every home, but there's a need for a library of 3D models now. You need the file to print. For designers, the focus is in the generation of these 3D models. That's where the value of 3D printing, and our company, comes from —our ability to create really unique designs. It's like MP3s, and how disruptive they were. We're the people who make the MP3s, I guess. We're the people who make the designs that get 3D-printed.

A lot of hobbyists who are really hardcore into 3D printing don't have the skills to make 3D models. There are websites with crowdsourced models where you can go and search for a spatula, for example, and download the files. That's what the consumer market will look like; the industry side of it is where the content is created.

Are we talking about the business to consumers (B2C) type of businesses? In the manufacturing sector, for example, there are familiar practices and use cases that are well established.

Yes. Products are going to change because of 3D printing. Nothing has to be mass-produced necessarily, which means a lot of things can be unique and potentially customized. I could see a vertical of retail where people can choose and customize a particular product and then produce through 3D printing. Whether or not the consumer wants to have something like that, whether the extra cost of 3D printing will be offset by the value of having a customized piece.

There's also the development of applications that will make the technology more available and easier to use, right?

I think some companies are actively pursuing apps and programs specifically geared towards people who don't have any experience in 3D design. I don't see customers wanting to learn 3D modeling, but I can see this realm of software being created, interfaces that make it possible for 3D printing to benefit a wider demographic of people.

How do you see your company evolving? What is your hope?

We are constantly experimenting. I think that's the exciting part of being a member of the 3D printing community right now because so much is up for grabs. The potential is limitless, seemingly, and so our hope is to

keep innovating and coming up with ideas that will make people actually look twice. It's not just an article that they sift though and go, "Oh, another 3D printing article," but things that have relevance in their lives, things that are personalized, things that they're happy to share. As we gain more insight into what the strengths of 3D printing are in our business-to-business work, I think our hope is to search for an application that has real value for the mainstream, something they will really care about.

Hyphen Services

Mark Barfoot

Quick Facts

Year founded: 2012
Number of employees: 15
Top industries served: Consumer and commercial products
Partnerships: University of Waterloo 3D Print Centre
Awards: Advanced Applications of AM technical design competition winner (AMUG Conference, April 2013)

HYPHEN

Hyphen Services is a division of Christie Digital Systems, a visual technologies company located in Kitchener, Ontario. Hyphen opened a year ago to allow outside companies access to Christie's prototyping and environmental testing facilities. It is the only facility in North America with both prototyping and testing facilities under one roof. Hyphen offers a full suite of rapid prototyping 3D printing technologies, such as selective laser sintering (SLS), fused deposition modeling (FDM), Polyjet and stereolithography (SLA).

MaRS Market Intelligence spoke with Mark Barfoot, managing director of Hyphen Services.

What industries are some of your biggest clients in?

It really varies in terms of industries and businesses. Our clients range from small startups to larger corporations like NCR and COM DEV International. As for industries, we're dealing with both consumer and commercial products, including aerospace and automotive, and have lately been doing a few medical prototypes. We have even had artists asking us to print sculptures for them. It's pretty much the full gamut of industry types that are out there.

With the recent hype around 3D printing, do you find that it has been easier to sell your services to other companies?

When we launched we expected it to be an easier sell than it actually has turned out. Here at Christie, we really use rapid prototyping to the fullest, and we just assumed that there were a lot more companies doing it at that same level, just maybe getting it from somewhere else. What we're finding is that not many companies in Canada have really embraced the technology and understand what it can do. As a result, we spend time explaining the various technologies to our clients and assuring them that we are providing them with parts that will suit their application and budget. By taking the time to do this, we get return customers that expand their use of printed parts to other projects.

What are some of the other challenges Hyphen has had to deal with?

Hiring has been a challenge. It's hard getting staff who understand the technology. There are few in Canada that have the training. We currently have a posting for a sales rep position, but trying to find somebody that has any sort of relevant experience is a challenge.

Another challenge is that there's a lot of media hype out there about 3D printing, but it's very hard for people to actually understand what they are purchasing. It's hard for people to distinguish between a company like ours that has a wide range of industrial grade machines from someone that has a small entry-level machine in a garage.

The other issue we sometimes have with the machines is getting service technicians into the country, because there are very few people available in Canada to service them. We've had problems getting them across borders to work in Canada.

Are your clients mostly from Ontario or across Canada and the US?

I would say at this point that a major portion is from Ontario. However we're starting to see more and more requests outside of Ontario as we get our name out there among the other provinces. We're also now getting quite a few requests, especially over the last few months, from the US.

How do you see Hyphen evolving? Where do you hope to see it going in the future?

Hyphen will continue its growth by increasing its machine capability. A good example is that we're in the middle of evaluating whether to add metals technology (DMLS), where we can actually and truly print parts out of metal to render an aluminum, titanium or stainless steel part. This technology is a game changer, because you're able to do things that before were only ever done by computer numerical control (CNC) machining.

Do you do any work in bioprinting, prosthetics or medical printing?

At this point we don't have any bioprinting technology but we do have a few clients in the medical field. Christie has its own medical products group, so we've printed parts for its products. We've also done a few other small instrument prototypes, as well as some prosthetics and medical visualization models. I definitely see this being a potential area of growth for Hyphen, especially if we add the metal technology.

What are some of the major advances or changes that you're noticing in the sector?

With the media hype there is a lot more awareness of 3D printing. There are a lot of people out there quoting the low-end 3D printing machines. I've seen people advertising that they do 3D printing and all they have is essentially a thousand-dollar printer in their garage. That's not really the same as what Hyphen or some of the other larger service bureaus that are around do. The media is building awareness and aiding people to understand it a little more, but there's a lot of misinformation out there. Some media say that everything is going to be 3D printed in the next four years. That's not really going to be the case in my opinion.

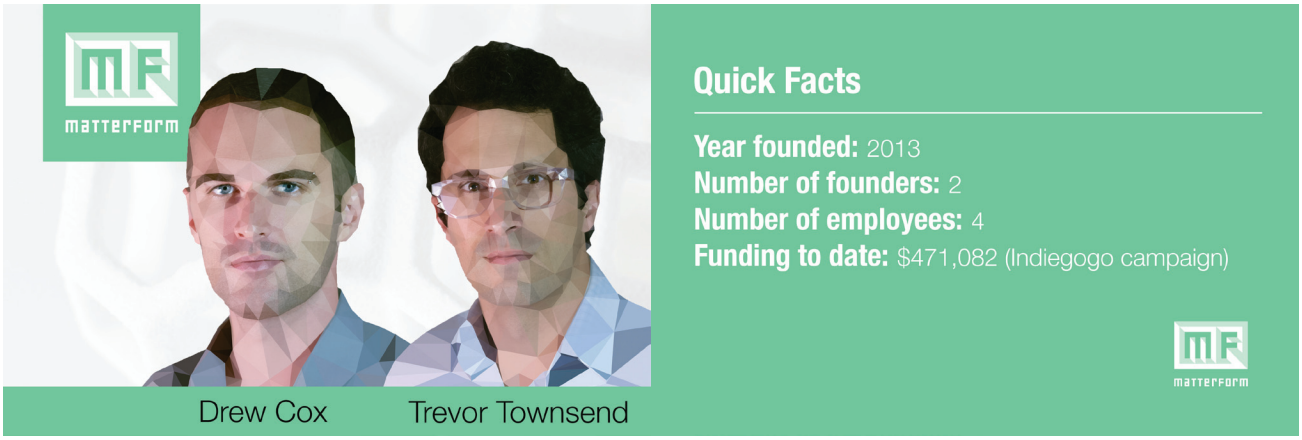
And why do you think that?

You just can't replace an injection-molded part that is built in seconds with a 3D printed part that will take from four to 48 hours to make. The $2,000 machines that are out there currently can build some basic parts. However, their surface finish isn't great and they are very finicky to use. Unless you really are somebody that likes to tinker, you're not going to keep those machines running. From a commercial standpoint, the part quality is in no way comparable to a high-end machine. There is also the size limitation to consider. Typically, the current machines of that size have a five-by-five-by-five-by-five build area, which is fairly small, and so your part size is limited.

The other issue is: how do you get the computer-aided design (CAD) model? If you don't have a CAD package, how are you going to get a model? Yes, you can scan it but scanning is not as easy as some make it sound. It takes time to scan it, but it also takes a lot of time to manipulate the scanned data to obtain the final, good data that will build a quality part.

I think there are a lot of things that need to be done to get everybody to use 3D printing. A lot of people can't get their microwave to work, let alone would be able to have and operate a 3D printer next to their toaster. I don't think that's going to happen. Some talk about using it to make replacement parts, so if something breaks you can replace it. Well, there would have to be a huge mind shift in industry because most manufacturers aren't going to post the model of their broken parts. That's where they make money, from the service parts.

Matterform



Matterform is a Toronto-based company that designs and develops new products in the 3D scanning and printing space. Its main product is an affordable 3D scanner designed and developed by the company. The scanner offers quick, high-quality scanning of real-world objects for use in many applications including printing, 3D animation, research, archiving and games. Users can take a physical object and turn it into a digital 3D model on a computer using the scanner, which is compatible with all 3D printers and online 3D printing services.

MaRS Market Intelligence spoke with Drew Cox, co-founder of Matterform.

Can you tell us about the background on the company and how Matterform came to be?

My partner, Adam Brandejs, and I originally founded the company. The idea was based off of a project that we were doing last year. We started making our 3D scanner around September of last year and within a couple of months we had a product that we thought we could open a business with. We founded the company in February 2013 and opened an Indiegogo campaign in March to raise the capital we needed to continue the business. It did really well. We were the highest funded campaign outside of the US in crowdsourcing history. After the campaign closed, we continued developing the 3D scanner, which is our one and only product at the moment. We're about to start producing the final production of the units and are preparing to ship them out before the end of the year.

What do you think allows Matterform to stand out from your competitors?

When we started, there weren't really any competitors at all. Now we're competing with the likes of MakerBot but there are some big differences between them and us. Our scanner is the cheapest one on the market right

now at USD $579. The next lowest cost 3D scanner before we launched was about $5,000. We're almost a tenth of the price. We have the same, if not better, accuracy than some of the scanners that are out there right now, like MakerBot's Digitizer and Kinect. We're also different because we made it from the ground up. To be honest, we have found that there really isn't a lot of competition. It's all sort of in the professional field and they're all selling expensive $20,000 scanners.

Can you give us an idea of the clients or industries you are working with?

We designed the product originally for consumers and everyday kind of people that were interested in trying something new. We call them hackers or makers. It turned out that there was a market there, but that wasn't really where the largest amount of people were interested. Our largest market ended up being in the science and research and development fields. There's everything from orthotics, dentistry, archeology and architecture to paleontology and entomology. There's a whole bunch of interest from all sorts of different regions and they're spread out pretty widely, but mostly in the science and research field.

Could you tell us how these clients or companies are using your scanner?

We built it for ourselves originally and our intention was to give you the ability to scan something that was organic and then be able to reproduce it and print it out on a 3D printer. Since then, there has also been all sorts of interest in the archiving of objects. Our scanner allows people to save objects three-dimensionally without any damage to the original object. Overall, our market varies quite heavily, from a guy who wants to scan his daughter's clay sculptures to a PhD student who is looking to scan topographic surfaces for a mathematical algorithm.

Are there any other ways you hope clients or companies will use the scanners in the future?

I hope people are going to use it in a way that surprises me and that I haven't thought of yet. I think they're going to play with it. I think they're going to try to find new ways to use it. There are definitely the applications that we talked about, like archiving, that are going to be big. The need for 3D content is going to grow in the coming years with the influx of 3D printing as an industry and the increase of manufacturing in Canada. So 3D content is going to be a big driver, and I think we're going to be able to help supply that. That'll hopefully be how people use it.

Has your company run into any legal issues while developing your scanner?

There are legal issues around the idea of trademark infringement when someone is scanning and reproducing a trademarked object. Like if you want to reproduce a Disney Mickey Mouse object or something, that's infringing on Disney's patent. Creating a tool like ours that allows people to scan objects raises questions in terms of "where do we stand morally?" and "where do we stand legally?

Have you noticed any major trends that have occurred in 3D scanning in the last couple of years?

The computational power of a normal person's computer has gone up exponentially. The other day I was talking with a senior vice president of engineering at a 3D scanning company that's been around for 15 years scanning automobiles in manufacturing. He was telling a story about how when he started, it would take 45 minutes to an hour and a half to do the same processing that I do on the fly with our scanner. In terms of speed and the ability to compute, it's pretty good. As 3D printing increases, hopefully we'll find some better solutions for manufacturing other than plastic. That's tough to say, because it really depends on what people do with the 3D printers when they start experimenting with it.

morro images

Tobias Wiegand

Quick Facts

Year founded: 2009
Number of founders: 1
Number of employees: 5
Partnerships: Generator at One
Awards: Best in Show - Hard Lure (ICAST, 2012 & 2013)
Best Animation - *StrAngel* (Catalina Film Festival 2013)

morro images

morro images Inc. specializes in two fields that are central to the entertainment industry—visual effects (VFX) and 3D computer animation. The company also works in the product development space, which uses state-of-the-art 3D scanners and printers.

MaRS Market Intelligence spoke with Tobias Wiegand, president of morro images Inc.

Can you give us a bit of background on your company and how morro images came about?

After finishing my studies at a film school in Berlin, I started a company in Germany in 2004, which specializes in 3D animation and visual effects for film and television. We had a good start from the very beginning and made a name for ourselves there. In 2008, we joined forces with another company in Berlin to increase our base of operation and we became "morro images Inc". At the end of 2008, I came to Canada. morro images was incorporated in 2009.

What do you think distinguishes morro images from some of your competitors?

First and foremost, it's the diversity of expertise that we have. We utilize the same tools that any animation, visual effects or product development company would use, but we cross-pollinate our talents. I think that's where we set ourselves apart from the rest. We are knowledgeable in animation. We are knowledgeable in VFX. We are knowledgeable in advanced manufacturing. Our knowledge continues to grow rapidly so we stay on the cutting edge.

Could you give us a couple of examples of how your clients use your services?

On the product development side, we are working with Koppers Fishing and Tackle. We've been assisting its development process since 2010 and have had consistent and great success.

There's a prestigious trade show in the fishing industry called the International Convention of Allied Sportfishing Trades (ICAST), and the association that runs it, gives awards to the most innovative, creative and best performing new products. You could say that it's comparable to the Oscars so it's very important! For two years in a row, the products that we helped design, and subsequently submitted for consideration at ICAST, have won the "Best in Show Award" in the category of "Hard Lure".

On the visual effects and entertainment side, we created our own 17-minute short film, called StrAngel. It's a fully animated 3D feature film, developed entirely in-house. It has toured around the world and been picked up by quite a few film festivals. StrAngel was invited to the Cannes Court Métrage in Cannes, France and the Catalina Film Festival in California, where it won the "Best Animation Award".

What challenges has morro images encountered?

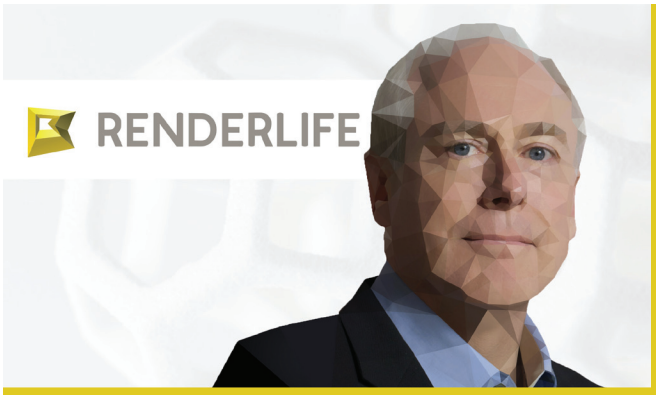
One challenge we deal with is that companies today are more and more competing based on price alone. Unfortunately, quality is not always the prime factor for clients. I think the best route is always to try to develop your own product. Develop your own intellectual property and try to get that to a market. If you can find people that are interested in it and who will purchase that product, you will be successful.

On the entertainment side—or the 'cultural side' of the company—there are always financial challenges. Unless you apply for government funding or grants, you have little chance to make a cultural product, such as a film or game, and bring it to market. A private investor, who needs to invest a substantial amount into your project, is basically a requirement! Culture is difficult to fund and sell, particularly in hard economic times, yet it's a very important part of our lives. In our discussions with the Canadian government, we have seen that culture funding comes up short and is especially noticeable with their various funding reductions.

In the last couple of years, have you noticed any major trends or changes within this sector?

Entertainment content has actually become increasingly common. Additionally, the trend is going towards cheaper and quicker labour. In the advanced manufacturing field, printers and materials are cheaper. The materials are also getting better and the quality is rising. There are amazing new print materials—you can print glass, steel, chocolate, whatever you want! In the end, these are all just tools to get your ideas out and, ultimately, it does all come down to the idea. It's exciting for us that technology is advancing in a way that gives us the flexibility to choose our materials and tools. I'd like to add that while everybody seems to be very fascinated with 3D printing technology, and you can own the nicest 3D printer in the world, one still needs to have good ideas and the skills to create content with it, or that printer will never be put to use. Technology generates opportunities for people who have the talent to create and the skill to use these tools. Not everyone can do that!

RenderLife



Chris Cawston

Quick Facts

Year founded: 2012
Number of founders: 2
Number of employees: 9
Top industries served: Design, advertising, film and TV
Number of images in catalogue: +500

RENDERLIFE

HotRenderLife is a marketplace for "stock" assets, or 3D high-quality production-ready type of images. The company provides 3D art to professionals in the design, advertising, and film and television industries, who need mid and background images for their work. A curated shop of assets, RenderLife not only provides license images, it also helps artists sell their own work through its platform. A successful Toronto-based enterprise, the company is already exploring opening a segment of the marketplace for printable assets, which are images that are suitable for 3D printing.

MaRS Market Intelligence spoke with Chris Cawston, CEO of RenderLife.

Can you tell us about the background of the company and how it came to be?

We got started a little over a year ago. Jeff Mann, one of the co-founders, was running a design studio, working with 3D assets. He couldn't get his hands on any reliable stock assets and was stuck creating everything from scratch every time. When a client contacts you, for example an auto company that wants you to show off one of their vehicles, you put that vehicle in a setting with buildings in the background, people, trees and so on. Ads are often tailored for local markets so the ad for San Francisco might have the Golden Gate Bridge in the background while an ad for the Toronto market might show the CN Tower. Building these images every time is both time consuming and expensive. In other mediums, such as 2D, professionals rely on services like Getty Images to source these stock images. As 3D continues to grow, there will be a great market for these stock assets to enable 3D productions.

So what was the solution?

Jeff came up with the idea of a marketplace for quality assured, production-ready stock assets for professionals who are in his type of profession. He approached some folks, capital type, and pitched the idea. They found it interesting but wanted somebody else to be involved, someone with a track record of starting and building businesses. They contacted me and explained that they'd be willing to put up the money if I was willing to go in as CEO so I joined the project.

It's important to understand what drives our market and what problem we are trying to solve. All participants in the commercial 3D space, whether they are content creators or consumers, are concerned with creativity, deadlines and profit. The good news is that the 3D space is full of talented people who are passionate about what they do, and enabling technology is fabulous and advancing rapidly. The bad news is that the business

models are still immature. One example is the lack of an efficient marketplace for 3D assets. Content creators are forced to create virtually every asset they need from scratch, costing them valuable time and money while limiting the opportunity for content owners to monetize the 3D assets they have already invested to build.

RenderLife is a transparent, curated, quality assured marketplace for 3D assets. An efficient marketplace will remove friction and increase profits for current participants and will also help to increase rate of growth and the overall size of the 3D market.

Let's talk about your challenges. What keeps you awake?

We are getting our funding from various groups here in Canada, but it's too shoestring for what we need going forward. I think there's a high probability that we'll end up getting some future funding from the US to get us to the next level. Over the next few years, the market will gravitate to the best source and services for stock 3D assets. We will be that source.

What are your next steps?

We're building an inventory of stock assets and some of those assets would be suitable for 3D printing. 3D stock images need to be 'watertight' to be printable: images require smooth field surfaces on all sides to be printable and a lot of assets that are created for image-only purposes today don't meet that criteria. There are various standards to make assets printable, and there are different ways of making those standards happen—some are manual, some are automated. There are different applications available to make the transition but there is not enough of a market yet for us to make the investment. However, we see standards starting to narrow down and now we can see which direction the market is moving.

That's the strategy then?

I think that as the market evolves, it certainly will be. There are quite a number of segments to the 3D printing market including manufacturing and prototyping, which is related to manufacturing, and others. But there's also going to be a hobbyist market, a consumer segment. I don't think it's just a strategic decision; there's actually a pretty well-sized market segment that's going to evolve out there, as people get used to the idea and start seeing the opportunity that the application provides them. It's not a big market today, but I think that will come along fairly quickly. Yes, it is strategic, but I think it's also going to turn into a growing and profitable market segment.

I guess this is coming from looking at the market and seeing new opportunities, like 3D printing growing?

The use of 3D assets in all sorts of applications such as film, television and advertising is growing rapidly. 3D assets offer huge advantages over traditional 2D media, like flexibility and the ability to do things you just can't do with the 2D medium. The market is realizing that the technology is coming along, adoption is coming along and it's growing at a much faster pace than other segments.

I guess the bottom line is that this is a very meaningful market already, and that will grow quite rapidly over the next few years. I like the fact that we are the first into this space, going after what I would refer to as the 'production-ready' asset segment. I'm also really excited about the talent that we've been able to attract; it's really world class. The technical people that we've got have won two Academy Awards and worked all over the world. They've worked in Los Angeles, New Zealand, London, and we've got them so I'm happy. The challenge that we've got now is just getting to scale.