3D Printing As A Consumer Technology Business Model

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ABSTRACT

Although the technology for 3D printing has been around for more than three decades, its full potential is just beginning to be realized in the business world. Ideas for 3D printing run the gamut from the hobbyist printing jewelry and toys to the medical industry researching 3D printing of human organs. One way businesses are utilizing 3D printing is through support services within their own business processes, referred to in this paper as a consumer technology business model. As with any emerging use of a technology, legal and ethical issues will arise. This paper shows how 3D printing has evolved, why businesses are realizing the strategic potential for 3D printing to create a competitive advantage using a consumer technology business model and why this could raise legal and ethical issues associated with existing laws related to the use of 3D technology.

Keywords: 3D Printing, 3D Technology, Consumer Business Model, Technology Business Model, Support Services, Intellectual Property

INTRODUCTION

Our technology-enhanced world appears to be advancing exponentially. Businesses are already considering the use of drones for product delivery (Barr, 2013; Frey) that may be transported across the country by remote-controlled airplanes (Ross, 2011). Will the future also bring the capability for consumers to build their own products at home? Hod Lipson, a professor at Cornell University and co-author of the book, "*Fabricated: The new World of 3D Printing"* (Lipson & Kurman, 2013) seemed to imply the possibility when he was being interviewed by the New York Times and spoke of being able to print a robot that could walk itself out of the printer fully functional, batteries and all (Hansell, 2007). The possibilities are endless.

When Gartner (2013) listed 3D printing as one of the "Top 10 Strategic Technologies for 2014," it signified the impact 3D technology is making in today's business environment and for the future. The technology behind 3D printing has been used for more than 30 years, (Bradshaw, Bowyer, & Haufe, 2010) so why is it now being recognized as a "strategic technology?" Gartner (2013) explains that a "strategic technology" can be one that already exists, but, for a variety of reasons, might now help a business become more competitive. The authors illustrate how this technology is being used strategically by exploring 3D printing from a consumer technology business model and emphasize the importance of the impact current laws may have on the model.

Previous research provides many examples of industries that are benefiting or could benefit from the use of 3D technology. These industries include product design, education, manufacturing, fashion, science, architecture, medical and pharmaceutical businesses (Dimitrov, Schreve, & DeBeer, 2006; Marcoux & Bonin, 2012; Giller, Azzolino, & Davidson, 2012). Additionally, there is existing research that provides many examples of the ways companines are using 3D printing technology within their business model as a competitive strategy. These include customization of products, product design, rapid prototyping, and creating small numbers of specific products, which may also be called "short-run manufacturing" (Giller et al., 2012; Vinodh, Sundararaj, Devadasan, Kuttalingam, & Rajanayagam, 2009; Gartner Newsroom, 2013; de Jong & de Bruijn, 2013). While previous research provides important examples of how businesses are using 3D printing, this research focuses on ways companies in general might use 3D printing technology through re-engineering their current business model, allowing them to decrease costs and, therefore, increase their competitiveness in the market.

Businesses can create an enhanced consumer technology business model by adding 3D printing as a support structure to their existing business processes. Principle features of the support structure model include printing replacement parts and offering customers the ability to download 3D printable files for their products' replacement parts. Customers could then print them in their own home if they own a 3D printer or at a business that offers 3D printing and delivery services. The specifics of this enhanced business model will be discussed throughout this paper. The criteria that the authors believe has led to the development of this consumer technology business model includes decreasing cost trends of 3D printers and the foresight of businesses to re-engineer existing business practices from a support service perspective. Each criterion is discussed in detail in the following sections.

Lastly, when a technology gains popularity in strategic and competitive ways, questions naturally arise about the ethical and legal uses of the technology. Therefore, it is important to discuss the implications of current laws and court cases that pertain to 3D technology.

BACKGROUND

3D Printing Methods

3D printing methods are certainly not new; the technology has been in existence since the 1980s. The three most common printing methods used in 3D printers today are fused deposition modeling (FDM), selective laser sintering (SLS), and Stereolithography (SLA).

Fused Deposition Modeling (FDM)

Fused deposition modeling was developed in the late 1980s by S. Scott Crump (Crump, 1992) who cofounded Stratasys, a company that would later commercialize the process in the early 1990s. The idea came out of Crump's work using AutoCAD and CNC mills and, thus, this type of printing was built to use the same concepts as a CNC mill. FDM is an extrusion deposition method where a material in the form of filament wire is fed through an extrusion nozzle. The nozzle heats the material and a series of motors control the position of the nozzle to move it across a building platform on the X, Y, and Z axis. FDM printing has more recently become a popular method of consumer 3D printing due to the expiration of key patents and adoption amongst hobbyist groups (Banwatt, 2013).

Selective Laser Sintering (SLS) and other binding technologies

A second method of 3D printing employs the use of lasers to bind a granular material into a solid. This method was patented by Joseph Beaman, James Darrah, and Carl Deckard in 1986 (Beaman, Darrah, & Deckard, 1986). In this process a layer of the granular material is spread across a bed where the laser moves across the bed fusing the first layer together. Once complete, the bed lowers and another full layer of the material is spread across and the process repeats itself. This process does not suffer from the restriction of needing support material like the FDM process and also has a wider range of the materials available to print with including metal. The binding process has also been developed to be used with inkjet printers and binding agents rather than lasers allowing for full-color prints (PolyJet Technology, 2014).

Stereolithography (SLA)

Stereolithography, which was invented and patented by Charles Hull in 1984 (Hull, 1984), is a process of curing a liquid resin into a solid using light exposure. A bed is lowered into a vat of the resin and a projector displays each layer of the print onto the bed which slowly rises out of the vat. This process requires little support structure and can be very high in resolution. The SLA process is credited as the true birth of 3D printing in the 1980s and Charles Hull would later co-found 3D Systems (A Brief History of 3D Printing, 2014).

3D Printer Manufacturers

Soon after the development of several types of 3D printing methods, companies started designing and manufacturing 3D printers for the various types of 3D printing technologies. A brief history and description of several companies are provided in the following paragraphs.

Stratasys provides 3D printers, materials and applications for several different types of industries, including aerospace, dental, medical, architecture, automotive and education (Stratasys for a 3D World, 2014). Stratasys went public in 1994 (Stratasys, Inc. Announces initial Public Offering of 1.2 Million Shares of Common Stock, 1994) and offers a wide variety of 3D printers using several different methods. In 2012 they merged with Objet (Stratasys and Objet Complete Merger, 2012), a very popular professional line of printers using the SLA method and UV light. In 2013 Stratasys purchased MakerBot Industries, one of the most popular consumer printer companies, for $403 million (Stratasys and MakerBot Complete Merger, 2013).

Co-founded by Chuck Hull who invented early 3D printing in the form of stereolithography, 3D Systems covers both consumers under its "Cubify" brand, professionals with their ProJet line, and variety of high-end printers for production that are used in a variety of industries. 3D Systems is a closed-source company that holds key patents in the industry. In November of 2012 they filed a lawsuit for patent infringement against Formlabs, a Kickstarter-funded printer that used the SLA manufacturing process (3D Systems Announces Filing of Patent Infringement Suit Against Formlabs and Kickstarter, 2012).

The RepRap project (which stands for replicating rapid prototyper) is an open source group that designs printers using additive manufacturing (Ecker, 2011). The group has designed four printer models but hundreds of variants exist and several companies including MakerBot and PrintrBot were built on the early success of the RepRap project.

MakerBot Industries was cofounded by Bre Pettis, Adam Meyer, and Zach Smith (who was previously a founder of the RepRap Project) (Jepson, 2007). Born out of the idea of making a consumer version of FDM-style RepRap printers, Makerbot unveiled their first prototype, the Cupcake CNC, at SXSW in 2009. The company remained open-source until Fall 2012 when they announced their most recent line of printers, the Replicator 2 and 2X (Pettis, 2012). In 2013 they announced and began selling a 3D scanner. They were bought by Stratasys in June of 2013 and continue to run as a standalone unit within the company.

Printrbot is one of several Kickstarter success stories that have sprung up in recent years. Brook Drumm unveiled a $500 kit for a 3D printer based on the RepRap project with a goal of raising $25,000. He would close out the project raising $830,827 turning a hobby machine into a full-fledged business. Today Printrbot sells four models, the Printrbot Simple, Printrbot Junior, Printrbot, and Printrbot Plus. The low cost nature of these printers has led to their popularity and Printrbot continues to sell both kits and assembled machines for between $300-$1,000 (Printrbot, 2014).

Another Kickstarter success, Formlabs unveiled their Form 1 3D printer as a Kickstarter project with a unique design and low cost. Of particular interest was that this was an SLA printer of which few consumer versions existed. The crowdfunded project raised 2.9 million dollars, a record for a tech project on Kickstarter at the time. They recently raised $19 million in a Series A funding round (Formlabs Announces $19 Million Series A Round to Disrupt 3D Printing, 2013). In 2012, Formlabs was sued by 3D Systems for patent infringement but production of their printer continues to move forward (Flaherty, 2012).

Cost trends of 3D printers

In the past 30 years since the invention of 3D printing processes, the market cost of 3D printers has been on a steady decline. There are a number of reasons for this decline. Competition in the market has led to more competitive pricing. Where initially a small handful of companies were producing these machines, with the emergence of open source 3D printer designs there are a large number of companies that produce 3D printers at a much lower cost (RepRap, 2013; Stemp-Morlock, 2010). The expiration of key patents around the use of fused filament deposition allowed for these open source designs to flourish.

The FDM method of printing is one of the most popular methods of 3D printing today due in large part to low cost barrier to entry. Indeed companies that historically marketed and priced their products in high-end industries have expanded their portfolio to market to the home consumer and small businesses with low-cost printers. Stratasys bought MakerBot, a well-known producer of low-cost FDM printers, to expand their market reach in this pricing tier and 3D Systems produces a "Cube" line of printers in the sub-$3000 range. As technology matures and competition in this space continues to diversify, the cost of 3D printing will continue to adjust creating an affordable entry point for the home consumer and expand the prevalence of this technology making the inclusion of 3D printing within a business a viable and cost-effective option (Marcoux & Bonin, 2012). Table 1 presents data showing the pricing trends of 3D printer manufacturers over a period of several years. Even though the data shows dissimilar prices between companies, it proves the point that prices for 3D printers have lowered vastly since the 1990's.

Table 1 Product Pricing Over Time

Company	1992	1996	2000	2005	2009	2010	2011	2012	2013
Stratsys	3D Modeler $130,000	Genisys $50,000	Dimensio n $30,000					Mojo $10,000	
3D Systems				Spectrum Z510 $50,000					Cube $1,390
Makerbot					Cupcake CNC $750	Thing-0-matic $1,299		Replicato r $1,799	Replicat or 2 $2,199
Printrbot							Printrbot $499	Printrbot Jr $399	Printrbo t Simple $299

Note: Table 1 information obtained from the following sources: (Stratasys, Inc. History; Stratasys Gets Its Mojo With New 3D Printer, 2012; 3D Systems Unveils Next-Gen Popular Cube Consumer 3D Printer, 2013; Kraft, 2009; Pettis, Introducing The MakerBot Replicator™, 2012; MakerBot® Replicator™ 2 Desktop 3D Printer Sets New Standard, 2012; Meet Our Alu Extruder, 2014; Drumm, 2011; Printrbot, 2014)

BUSINESS MODELS

There are copious existing business models that provide 3D printing services using sophisticated 3D printing technology. One type of business model specializes in 3D prototyping products for other companies. A second business model, similar to the first, is used for "short-run manufacturing" in which a client company only needs a very small number of a product over a period of time (Gartner Newsroom, 2013). It would be cost prohibitive for a company to buy a 3D printer to create a product when only a few are needed, such as products used for special one-time events. A third business model is the retail 3D printing store where customers can pay to print their own designs when they don't have 3D printers of their own. This business model is similar to the business model for commercial 2D printing services. Some 3D printing services business examples include MakerBot, The 3D Printing Store, and GetPrinting3D.

The business model the authors believe is viable for existing businesses and future businesses relates to using 3D printers for support services within existing business models. What makes it so flexible is that it can be incorporated into diverse types of businesses, including the ones mentioned previously. The model would primarily involve businesses printing replacement parts and providing the same capability to their customers in suitable cases.

The benefit of this model is that it provides a general capability that can be incorporated into diverse companies in different ways. As shown by the examples in Table 2, this type of business model is already in use by several different companies. Some examples from Table 2 include replacement parts for musical instruments, parts for very sophisticated machines such as fighter jets, replacement parts for consumer devices and replacement parts for obsolete products that may no longer be supported by the original manufacturer. Consumers and businesses are seeing the financial benefits by cutting costs from not having to order parts from a third party supplier, and convenience benefits through the ability to print the part anytime and anywhere a 3D printer is available. Possible future capabilities are also included in Table 2, such as consumer manufacturing of entire devices and taking 3D printers on space flights for maintenance and repair operations.

Table 2 Examples Of The Use Of 3D Printers As A Support Service

Company Or Category	Type Of Business	Use of 3D Printing as a Support Service
Teenage Engineering	Maker Of A Synthesizer	Posted the 3D design files of various components on digital object repository and is instructing 3D printer-equipped users to print them out instead of buying them (Dayal, 2012).
Openmoko	Open Hardware Phone	The CAD files are available so that others can customize the case for the phone (Main Page, 2013) .
Raf Tornado	Fighter Jets	Company is using 3D printing technology for the first time. It is hoped the technology will cut the RAF's maintenance and service bill by over £1.2m over the next four years (RAF jets fly with 3D printed parts, 2014).
Thingiverse	Repository For Sharing User Created Files	Includes many examples of replacement parts available on the Thingiverse (Replacement Parts, 2014)
Nasa	To Print Needed Items During A Spaceflight	The toaster-sized printers would allow astronauts to create tools, spare parts or supplies needed during a spaceflight. NASA expects to launch the first 3-D printer into space in the fall of 2014 (NASA to launch 3-D printer into space to create tools abroad, 2013).
Loudspeaker	Consumer Electronics	The achievement suggests that 3-D printing might soon be mature enough for people to manufacture complete devices on demand (Charles Q. Choi & Txchnologist, 2013).
Cad Drones	Open Source Community	This open source community offers information and resources for people to find CAD designers and 3D printing companies that can provide replacement parts for hobbyists and commercial drones. (Sayej, 2014)
Parts2Print	Replacement Parts For Consumer Devices	For example, 3D printing a replacement hinge part for a vacuum cleaner (Dyson DC25 Repair by 3D Scanning, GeoMagic Fix and 3D Printing a replacement Tool Catch, 2012)
Obsolete Parts	Working With Products That Are No Longer Supported By The Original Manufacturer	Redesigning original parts that are no longer available. For example, Jay Leno redesigned an original heater for a 1907 White Steamer. (Leno, 2009) Printing a stock pattern collar adapter for a 20 year old power tool Bosch 1611 (Cochrane, 2014)
Home Consumers	Product Repair	Examples: (Cochrane, 2014) Replacing a plastic fitting on a car luggage carrier Creating an adapter for a bike rack to attach a rear light Printing replacement snaps and clips

The replacement part business model is further enhanced by the decreasing costs of 3D printers as previously shown in Table 1. Because this model is a viable and cost effective option for many businesses, it will likely continue to grow and adapt to other areas for the following reasons: the quality of 3D printing is improving all the time with better printers being designed and manufactured, the types of materials available for 3D printers are expanding and the availability of 3D printing devices from different manufacturers is continuing to grow as costs continue to decrease (Chavez, Molitch-Hou, Horne, Park, Sher, & Taylor, 2014).

Even though this model seems to be a fairly simple solution for decreasing costs and increasing a company's competitive advantage, it does not come without risk. Many laws and court cases already exist that directly relate to 3D printing technology. Specifically, patent and copyright laws are two areas companies need to pay close attention to when incorporating 3D printing into a business environment.

LEGAL CONSIDERATIONS

"A copyright is a right against the world. Contracts, by contrast, generally affect only their parties; strangers may do as they please, so contracts do not create 'exclusive rights'." (ProCD, Inc. v. Zeidenberg, 1996, p. 1454) This means that third parties may become embroiled in an IP lawsuit, whereas in a contract dispute the third-party is not liable on a dispute between the two contracting parties. For example a contract dispute between the manufacturer and the consumer will not extend liability to the online service provider, unless there is some legal theory that brings the third party into the dispute, such as an implied warranty, etc. For example, in *Grokster* (Metro-Goldwyn-Mayer Studios, Inc. et al. v. Grokster, Lted., et al. , 2005), third parties may also be brought into a patent dispute between the patent holder and the direct infringer, on the theory of contributory infringement. For a third party to be liable for contributory infringement, the court must find that there is actual direct infringement and that the contributory infringement rose to the level of some "inducement".

> In referring to a party that 'induces infringement,' this provision may require merely that the inducer lead another to engage in conduct that happens to amount to infringement, i.e., the making, using, offering to sell, selling, or importing of a patented invention. See 35 U.S.C. §271(a).On the other hand, the reference to a party that 'induces infringement' may also be read to mean that the inducer must persuade another to engage in conduct that the inducer knows is infringement. Both readings are possible. (Global-Tech Appliances, Inc., et al., v. SEBS S.A., 2011, p. 2065)

Conversely, the direct infringer's intent is irrelevant. "Direct infringement has long been understood to require no more than the unauthorized use of a patented invention" (Global-Tech Appliances, Inc., et al., v. SEBS S.A., 2011, pp. 2065, n2), see *Aro Mfg. Co. v. Convertible Top Replacement Co.*, 377 U.S. 476, 484(1964); 3 A. Deller, Walker on Patents § 453, p. 1684 (1937).

3D printing related lawsuits may also draw in "third-party" litigants other than the manufacturer and the consumer. Some businesses that host and distribute 3D designs or 3D printer related products online may find themselves named as a defendant in a lawsuit. Thingiverse and Shapeways will obvioulsy fall into this category, yet other firms such as eBay and Kickstarters may also be subject to a potential lawsuit, or take down notice, involving a patent or copyright issue.

The Digital Millennium Copyright Act (DMCA) includes a "safe harbor" provision legislated to protect (online) service providers from liability based on third party infringement. The DMCA is a tool that may be employed by the copyright holder to have an alleged infringing item removed from a website. Conversely, the DMCA provides immunity, or "safe harbor", for the online service provider so long as they comply with the statute. The 17 U.S.C.S. § 512(c) safe harbor will apply only if the service provider:

> (A)(i) does not have actual knowledge that the material or an activity using the material on the system or network is infringing; (ii) in the absence of such actual knowledge, is not aware of facts or circumstances from which infringing activity is apparent; or (iii) upon obtaining such knowledge or awareness, acts expeditiously to remove, or disable access to, the material; (B) does not receive a financial benefit directly attributable to the infringing activity, in a case in which the service provider has the right and ability to control such activity; and (C) upon notification of claimed infringement as described in paragraph (3), responds expeditiously to remove, or disable access to, the material that is claimed to be infringing or to be the subject of infringing activity. (17 U.S.C.S. § 512(c)(1)(A)-(C)., 1998; Viacom Int'l, Inc. v. YouTube, Inc., 2012, p. 2)

For example, the Digital Millennium Copyright Act becomes extremely important for companies like Shapeways and Thingiverse where anyone can upload a 3D design onto their web site. Accordingly, if Shapeways follows the appropriate steps under the DMCA, it will enjoy immunity from a plaintiff's copyright infringement claim against one of the website's users. In fact, Shapeways duly publishes its notice against copyright infringement on its website (Shapeways Content Policy and Notice Takedown Procedure, 2014). Although much of the notice is directed to copyright issues, the notice includes stated policies against other undesirable uses: "Some examples of content that is prohibited and will be removed (private or public): 1.Content that may infringe on the rights of a third a party…" (Shapeways Content Policy and Notice Takedown Procedure, 2014, p. 1). Shapeways has arguably written an "in house" take down policy for alleged IP infringement that goes beyond copyright issues. Hence, Shapeways has incorporated its own policy and must therefore enforce it consistently to avoid third party liability. Thingiverse also posts its policy regarding IP infringement. Its policy expressly extends to patent and trademark infringement (Intellectual Property Policy).

The DMCA does not extend to patents, but should Congress determine the need for a parallel statute to protect online service providers from patent actions based on contributory infringement, the future may dictate a DMCA-like statute for patents.

SUMMARY AND CONCLUSIONS

Even though 3D printing technologies have been in existence since the 1980s, companies are now beginning to realize the possibilities of using this technology within their business model for competitive advantage. Several events have contributed to this realization, including the expiration of 3D technology patents in recent years, which has opened up the market for manufacturers to design lower cost 3D printers, making them economically available to many businesses. Because of the decreasing cost trends for 3D printing technology, companies have found several ways to utilize this technology as a strategic advantage. The authors discussed a support services business model for using 3D technology to print replacement parts within the company and possibly provide the same capability for customers for certain types of replacement products. This business model allows organizations to increase their competitive advantage through decreasing costs by not having to order parts from a third party, decreasing the turnaround time between ordering and receiving, and providing better customer relationship service opportunities through faster response time to consumer requests for replacement parts.

As shown in Table 2, there are many examples of using 3D printing for replacement parts already in existence. The authors believe this model can be expanded and customized by a great number of different types of organizations that are currently not taking advantage of using 3D technology for their support services. The future of this capability can lead to many opportunities for businesses and consumers as other technologies continue to emerge. Hansell (2007) gives several examples of printing not only replacement parts, but entire products for a minimum cost. These products could be printed from a consumer's home, the company, or even a third part 3D retail printing company. The possibilities are vast. Companies will continue to realize the competitive advantages of a consumer technology business model as 3D printer costs continue to become more economical and as the quality and type of materials used in 3D printers continues to expand.

Companies must also be cognizant of the legal implications for this business model. The support service 3D printing business would be on solid legal ground to 3D print replacement parts from a file that it directly receives from the manufacturer of the original part, so long as the manufacturer permits the arrangement. In fact, the 3D support service should maintain a written agreement with the manufacturer which covers intellectual property as well as consumer, or end-use, product liability issues.

Legal problems may surface where the 3D printing support service engages in reverse engineering of parts, or scanning parts to 3D print for consumers. A 3D printing support service could face an infringement action if it routinely 3D prints patented parts to sell without permission. Likewise, should the 3D printing support service print a replacement part that contributes to someone's harm, the injured party may bring a lawsuit against the 3D printing business under a negligence product liability theory, particularly where the manufacturer did not authorize the 3D printing of the part. The manufacturer could defend against the lawsuit on the grounds that its design, or part, was substantially altered when it left its control, or that the 3D printing of the object made it unsafe. Perhaps the 3D printed object was slightly different in terms of material, measurement, or it failed to include necessary warnings.

Finally, companies using a 3D printing consumer technology business model as a support service should know when new and existing legislation impacts consumers. For example, a material or object that was previously legal to produce as a toy may become prohibited under new legislation. Many consumer products require warnings by regulators and failure to include these warnings in conjunction with the sale of the 3D printed object may result in legal action. If companies are to benefit from using a 3D printer for support services within their existing business model, they must also provide guidance, policy and even training on how to provide these services within the legal requirements.

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