After the Hype:

The Way Forward for 3D Printing

Alexander Pizzirani

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1 Alexander Pizzirani is a member of the class of 2016 at the University of Chicago.
Abstract

Over the last few years, 3D printing has gone from being relatively unknown outside of the manufacturing industry to being hailed as a revolutionary technology that would yield “a factory on every desk” before retreating from the limelight as current technological limitations became more widely understood (The Economist). Despite these limitations and the corresponding decrease in popular interest, it is apparent that, just like the sudden boom in interest that preceded it, this sudden decrease in interest is also out of proportion given the remaining limitations of the technology and the sector as a whole. In particular, it is apparent that in the consumer space 3D printers are still becoming more common and find a natural home in educational settings. Furthermore, despite the popular focus on consumer applications of 3D printing, it is industrial 3D printing that continues to experience significant growth. At present, weaknesses in the value proposition are undermining the ability to justify the price for 3D printing for consumers.
Introduction

Many remember the excitement surrounding 3D printing in 2013. A wave of media coverage and share price growth fed on each other, pushing share prices for companies in the sector to all-time highs. As the year ran out, that interest suddenly faded, leaving stock prices to gradually deflate over the course of the year, returning to pre-2013 levels. 3D printing companies’ revenues and profits have increased, yet the technology still faces significant limitations. This begs the question, what awaits this industry in the short-term?

Technical Basics of 3D Printing Technologies

Since their invention over twenty years ago, 3D printing technologies have revolutionized the manufacturing industry, initially for prototyping, but increasingly also for mass production. The great advantage created by 3D printing stems from their ability to directly convert a computer assisted design (CAD) file to a physical product, without the need for the supply chains, overhead and lead time necessary for traditional mass production methods. This is useful because it allows much faster design cycle iterations, making greatly accelerated prototyping and mass customization feasible. Furthermore, 3D printing is an additive process, allowing for more efficient use of materials than traditional subtractive processes such as milling or lathe-turning, leading to lower material costs (Excell, Nathan).

At the most elementary level, 3D printers work similarly to 2D paper printers; they take a digital file and produce a physical copy. Unlike 2D printers, 3D printers utilize computer assisted design (CAD) files to produce a three-dimensional object. There are three main types of 3D printing technology: filament-based technologies, powder-based technologies and laser-based technologies. In each case the machine converts the object depicted by the CAD file into a stack of horizontal ‘slices’ which are then recreated one on top of the other in the machine to produce a physical replica. Filament-based technologies, such as fused filament fabrication (FFF) or the equivalent filament deposition modeling (FDM), take a thin plastic rod, the filament, melt it and then deposit it to generate these layers (Chee, Kah and Chu p.129). FDM technology is the one most commonly used by consumer level machines, because of the relative simplicity of the printer design and the economic and logistic convenience of using plastic filament. In powder-based machines, a liquid binder is deposited on a layer of powder particles to bind them together (BBC). Once each layer is complete, the layer of powder is replenished on top of the completed layers and the process repeats. Largely because of the cost and size of the machines, this technology is generally used for 3D printing ceramic, metal and plaster-like materials for industrial uses. Resin-based systems function similarly to powder-based systems, with the exception that the material is a liquid light-sensitive resin, which is solidified using a laser to form the component layers of an object ("Technology in Action - Stereolithography Video and RTV Mold Video"). This is the oldest technology and is generally used for industrial uses, but has recently begun creeping into the consumer space, in the form of machines such as the Formlabs Form 1.
Hype and Disillusionment in the Recent History of 3D Printing

In order to understand the current state of the consumer 3D printing industry, it is useful to understand how the industry has developed, particularly considering the rapid rise and fall in popular interest in the technology over the last two years.

Although they were invented in the 1980s, filament-based 3D printers only started to become available to the public in 2007 with the launch of the RepRap Darwin. RepRap Darwin is an FFF printer developed by the RepRap project, whose goal is to produce a 3D printer that can print most of its components ("RepRap"). It is important to note that all of the designs developed by the RepRap project are open source, meaning that users were freely allowed to duplicate and modify the product’s software and hardware. The open nature of the technology’s basic intellectual property has been instrumental to the proliferation of these machines, both in terms of how many individual machines have been built, as well as the number of different designs available. The image in Appendix 1 gives an idea of the extent of this proliferation. As this proliferation occurred, there was a corresponding rise in popular interest and expectations relating to the technology. The stock prices of Stratasys and 3D Systems (the two foremost 3D printing companies with exposure to the consumer market), Google Trends data, and the number and success of 3D printing related Kickstarter projects demonstrate the rise and fall in the popular view of 3D printing technology, as well as how this craze manifested itself.

The strongest signal reflecting the sudden explosion and subsequent collapse of interest in consumer 3D printing was the rapid rise and fall in the price of shares in 3D Systems (DDD) and Stratasys (SSYS) over the course of 2013 and 2014 (Figure 1). The chart clearly shows that these shares experienced explosive growth over the course of 2013 and then promptly retreated just as rapidly over the course of 2014.
Figure 1. DDD and SSYS share price versus the S&P 500 between January 11, 2013 and January 12, 2015. At their peak on January 3rd, 2014, DDD closed at $96.42 per share, representing a 145.78% increase over its price at the start of the period. SSYS closed at $136.46, representing a 66.90% increase over its price at the start of the period. By January 12, 2015, these gains had been entirely erased, with shares of DDD having lost 20.33% of their value over the period, while SSYS was down 7.71% for the period, and the S&P 500 had gained 38.43% without experiencing any significant fluctuations. Image courtesy of Google Finance.

Another signal directly measuring interest in 3D printing over this period is the Google Trends for the search term “3D Printing” (Figure 2). As the chart clearly shows, the search volume peaked in May 2013, before falling to an average of 60% of the peak volume for the following months, preceding the stock price shift in the same direction.

Figure 2. Google Trend Chart showing search volume for 3D printing in the recent past. Image courtesy of Google Trends.

As shown by the trend in DDD and SSYS stock, it is clear that people were willing to literally buy into the wave of interest surrounding 3D printing. Besides buying stock, people also did this by backing Kickstarter
projects with the goal of producing 3D printers. As of January 2014, the peak of the 3D printing stocks, 3D printing projects on Kickstarter had achieved the following results ("Kickstarter Stats"):

<table>
<thead>
<tr>
<th>Category</th>
<th>3D Printer Kickstarters</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launched</td>
<td>53</td>
<td>126,977</td>
</tr>
<tr>
<td>Successful (% of total)</td>
<td>49 (92.5%)</td>
<td>54,054</td>
</tr>
<tr>
<td>Raising over $100K (% of total)</td>
<td>28 (52.8%)</td>
<td>1034</td>
</tr>
</tbody>
</table>

The very high percentage of successful projects, as well as their ability to successfully raise large amounts of capital, underlines the extent to which people were willing to buy into home 3D printing in particular. Enthusiast-driven developments like these also highlight a key aspect of the industry; early adopters were very community-oriented due to the open-source origins of many of the projects as well as the difficulties associated with early adoption of a technology. Printers needed time-consuming calibration and maintenance; the conversion of CAD files into a printed item was often difficult. In particular, transforming the computerized design into something the printer could read was a multi-step process which required running the file through several programs hacked together by other users. These programs were developed in an open-source framework, meaning that anyone could modify or improve the code, making cooperation a key aspect of the consumer 3D printing community. This was very fortunate, given the issues with usability and instability that often plagued these programs. Additionally, the ventures manufacturing these devices were all very small and often struggled with supply chain issues, effective customer service and a limited ability to improve their products, further hampering progress in the industry.
Current Widely Available Offerings and Pricing

<table>
<thead>
<tr>
<th>Manufacturer and Device Name</th>
<th>Price as of January 2015</th>
<th>Retailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratasys Makerbot Replicator 5th Generation</td>
<td>$2899.00</td>
<td>staples.com, homedepot.com, amazon.com</td>
</tr>
<tr>
<td>Stratasys Makerbot Replicator Mini Compact</td>
<td>$1375.00</td>
<td>staples.com, homedepot.com, amazon.com</td>
</tr>
<tr>
<td>3D Systems Cube 3D Printer</td>
<td>$999.99</td>
<td>staples.com, amazon.com</td>
</tr>
<tr>
<td>3D Systems CubePro 3D Printer</td>
<td>$2799.00</td>
<td>staples.com, amazon.com</td>
</tr>
<tr>
<td>4th Generation Solidoodle</td>
<td>Currently $699.99, regularly $999.99</td>
<td>staples.com, amazon.com</td>
</tr>
<tr>
<td>Afinia H-Series H480</td>
<td>$1299.00</td>
<td>staples.com, homedepot.com, amazon.com</td>
</tr>
</tbody>
</table>

Data courtesy of Staples, Home Depot, and Amazon.com.

Causes of Disillusionment

Overall, the main reason why 3D printing fell out of favor in 2014 was increased awareness of the technology’s shortcomings. Just as the reports of the possibilities offered by 3D printing and its integration into the mainstream caused an overly optimistic rush to buy shares in 3D Systems and Stratasys, these realizations caused a similarly sized correction downward in their stock prices. The limitations 3D printing faces currently fit into two main categories: practical limitations and worries about what can be made with the devices.

Practical Limitations

Price vs. Utility: The fundamental issue hampering the mainstream adoption of 3D printers is that the utility the average mainstream consumer can derive from having a 3D printer in his home is still not enough to justify what is currently approximately a one-thousand dollar purchase. The items that a home 3D printer can produce are currently limited to plastic items that would otherwise be produced by injection molding or whatever consumers can find on an online database of models. The main reason industrial printing’s current prospects and degree of development are currently superior to their equivalent on the consumer side is that 3D printing offers greater benefits to industrial users. 3D printing allows manufacturers to rapidly prototype new designs, produce designs that cannot be constructed using traditional methods and reduce cost by reducing material waste (Businessweek, PwC). These advantages allow industrial users to readily generate a return from their devices, spurring their adoption and development. These returns also increase 3D printer manufacturer’s pricing power, allowing for the stronger margins their industrial offerings have produced.
Materials: Another limitation in the consumer market is that home 3D printers can still only produce plastic items. Improvements to printed objects such as the integration of electronics or smoothing their surface are still relatively complex, and prints in metal and ceramic are still exclusively available with industrial grade printers (Griffin).

Ease of Use: Even though the current generation of 3D printers has demonstrated substantial improvements in their usability, through the inclusion of innovations such as self-calibration, there are still significant challenges to be tackled in the area. In particular, models for 3D objects remain difficult to obtain. This difficulty persists despite improvements in online 3D model databases, 3D scanning technology and modeling programs, which are gradually alleviating the problem. This obstacle stands in the way of one of the main projected mainstream uses of 3D printing technologies: the independent production of spare parts in the home. The idea is that, if a simple component in a household appliance breaks, it should be fairly straight-forward to reproduce it on a consumer-level 3D printer. However, this concept fails given the persistent difficulty in creating the model necessary to direct the printer’s construction of the new item.

Worries about the Potential Uses of 3D Printing

Infringing on Intellectual Property Rights: Particularly with the rise of 3D scanners (devices that collect data about the surface of a 3D object and convert it into a 3D model with varying degrees of success and precision), there is a risk that 3D printers will be used to infringe on the intellectual property (IP) rights of designers and manufacturers. Given the track record of people using older technologies such as copy machines, camcorders and peer-to-peer file-sharing sites to illegally copy books, movies and digital media, it seems inevitable that hardware designs will not escape the human drive to copy. If we consider the relative failure of government to curb the spread of illegal copies in the preceding examples, it seems likely that a similar situation will result with 3D printing as well. Conversely, the ability to copy IP adds an additional reason to buy a 3D printer, suggesting that this issue might even spur their adoption.

Production of Firearms: Unlike the previous issue, which is based in reality and is largely unavoidable, fears about the use of 3D printing for the production of firearms are severely overstated. While it is true that people have successfully produced firearms with 3D printers offered at a consumer price point (for example, the Defense Distributed Liberator), it is abundantly clear that there are far easier ways for someone to obtain or even improvise a firearm. Existing 3D-printed firearms are also limited by the fact that they are single-shot devices (either by design or because of the weakening created in the plastic by firing a round) that can only use very low-pressure ammunition and still require metal components to fire effectively. People have a long history of improvising firearms, manufacturing them from kits or simply stealing them. All of these possibilities are superior to 3D printing a firearm and will remain so for the foreseeable future, making this a largely irrational
objection to 3D printing. The irrationality of this objection becomes thoroughly apparent when we consider that the healthcare industry is currently one of the main users of 3D printing, and poised to benefit from some of the most promising current 3D printing research.

The Road Ahead

Despite the undeniable reality that the general public’s interest in 3D printing has faded, the industry still faces healthy growth prospects, both for industrial- and consumer-level machines. Stratasys’ Q3 2014 earnings call presentation reported a 61.5% year-on-year increase in total revenue (Stratasys Q3 Presentation, Stratasys 20-F). 3D Systems reported a 20.3% year-on-year increase in revenue in its Q3 2014 10-Q (3D Systems 10-Q). On the consumer side, both company’s consumer divisions have also enjoyed strong growth in terms of units sold (Stratasys 20-F, 3D Systems 10-Q), although it is unclear who is buying the devices. Both Stratasys and 3D Systems have begun selling their devices through mainstream outlets (including Home Depot, Microsoft Stores, Staples and Amazon). Given the practical issues outlined previously, it seems unlikely that true mainstream consumers are driving this growth in sales. Both filings by Stratasys and 3D Systems also fail to discuss the origin of these sales. But it seems most likely that this growth is being driven by the growth of the 3D printing enthusiast community, as well as applications in educational contexts.

The enthusiast community has existed for some time now, and as consumer level 3D printers decline in price and capabilities improve we should expect that the barriers to entry to 3D printing as a hobby would decrease and thus the community would expand. On the other hand, educational use would appear to dovetail perfectly with the current state of consumer 3D printing devices. By and large, machines have become reliable enough to print without constant supervision, and the fact that most of the main manufacturers have produced more than one generation of the machines has helped smooth out kinks in the supply chain, design and customer support of the devices (PwC). Perhaps counterintuitively, limitations in the machines’ capability provide a useful teaching opportunity in the context of STEM (science, teaching, engineering and math) education as a way of introducing students to concepts including computer-aided design, troubleshooting and considering material/machining drawbacks as a constraint to design, which are abundant in STEM research and industry. The current price range of basic 3D printers means that they fall into the same range as other tools a school might buy for its students. For instance, seven hundred dollars could be used to buy a 4th Generation Solidoodle, a relatively common consumer 3D printer, or two Inspiron Desktop 3000 Series educational-grade desktop computers from Dell (Dell). Even though this comparison at first glance might make the 3D printer seem expensive, one must consider the fact that each student does not need access to their own 3D printer in the same way that they would to a computer, suggesting that it is indeed a good deal in terms of educational value provided.
Meanwhile, despite these continued improvements in the aftermath of the consumer 3D printing stock fall, consumer 3D printing does not provide margins as high as those found in industrial 3D printing for companies in the sector. This is true for both Stratasys and 3D Systems, according to their financial filings and analyst conferences. This was a central theme during the last Stratasys earnings call, in which Stratasys COO Erez Simha stated that the addition of Makerbot “had an impact on the combined operating margin of the Company” addressing questions from a Piper Jaffray analyst regarding the decrease in the company’s third quarter margin, before David Reis, the CEO added that Stratasys’ “core business did have improved margins”. (Stratasys Conference Call). 3D Systems’ Q3 2014 10-Q revealed that despite growth in the company’s consumer 3D printing volume, the share of revenue accounted for by consumer 3D printing fell year on year from 9.9% in 2013 to 7.1% in 2014 (3D Systems 10-Q). Going forward consumer 3D printing margins will have to increase to justify their continued existence in their producer’s lineups. There are a few possible ways for this to occur. The first and simplest solution to implement in the short term would be to develop ways to cut the cost of producing consumer printers, either through direct manufacturing commonalities with their industrial offerings, or simply by increasing the scale of production and exploiting economies of scale. In the long run, it seems that the way forward will have to be the development of devices that offer better capabilities and value for the average consumer to justify a hefty initial investment on their part and produce a healthy margin for their manufacturers.

If these changes on both the consumer and manufacturer sides fail to occur, it seems likely that consumer 3D printing will approach the situation of the rest of the consumer electronics industry, i.e. a highly competitive market largely saturated by poorly differentiated products producing low margins and profits for manufacturers (Jackdaw Research). The longer the current practical limitations and margin woes continue the more likely consumer 3D printing is to continue its current retreat into renewed relative obscurity.
Works Cited


