Financing for Growth in Additive Manufacturing

By

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SUBMITTED TO THE MIT SLOAN SCHOOL OF MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF BUSINESS ADMINISTRATION
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2018

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Submitted to MIT Sloan School of Management
on May 11, 2018 in Partial Fulfillment of the
requirements for the Degree of Master of Business Administration.

ABSTRACT

Digital fabrication technologies have been improving their capabilities and
competitiveness steadily over the past decade and may be approaching an inflection point in
their enterprise adoption. However, several important technological, economic (cost) and
business (adoption risk) barriers stand in the way of broader adoption. This research seeks to
explore the rich history that has driven the growth of Additive Manufacturing (3D Printing) in
the application of manufacturing of a displacement or augmentation of current production-
level techniques, what business model or characteristics will continue to drive growth and
industrial adoption, and the current limitation that must be overcome to unlock broader
enterprise adoption.

Furthermore, from the viewpoint of growth financing, this paper seeks to answer two critical
questions to highlight investment opportunities in the space of Additive Manufacturing; 1) Where is digital fabrication positioned to compete with traditional manufacturing methods over the next five years and what are the key enablers, and 2) As digital fabrication becomes more competitive for different applications, who in the value chain benefits the most.

Thesis Supervisor: Matthew Rhodes-Kropf
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INTRODUCTION

Digital fabrication technologies have been improving their capabilities and competitiveness steadily over the past decade and may be approaching an inflection point in their enterprise adoption. However, several important technological, economic (cost) and business (adoption risk) barriers stand in the way of broader adoption.

Thesis Objectives

This paper seeks to explore the rich history that has driven the growth of Additive Manufacturing (3D Printing) in the application of manufacturing of a displacement or augmentation of current production-level techniques. In addition, an analysis of what business model or characteristics will continue to drive growth and industrial adoption, and the current limitation that must be overcome to unlock broader enterprise adoption.

Specifically, from the viewpoint of growth financing (Venture Capital & Private Equity), this paper seeks to answer two critical questions to highlight investment opportunities in the space of Additive Manufacturing;

1. Where is digital fabrication positioned to compete with traditional manufacturing methods over the next five years (on a performance basis) and what new product and supply chain capabilities will digital fabrication enable (mass customization, on-demand manufacturing)? What emerging technologies and startups (materials, equipment, services, applications) will enable that?

2. As digital fabrication becomes more competitive for different applications, who in the value chain (material makers, machine makers, service providers, application developer/end users) is going to benefit the most (e.g. which parts of the value chain are most defensible and which are most likely to be commoditized).

What this Thesis is Not

Where-as a lot of perspectives have already been written in the area of additive manufacturing and adoption, this paper does not seek to duplicate or reinvent this well covered research. Therefore, the
following topics will not be explored but rather will be referenced from industry analysts and professionals for context.

- **Industry specific uses** will not be researched in depth, there has been heavy coverage from industry experts in this space.

- **Adoption projections** has been widely speculated by industry experts such as some prominent industry authorities such as Wohlers Report and Sculpteo’s annual state of the industry surveys.

- **Desktop printers** will not be a focal point as this study specifically explores growth in production-augmented additive manufacturing. The desktop printers are widely used by engineers for prototyping and hobbyists, therefore these specifically businesses are omitted (i.e. Makerbot).

**Research Methodology**

To derive insights and provide a pragmatic perspective in application and investment opportunities within additive manufacturing beyond theoretical synopsis, I worked closely with the investment team at an early-stage venture fund in NYC, Particle Ventures. This venture fund focuses its funds primarily on investments in digital transformation within slow-sector industries (manufacturing, construction, agriculture, etc.) Furthermore; to supplement findings, primary and secondary research was conducted through the following means;

- **Primary research** – answering critical qualitative questions by interviewing entrepreneurs, operators, and experts in these frontier markets which the rest of the VC community is just starting to think about. Examples of interviews conducted included:

  High-Tech Research experts (Google & Apple), Executive Professionals in the industry (Advanced Technologies, McKinsey, BCG, Cincinnati, Stratasys), Founders of startups currently operating and exited (Formlabs, Desktop Metal, others), Academic Professionals including PHD students and professors (MIT Media Lab, MIT Mechanical Engineering, MIT Material Sciences, and Rice University), Prominent VC investors that have invested in companies prominent companies such as Formlabs, Desktop Metal, Uber and many others.

- **Secondary research** – exploring the broader digital fabrication ecosystem to discern insights into the ecosystem of players, new techniques and ground breaking research, and financing trends that has driven the advancement and adoption in the market today, including;
Ecosystem analysis that explores 450+ players across the value chain, including segmentation of business models, value drivers and enablers, strategic movements within the markets, and companies’ concentration and technical advancements that has driven capital requirements and investor confidence.


Investment Activity was analyzed to understand where in the value-chain investment dollars were funneled in the past and which type of firms and characteristics drove capital requirements and how has that changed overtime.
WHAT IS ADDITIVE MANUFACTURING

Total Addressable Market

Since 3D printing’s introduction at MIT in 1985, today it represents $5 Billion dollars in the global market\(^1\), Industry experts such as BCG expects this figure to triple by 2020 and Wohlers Report predicts $20B by 2020 while reach $350B by 2035\(^2\). Since 3D Printing’s inception at MIT in 1985, these estimates are rather optimistic given the slow growth in adoption over the past 33 years and hints towards an inflection point in broader enterprise adoption.

There is no dispute, if Additive Manufacturing were to take off, it seeks to disrupt a very large portion of enterprise manufacturing. According to Wohlers Report the global economy is $80 Trillion with $12.8T (or 16%) representing manufacturing\(^2\). Let’s assume if 3D Printing techniques displaces just 5% of the global manufacturing GDP, the total addressable market could be as much as $640 Billion Dollars.

Applying the same assumptions for specifically, the United States; the World Bank quotes the united states GDP at $18.5 Trillion (2015 Actuals), with ~12% of that representing manufacturing for $2.22T.\(^3\) Again, assuming 3D Printing techniques displace just 5% of the United States’ manufacturing GDP, the total U.S. addressable market could be as much as $111 Billion Dollars.

Benefits & Value Proposition

According to Sculpteo’s State of 3D Printing report (surveying nearly 1,000 companies), 90% of respondents from America and Europe consider 3D Printing as a competitive advantage in their strategy. In addition, the drivers indicate that these users are predominately using 3D Printing techniques to “accelerate product development” (28% of respondents) followed by “offering customized products” (16%).\(^4\)

Furthermore, an abundance of additional benefits can be attributed to additive manufacturing such as curtailing expensive carrying cost of slow moving products and parts in warehouse. SAP has crunched the numbers on the benefits of reducing carrying costs, SAP quotes global inventory is over $12 trillion dollars, if manufacturing could reduce global inventory by just 5%, it would free up ~$500B in capital\(^5\). In

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1. BCG, How to Position Your Company In The 3D-Printing Value Chain, May 2017
2. Wohlers Report, March 2018
3. The World Bank, CY 2015
4. Sculpteo, State of 3D Printing, CY 2017
5. SAP, Metal 3D Printing using SAP Distributed Manufacturing, March 2017
addition, on-demand manufacturing can provide added benefits in the areas of increased availability of slow-moving parts, parts for emergency repair, shipping and transportation cost, and reduce import tariffs, and tax exposure.

Sculpteo concludes that 47% of industry survey respondents have reported a Return On Investment (ROI) for 3D Printing as being greater than the previous year, where-as this number was at 40% a year prior (2016) indicating a growing impact and value proposition.

3D Printing Techniques

There are many disparate 3D Printing techniques which hinders adoption and requires a skillset to understand the needs and limitations of each technique. Additionally, the techniques can vary according to materials used or method of printing. Techniques can dictate speed, time to print, quality, print resolution, and material type. There are 13+ different printing techniques out in the market today and growing with new technical advancements in materials. Techniques that lead the market today are Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), and Stereolithography (SLA). The reason for this proliferation of techniques was due incremental advancements that addresses limitations in a technique or to circumvent techniques while patents (expiring after 20yrs) were in place.

- SLS (1986) - SLS leads to mass customization in manufacturing and was developed at UT. The first SLS (selective laser sintering) machine becomes viable and years later the patent was acquired by 3D Systems. This type of machine uses a laser to fuse materials into 3D products. This breakthrough opens the door to mass customization and on-demand manufacturing of industrial parts, and later, prostheses. That same year Objet, a 3D printing systems and materials provider, creates a machine capable of printing in multiple materials, including elastomers and polymers. The machine permits a single part to be made with a variety of densities and material properties.

- FDM (1989) - Fused Deposit Modeling technique was developed by Stratasys. FDM printed parts are used for functional testing and engineering application. The high performance thermoplastic materials it uses allow for great properties, opening the door to rapid manufacturing amongst other applications.

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6 Sculpteo, State of 3D Printing, CY 2017
7 Deloitte, Disruptive Manufacturing – The Effects of 3D Printing, Undated
• SLA (1992) - The first SLA (stereolithographic apparatus) machine is produced by 3D Systems. The machine’s process involves a UV laser solidifying photopolymer, a liquid with the viscosity and color of honey that makes three-dimensional parts, layer by layer. Although imperfect, the machine proves that highly complex parts can be manufactured overnight.\(^9\)

Materials are a main driver for 3D Printing techniques, however one key limitation has been industrial grade metals printed with speed, resolution, and affordability. In the market today, the use of plastic has grown from 73% to 88% Year-over-year. Whereas resin materials known for its solid properties 35% from 27% YoY, followed by metals at 28% from 23% the prior year, largely driven by new techniques in Selective Laser Melting (SLM) and Direct Metal Laser Sintering (DMLS) and more affordable means to print metals.\(^{10}\)

Additionally, 3DP printing techniques offers benefits that traditional manufacturing cannot deliver. For example; mass customization, shorter design and lead time, simplifying the supply chain and manufacturing process, and lastly provides a significant reduction in materials waste.

Use Cases

3D Printing has been and continues to be largely leveraged for prototyping activities within R&D and Engineering. According to Sculpteo’s 2017 State of 3D Printing report, 3D Printing applications are as follows within the industry; Prototype: 34%, Proof of Concept: 23%, Production: 22%, Market Samples 10%, followed by nominal single digit amounts in education, art and hobby.\(^{10}\)

To further support the assertion, the following departments have reported to be leveraging 3D Printing techniques; 62% R&D, 53% Design, 40% Production, 28% Engineering, and single digits for all other department such as maintenance.\(^{10}\)

\(^9\) Deloitte, Disruptive Manufacturing – The Effects of 3D Printing, Undated
\(^{10}\) Sculpteo, State of 3D Printing, CY 2017
Industry Application and Adoption Projections

Today, the top industries to adopt 3D printing techniques have been automotive, aerospace, medical and consumer. Largely these trends have been led by prototyping and mass customization of products. Several examples of these areas are as follows:

- **Automotive**: BMW, Premiere in the i8 Roadster. The mounting for the top cover would not have been possible using a traditional casting process. Now the 3D printed car part is stronger and weighs less.\(^{11}\) and according to EY, they forecast 49% of automotive companies will directly manufacture 3D Printed car parts to achieve operational efficiencies.\(^{12}\)

- **Aerospace**: GE’s fuel nozzle that lowers fuel consumption by 15%, by making these products more lightweight overall reducing the cost of ownership.\(^{13}\)

- **Medical**: Casting of orthopedic tooth casting and orthopedic aligners with a dominate provider in the industry providing the printers to orthodontist, dentists, and labs with the value proposition of dramatically shortening delivery times, improving service levels, while also potentially reducing costs and creating perfect fitting aligners in minutes.\(^{14}\)

- **Consumer**: Producing insoles for shoes, developed by companies like SOL (medical grade and direct to consumer insoles), similarly being explored by the strategic partnership between Adidas and Carbon 3D.

Some experts predict production application of 3D Printing techniques will grow to $7.4 billion and the consumer market to $0.4 billion. But growing at a CAGR of 29% and to the value of $12 billion, prototyping will continue to be the predominate use-case for those companies that continue to improve their offerings.\(^{15}\)

\(^{12}\) EY, Global 3D printing Report 2016, CY 2016
\(^{13}\) 3DPI, The Future of 3D Printing, Lee-Bath Nelson, June 2017
\(^{15}\) 3DPI, The Future of 3D Printing, Dr. Conor Maccormack, October 2017
Several industries have embraced 3D printing

<table>
<thead>
<tr>
<th>Current applications</th>
<th>Imminent applications</th>
<th>Ideal applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Automotive</strong></td>
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<tr>
<td>Specialized components for engine production</td>
<td>New products with prior design for manufacture limits</td>
<td>Low to medium volume</td>
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<tr>
<td>Innovative designs, such as concept car chassis</td>
<td>Lightweight structures, such as chassis</td>
<td>High value-to-weight ratio</td>
</tr>
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<td><strong>Aerospace</strong></td>
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<tr>
<td>Production-approved components, such as fuel nozzles</td>
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<td>Prototype jet engine parts</td>
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<td><strong>Medical</strong></td>
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<tr>
<td>Orthodontic implants for hips and spines</td>
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<td>Complex multi-part assembly under traditional manufacturing</td>
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<tr>
<td>Surgical guides</td>
<td>Personalized prosthetics</td>
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<tr>
<td>Custom jewelry</td>
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</tr>
<tr>
<td>High-performance sporting goods</td>
<td>Fashion accessories production</td>
<td></td>
</tr>
</tbody>
</table>

Source: A.T. Kearney analysis

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16 AT Kearney, 3D Printing: A Manufacturing Revolution, CY 2015
HISTORY & EVOLUTION

History

3D Printing technologies have reached its peak hype (and corresponding investments) years ago and now in a period of hype hangover. Investors and industry critics alike believe that this may have all been a disillusion as no major advancements have taken place, nor has industry verticals seen massive applications within their production cycles. The reason for this is because of the many limitations still pronounced today, such as speed, costs, precision, accuracy, and quality; all of which is addressed within cover in the ‘Challenges’ section.

1980’s to mid-2000’s

Since inception in the early to mid-1980’s where innovations in new 3D Print techniques and materials were advancing quickly. Patents and legal battles forced companies to innovate and protect as they deliver their value propositions to the market. For example, the SLS (Selective Laser Sintering) technique was born which allowed many other types of mixed materials and various properties to be printed. It was during the late 1990’s it was difficult for a 3D Printing equipment company to gain access to capital which can be attributed to the .com/software revolution that had much higher margins and lower capital requirements. Shortly after the .com-burst innovation in the 3D Printing areas started to take flight again with the first 3D printed organs using patient’s cells were tested and accepted by human bodies, including the first 3D printed kidney in 2002.

Mid-Teens

For the next 15 years, only incremental advancements in materials and techniques had been taking place however broader application was being explored. From 2013 - 2014 there was much hype and increased capital injected into the 3D Printing space. The desktop printer was just entering the mainstream consciousness, bio-printing was providing new promises of revolutionizing the healthcare industry and access to capital was flourishing. New advancements that contributed to the hype during this time included; the world’s first 3D Printed robotic aircraft, 3D printed car, 3D printed gold and jewelry, and also the first 3D Printed prosthetic jaw was implanted (2012).\(^\text{17}\)

It wasn’t until the predominate technique patents began to expire through 2016, mostly owned by (and helped bring to dominance) the market leaders, 3D Systems and Stratasys. By 2016 many startups began

\(^{17}\) Deloitte, Disruptive Manufacturing – The Effects of 3D Printing, Undated
replicating the technologies and developing new innovative business models on top of these
technologies in order to compete more efficiently within the market.\textsuperscript{18} For example, Shapeways launched their co-creation community service for DIY 3D Print hobbyists allowing artists, architects, and designers to share and print. It was during this time when venture capital firms began gaining excitement with the promises of 3D Printing and wider enterprise adoption within the market.

Present Day

Today, many of those companies have closed, unable to sustain growth in the market and have led investors to become skeptical of its promises.

Like many mature markets, today we are seeing an influx of consolidation by the biggest players (i.e. Stratasys, 3DSystems) in the market that were the benefactors of early patents, are no longer innovating and now seek competitive advantage through patent acquisitions and equity infusions of new techniques. Several of the drivers for an increase in market consolidation activity within 3D Printing are; gaining early-adopter customers where current use-cases are few and far between, talent acquisition to support existing clients, and lastly industry users are making strategic acquisitions to bring talent and techniques in-house to further build out and control their capabilities.

New novel patents being developed are incrementally making current technologies more reliable, however are having troubles rolling-out game changing technology and actually making ripples in the market. Though the outlook is not all bleak, section 'Synopsis of Findings in Growth Financing' explores additional innovative opportunities that are likely to disrupt and gain tractions.

Deal Activity

Platform's such as Pitchbook allow for the surveying the investment landscape since 1990’s including Venture Capital funds ($0-$25Million) Private Equity ($25+ Million), and M&A activity. Overall, total capital being invested in the 3D Printing industry across the value chain (materials, equipment, design, services) has been increasing. This increase is driven primarily by few very large deals which signals consolidation in today’s overall investment landscape. The below infers the objectives of each investor class:

\textsuperscript{18} TechCrunch, How Expiring Patents Are Ushering in the Next Generation of 3D Printing, May 2016
• **Venture Capital** firms seek to make investment early with budding startups that have a large risk of failure or stagnation and thus can command large amounts of ownership equity to compensate for their risk of return. Returns are contingent on future exit multiples driven by either a buyout from a private equity firm, an acquisition from a strategic company, or an Initial Public Offering (IPO). Expected multiples will range between 7X - 10X return on their investments, investing in companies they believe may have sustainable competitive advantage. This investment behavior can often lead to continued investment in flailing companies for resurrection as these early investors don’t want to lose their equity position while still hopeful of an exit.

• **Private Equity** motivations are largely driven as steady growth investments. The companies these firm are investing in are larger, have a significant customer base and traction in the market - their business models proven out, and a steady growth trajectory. Private Equity firms are motivated by assisting these companies on their growth journeys by providing capital to be deployed for growth initiatives with a hopeful exit to a large corporate acquirer providing a multiple on invested capital (MOIC) of 20-25% or an IPO.

• **M&A and Strategic Investments** are driven by several motives and two types of companies. First type of company engaging in this activity are large corporates operating within the 3D Printing value chain (Example deals include; Stratasys/Solid Concepts, 3DSys/Layerwise, Arcam/Advanced Powders, Carpenter Tech/Puris) These companies look to secure competitive advantage via patents or people skills (also known as an acqui-hire). Second type of company are end-users in the industry (Example deals include; GE/Arcam, Siemens/Material Solns, Oerlikon/Citim) These companies primarily looking to adopt new capabilities and acquire the skill-sets to continue operations internally through acqui-hiring.

As part of the capital analysis (supported by figures below), three key insights can be drawn out from how the market has matured to-date;

1. **Companies are Maturing:** Observed by the growth in PE deals (+10% 5yr deal count CAGR), this uptick in activity at much larger dollar amounts signals a maturity of the companies that had promising innovations and market adoptions in the past several years.

2. **Investor confidence is decreasing:** While there are few PE deals overall (22), total amount of VC deals is quite large (124) though this figure is down 5% YoY and 30% the previous year showing signs decreasing investor confidence. Note that over 40% of VC deal-flow are at the seed funding level
($0-$500K capital) which indicates a lot of innovations are still being explored by budding entrepreneurs.

3. **Market is consolidating:** Though driven up 16% CAGR over the past 10 years, we can infer that the +30% YoY of invested capital is largely driven by an influx of M&A (+17% 5yr deal count CAGR) plays for acquiring the viable businesses. M&A activity in 2017 alone represents 31 exits as compared to two IPOs. Since 1990 there has been a total of 179 M&A deals compared to 11 total IPOs.
### Exhibit: 3DP Deployed Capital Landscape

**General**

Type of Funds (Year End) | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017
---|---|---|---|---|---|---|---|---|---|---|---
Total Capital Invested | $341.0 | $164.0 | $41.9 | $84.0 | $156.0 | $260.0 | $41.0 | $610.0 | $210.0 | $310.0 | $410.0
Total PPM Valuation | 30% | 3% | 3% | 16% | 16% | 16% | 16% | 16% | 16% | 16% | 16%

**Total Deal Count**

---|---|---|---|---|---|---|---|---|---|---|---
Total Deal Count | 20 | 18 | 10 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20

**Recent Trends**

---|---|---|---|---|---|---|---|---|---|---|---
Recent Trends | 20 | 18 | 10 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20

**Recent Deals**

---|---|---|---|---|---|---|---|---|---|---|---
Recent Deals | 20 | 18 | 10 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20

**Total Deal Value**

---|---|---|---|---|---|---|---|---|---|---|---
Total Deal Value | 200 | 180 | 100 | 300 | 200 | 200 | 200 | 200 | 200 | 200 | 200

**Recent Deals**

---|---|---|---|---|---|---|---|---|---|---|---
Recent Deals | 20 | 18 | 10 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20

**Recent Trends**

---|---|---|---|---|---|---|---|---|---|---|---
Recent Trends | 20 | 18 | 10 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20
Geographic Concentration

As of 2017, the majority of 3D Printing startups are concentrated in North America (92 companies) and Europe (62 companies) and a very distant third, Asia (9 companies). It is no surprise that the amount of capital being dispersed around the global are concentrated in North America (68% of total capital) and Europe (28% of total capital) as their economies represent some of the most advanced nations in technology, R&D, and engineering.

Exhibit: AM Global Footprint

|-------------------|------|------|------|------|------|------|------|------|------|------|------|------
| North America     |      |      |      |      |      |      |      |      |      |      |      |      |
| Company Count     | 9    | 24   | 28   | 36   | 47   | 84   | 96   | 87   | 100  | 109  | 102  | 77   |
| Deal Count        | 1    | 1    | 2    | 3    | 10   | 21   | 21   | 27   | 29   | 28   | 21   | 17   |
| Capital Invested  | $14.1| $237.3| $316| $80.0| $137.2| $182.0| $1,452.1| $263.8| $381.5| $217.1| $381.6| $453.8|
| % of Global Capital| 2%   | 7%   | 11%  | 6%   | 11%  | 19%  | 9%   | 7%   | 5%   | 3%   | 9%   | 3%   |
| South America     |      |      |      |      |      |      |      |      |      |      |      |      |
| Company Count     | 0    | 0    | 0    | 0    | 1    | 2    | 1    | 0    | 0    | 0    | -100%| -100%|
| Deal Count        | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | -100%|
| Capital Invested  | $0.0 | $0.9| $1.0| $0.1| $0.1| $0.4| $0.4| $0.4| $0.4| $0.4| $0.4| $0.4|
| % of Global Capital| 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   |
| Asia              |      |      |      |      |      |      |      |      |      |      |      |      |
| Company Count     | 0    | 2    | 3    | 8    | 11   | 7    | 9    | 2    | 1    | 1    | 2    | 1    |
| Deal Count        | 0    | 0    | 1    | 2    | 3    | 1    | 1    | 0    | 0    | 0    | 0    | 0    |
| Capital Invested  | $0.0 | $0.0| $0.0| $0.0| $0.0| $0.0| $0.0| $0.0| $0.0| $0.0| $0.0| $0.0|
| % of Global Capital| 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   | 0%   |
| Middle East       |      |      |      |      |      |      |      |      |      |      |      |      |
| Company Count     | 1    | 1    | 1    | 6    | 11   | 7    | 9    | 2    | 1    | 1    | 2    | 1    |
| Deal Count        | 0    | 1    | 2    | 3    | 3    | 1    | 1    | 0    | 0    | 0    | 0    | 0    |
| Capital Invested  | $9.0 | $9.9| $10.2| $10.0| $12.2| $12.0| $12.1| $12.9| $12.5| $12.7| $24.1| $102.3|
| % of Global Capital| 2%   | 1%   | 2%   | 2%   | 2%   | 2%   | 2%   | 2%   | 2%   | 2%   | 2%   | 2%   |
| Total             |      |      |      |      |      |      |      |      |      |      |      |      |
| Company Count     | 19   | 20   | 21   | 24   | 27   | 30   | 31   | 30   | 30   | 30   | 30   | 30   |
| Deal Count        | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   | 20   |
| Capital Invested  | $356.0| $391.7| $318| $845.5| $886.3| $994.2| $1,464.1| $1,132.2| $603.5| $1,631.4| $2,123.1| $6.3|
| % of Global Capital| 17%  | 12%  | 28%  | 68%  | 88%  | 92%  | 92%  | 92%  | 92%  | 92%  | 92%  | 92%  |

Who is Investing

The majority of investors (corresponding with the significant amount of deals) are still venture capital firms while PE shops don’t even compare to the amount of deals. Below the total number of deals of the top 10 investors within this space driven by VC firms.
Exhibit: Most Active Investors\textsuperscript{21}

<table>
<thead>
<tr>
<th>Investors</th>
<th>Type</th>
<th>Total</th>
<th>Last 2yrs</th>
<th>Last 5yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most Active Investors</td>
<td>Corp</td>
<td>28</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>3D Systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOSV</td>
<td>Accelerator</td>
<td>14</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Techstars</td>
<td>Accelerator</td>
<td>11</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Lux Capital</td>
<td>VC</td>
<td>11</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>500 Startups</td>
<td>Accelerator</td>
<td>11</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Y Combinator</td>
<td>Accelerator</td>
<td>10</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>NSF</td>
<td>Gov</td>
<td>10</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Mass Challenge</td>
<td>Accelerator</td>
<td>9</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>High-Tech Grundeferunds</td>
<td>VC</td>
<td>9</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>FABulous</td>
<td>Accelerator</td>
<td>9</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Note that the top investor with a total of 28 is the market behemoth 3D Systems ($1.16B market cap) – a 3D Printer equipment shop made famous for holding the patents of the dominate SLS and SLA techniques. 3D Systems fights for market share with their main competitor, Stratasys ($1.12B market cap). Investment activity from these ‘strategics’ and other large end-user corporations through their Corporate Venture Capital funds have been an uptick with the assumption to provide access, future investment opportunities, and customized products for their use. According to CBInsights, this activity type today represents 28\% of investment activity in the 3D Printing field today and growing.

Left Exhibit: Corporate vs. Industrial Printing Investors\textsuperscript{22}

Right Exhibit: Active Corporate Investors\textsuperscript{21}

\textsuperscript{21} Pitchbook, 3D Printing Landscape, February 2018
\textsuperscript{22} CBInsights, Corporate vs. Industrial Printing Investors, December 2017
Exhibit: Most Active Corporate in Industrial 3D Printing

Most active corporates in industrial 3D printing

23 CB Insights, Corporate vs. Industrial Printing Investors, December 2017
CURRENT LANDSCAPE & PLAYER MOVEMENTS

Since the inception of Additive Manufacturing (AM) techniques, many companies have come and gone in the equipment and materials spaces and new innovative business models have been developed, all looking to move the supply chain closer to the customer. Given the disparate 3D Printing technologies, skills sets required, and the capital outlays required – many service-oriented business models, known as Service Bureaus have surfaced providing access to these techniques and benefits to small and medium sized companies that don’t have the available capital or support to make large 3D Printing investments.

To additionally make ease of market adoption through service-oriented models, companies looking to redefine the customer experience of design and transaction activities. Below is each component within the value chain broken down to characterize each business models, technologies, players, movements, and trends.

Exhibit: Additive Manufacturing Value Chain

Value Chain Analysis

Supply & Materials

Supply and materials are the inputs the 3D Printers themselves. These companies’ business models can vary significantly from 3rd party material providers, exclusive partnerships with equipment providers, and also often R&D shops looking to advance breakthroughs in materials to develop patents that broaden the use-cases of 3D Printing application in the market.
Enabling Technologies:

- Materials can range anywhere from standard materials (ABS & PLA), specialized materials (Nylon, TPE, Acrylic), exotic materials (Wood, Gypsum, Carbon Fiber), and metals (Bronze, Copper). However largely the majority of the materials used in the market are standard materials such as plastics & resins, followed closely by metals.

Players:

- **Third Party Providers** provide a plethora of material varieties to various end users and industries. 
  Examples: Carpenter Technologies, Advanced Powders & Coatings, and Verbatim

- **Advanced Materials Providers** invest large capital in R&D, and typically requiring specialized 3D Printing techniques and equipment for their material advancements, driving integrations with equipment providers. Examples: Materialize NV, Nano Steel, Veridis3D

Trends & Disruptions:

- **Growth in metals** - Given 3D Printed, production tested metals are one of the precursors to broader industry adoption, forecasts suggest that the global market for 3D Printed metals will be $12B by 2028.24

- **Consolidation** - Within material providers for superior and broader product assortments. Example: Carpenter Technologies acquisition of Puris ($35MM in 2017)

- **Control of the value chain** - Many material companies either establish exclusive partnerships with equipment providers for proprietary, sole-sourced materials thus securing order volume. And others are developing the equipment themselves, developing the techniques suitable for their unique materials thus serving two business models. Example: BMF develops materials, equipment, and services for 3D Printed lenses

- **Moving supply closer to consumers** - The industry is beginning to see end-consumers (industry power-users like GE), moving the supply chain closer by acquiring materials companies, presumably to stave of disintermediation by competitors of key materials inputs that could potentially harm their margins. Example: GE acquisition of Advanced Powders

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Material advancements – New material breakthrough continue to be explored which is bringing new use-cases, capabilities, and reliability to the market. While some industry experts believe materials will become commoditized, VC firms believe if patented and controlled correctly could lead to explosive growth. Much of these breakthroughs are coming from large institutions in the areas of polymer bonded magnets, strengthened aluminum alloys, and bio-tech to name a few. Examples: Oakridge Labs, MIT

Equipment Manufacturers

The most concentrated of startups and competition is within the equipment provider space. Largely driven by techniques with existing patents can be augmented and incremental innovations are added to existing technologies.

Enabling Technologies:

- Comprised of Desktop and Consumer equipment providers and Industrial Equipment providers. The proliferation of companies in this space are driven by specialization required for a material or technique (i.e. FDM, SLA, SLS, +8 others), a function (PCB, Knitting & sewing), and print volume as determined by axis size. Examples: Stratasys, 3D Systems, Desktop Metal

Players:

- Consumer equipment manufacturers such as Makerbot (Stratasys), Robo, Printbot, Formlabs which serves consumer hobbyists, educational institutions like universities, and R&D shops.

- Industrial equipment manufacturers such as 3D Systems (SLA & SLS Machines), Stratasys (FDM Machines) EOS (SLS & DMLS Machines).

- Specialized equipment manufacturers such as Arcam (Advanced Powders), Luxexcel (Lenses), Desktop Metal (Industrial Strength Metal), and Carbon 3D (Carbon Metal).
• **New entrants** include large companies that have been attracted to the idea of enterprise adoption and are now looking for to stay relevant which includes significant powerhouses like Toshiba and Kodak.

*Trends & Disruptions:*

• **Growth in equipment providers** – 3D Print equipment manufacturers is a very crowded space, in 2015 62 companies sold industrial grade Advanced Manufacturing machines, up from 49 the year prior. In the U.S. alone 20 companies sold AM machines up from only 5 in just 2013.

• **Consolidation for product range** – There are large amounts of activities of the major players acquiring all across the value chain to broaden their offerings and reach for greater competitive advantage. *Example: Stratasys (industrial) acquisition of Maker Bot (consumer)*

• **Margin grabs through materials** – Many equipment providers will sole-source their materials to one manufacturer, often even leading to M&A activity to further increase their margins enjoyed by materials provider business models.

• **Production vs. prototype** – The biggest growth opportunity is displacing or augmenting production and the race between some of the largest equipment manufacturers has commenced to secure an early position in the market. HP just signaled their intent in the market to push to production only equipment.

• **Protecting the market via exclusive resale contracts** - Stratasys secures their distribution position by establishing exclusive contracts with the major resellers, making it difficult for HP and 3DSystems to elbow their way into the market. However, each of the companies continue to invest heavily on sales staff to further control the sale of the value proposition including piloting pieces of a potential customer’s supply chain to help articulate a change in production processes and the added benefits.

• **Incremental efficiency advancements** – Most new companies are developing new IP to decrease the time of printing via automated post-processing systems and increase the quality and accuracy of prints with real-time monitoring and adjustment systems. It’s no surprise there is much M&A activity in this space from the market giants who are innovating less.

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25 Wohlers Report, March 2018
Design & Engineering Software

Software is the digital layer and human interface to 3D Printing systems. This area continues to evolve to increase the accuracy of translating design to print, ease of design, workflow management, remote control and monitoring through APIs, and even access to new marketplaces.

Enabling Technologies:

- Though the digital layer is broad it is critical in the control and application of additive manufacturing printing. This includes 3D Scanning and digitization, online databases of files and crowd sources, CAD software, workflow control software, and topology optimization (accuracy).

Players:

- CAD Design & Rendering: Computer aided design software packages are lead primarily by giants although smaller companies are finding some traction in this area. In addition to a plethora of other open-source software that is compatible with many machines, by producing STL file (common file format accepted by all 3D Printers). *Examples: Autodesk, Materialise, Robo, and PrintBot*

- Workflow Management & MES: These software packages work to optimize the equipment themselves from up-time, automation, accuracy and quality control. *Examples: SAP, Authentize, and Carbon 3D*

- Crowd Sources: Opening a new marketplace for design sharing, companies are beginning to unlock ‘the crowd’ in sharing already architected, ready to print STL files. *Examples: CAD Crowd, Design Crowd, and Quirky*

Trends & Disruptions:

- Partnering across value chain to access the customer – As designers realize they do not own the customer, many companies in the design layer are finding the best way to market is by pairing up exclusively with providers in the market. *Examples: Make Printable & 3DHubs & Shapeways (Service Bureaus), Polar 3D with Flashforge (Equip mfg), Zverse with 3DSystems (Equip mfg)*
• **Consolidation to retain dominance** – The largest player in the space continues to flex its strength through acquisition, and others with deep pockets are following suit. Examples: Autodesk & Netfabb, DesignBay & Design Crowd

• **Service Bureaus investing to streamline processes** – Given the uptick from the market in Service Bureau business model (3DPrint outsourcing), many of these companies are investing in the digital layer to help automate their distributed workflows, decrease downtime, and provide ease of use to consumers via APIs to machines. Examples:

  Rapid Manufacturing – eRapid Plugin streamlines design > quote > production,
  Shapeways – Upload API allows users to upload designs to the marketplace,
  Sculpteo – CAD Cloud allows for better workflow automation, job scheduling, and capacity opt
  Plethora – CAD Add-in provides instant feedback on design compatibility and quotes

**Service Providers**

Service providers are taking various forms of business models to help make a better connection with 3D Printing and end users that have manufacturing needs. Typically, these Service Bureaus come in two forms; a managed (distributed) marketplace with a national or global network of 3rd party fulfillment providers or an open marketplace (open bids by any 3rd party provider). Often these companies will help the customer determine if their products are better served by 3DPrinting or other techniques such as cast molding or CNC and assist with RFQ process and funneling work orders to available fulfillment locations.

**Enabling Technologies:**

• Industrial and non-industrial scale services through distributed networks of printers, managed networks of printers, open networks, and lastly ecommerce which sells printed products made to order. These can all be summed up in the industry as Service Bureaus that provide the end to end service of 3D Printing (and other methods) to end users, thus reducing the cost barrier for consumers to leverage 3D Print techniques.
Players:

- **Large industrial service shops** largely own the machine shop space providing manufacturing services across many techniques to small and medium size business and engineering & R&D departments.
  
  *Examples: VoxelJet (3D), Plethora (CNC), 3DHubs (3D, CNC), Protolabs (3D, CNC, Injection), Stratasys (3D, Injection, Casting), Xometry (3D, CNC, Sheet Metal, Casting)*

- **Consumer services** provide 3D print services and open labs to consumers such as hobbyists.
  
  *Examples: Fablab (Local Mfg), You3DIt (Distributed Mfg), Colorfab (Managed Marketplace), Shapeways (Open Marketplace)*

- **eCommerce** companies provide the marketplace for manufacturers and consumers to transact.
  
  *Examples: Kwambio, Unmade, Wivv, Shapeways, Kabuku*

Trends & Disruptions:

- **Ownership of the value chain** - Some companies seek to own the customer and the customer's experience, test out the equipment and usecases, or to decrease costs of selling equipment outright (added service and training costs/barriers in the field). *Examples: Luxexcel & BMF (Lenses), Impossible Objects (Carbon Fiber, Glass, Kevlar)*

- **Incubator models** - Companies are serving as incubators to help businesses design, print, sell, and distribute (end-to-end) 3D Printed products to the end consumers. *Examples: Flextronics, Dragon Innovation*

- **Acquisition & strategic partnerships** - As companies begin to realize the service business models are reducing the cost of ownership and the barriers to printing while providing access to customers, many acquisitions and strategic partnerships are taking place. *Examples: Moog acquired Linear AMS, 3D Systems acquired Zcorp, Vidar, and 3DMe*

- **3D printable inventory libraries** - A new space just being explored are inventories of files ready for 3D Print, thus decreasing carrying costs of slow moving parts. *Example: AMZ 3D Printable Inventories of top selling items*

End Users
Today there are a handful of prominent use cases of large corporations leveraging 3D printing. Though typically these services are used for rapid prototyping, and less for production and repairs. There are still significant barriers to adoption today and according to Sculpteo’s survey, “Respondents show less interest in buying a 3D printer, which means they prefer to use external 3D Printing services to produce and manufacture their products.”

End Markets

- The worldwide 3DPrint market usage is expected to grow (Now | Future)

  - 29% | 49% Aero/Auto
  - 38% | 45% Plastics
  - 29% | 43% Mechanical & Plant Engineering
  - 27% | 42% Electronics
  - 28% | 38% Pharmaceuticals & Medical
  - 18% | 26% Consumer Goods Wholesale / Retail
  - 14% | 22% Energy
  - 10% | 16% Logistics & Transportation

Example Players

- Aerospace (GE / Siemens / NASA / US Army)
- Healthcare & Orthopedics (Stryker)
- Consumers & Mass Customization (Adidas)
- Automotive (BMW / Ford / Toyota / Caterpillar)
- Bio Medical (Mayo / Cleveland Clinic / Medtronic)
- Plastics (3M)

Trends & Disruptions:

- Expect growth in market usage and application - According to Wohlers Reports, 71% of manufacturers have currently adopted 3D printing techniques. What’s more, 52% of companies

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26 Sculpteo, State of 3D Printing, CY 2017
27 EY, Business Insider – All the Ways 3D Printing is Changing the World, September 2017
expect 3D Printing to be used for high-volume production with 3-5 years\textsuperscript{28} which is a very rosy picture of the future.

- **Still significant adoption barriers** - There are still significant barriers to applying 3D Printing broadly within end-user’s production and supply chains, including long build times, high costs, poor scalability, metal tensile strength, integration of dissimilar materials and parts requiring manual production methods, and certification and testing of material safety, quality, and durability.

- **Capability acquisition** - There has been an extraordinary amount of acquisitions and strategic partnerships within the market looking to test out the advantages and applications of 3D printing technologies.

Examples:
- GE partnered with Dragon Innovation Service Bureau
- Adidas partnered with Carbon, leveraging CLIP tech to move from proto to prod
- Ford has partnered with Carbon
- Siemens took a stake in Service Bureau Material Solutions
- Aetrex acquired SOLS (custom insoles)
- Oerlikon acquired Service Bureau Citim
- GE has made many acquisitions to vertically integrate (Arcam, Concept Laser)

\textsuperscript{28}Wohlers Report, March 2018
CHALLENGES OF ADOPTION & FINANCING

Despite the hype and advancements within 3D printing and the promises of additive manufacturing augmenting or even displacing pieces of manufacturing process has not fully been materialized, at least not as quickly as many investors and founders have hoped. There are eight primary challenges that the additive manufacturing industry must address to reduce the barriers of adoption.

1. Alternative techniques with economies of scale: Given the 11+ various print methodologies, most techniques may have different approaches but overlap on use-cases, thus these companies with various techniques must fight for the market based on their unique technique differences (i.e. SLS & FDM), further splitting the market share.

   Additionally, economies of scale will always limit the manufacturing application of 3D printing. The reason being that 3D printing techniques are limited to printing a single object at a time. Other similar digital fabrication techniques such as CNC milling (subtractive manufacturing) is still far cheaper and quicker to produce objects. Lastly, when products can be quickly mass produced for a one-time setup fee – die cast or injection molding will still be more advantageous for many companies.

Exhibit: Economies of Scale

![Injection Molding vs. 3D Printing Unit Costs](image)

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29 Shapeways Magazine, High-Volume 3D Printing vs. Injection Molding, October 2017
Though companies such as GE are still finding economic benefits of 3D Printing. For example, General Electric's fuel nozzles for Turbine engines – making them lighter and cooler through the ability of printing ports within the object, allowing better overall operating economics by reducing fuel consumption based on weight. Though GE does not need to mass produce these parts, to accomplish this, GE has spent a significant amount of capital acquiring the machines and talent to operate them – by having many simultaneous prints.

**Exhibit: Economics of 3D Printing Substitutes**

<table>
<thead>
<tr>
<th>Process</th>
<th>Parts Starting at</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>3DP</td>
<td>$95</td>
<td>1 to 50+ Parts</td>
</tr>
<tr>
<td>FDM</td>
<td>Low-Moderate</td>
<td>1 to 50+ Parts</td>
</tr>
<tr>
<td>SLA</td>
<td>Moderate</td>
<td>1 to 50+ Parts</td>
</tr>
<tr>
<td>SLS</td>
<td>Moderate</td>
<td>1 to 50+ Parts</td>
</tr>
<tr>
<td>PolyJet</td>
<td>Moderate</td>
<td>1 to 50+ Parts</td>
</tr>
<tr>
<td>DMLS</td>
<td>High</td>
<td>1 to 50+ Parts</td>
</tr>
<tr>
<td>CNC</td>
<td>Parts Starting at $85</td>
<td>1 to 200+ Parts</td>
</tr>
<tr>
<td>Cast Urethane</td>
<td>Parts at $1,495 (Setup + Per Unit)</td>
<td>25 to 10,000+ Parts</td>
</tr>
<tr>
<td>Injection Molding</td>
<td>Parts at $1,495 (Setup + Per Unit)</td>
<td>25 to 10,000+ Parts</td>
</tr>
</tbody>
</table>

2. **Scale and print axis limitations:** 3D Printed objects are limited in size depending on the printer and material being used. Below is an example of the print limitations for a white plastic polyamide which has a maximum size of 677 x 368 x 565 mm (roughly 2ft x 1ft x 1.8ft).

**Exhibit: Maximum 3D Printing Sizes for a White Plastic Polyamide Object**

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30 Protolabs, Service Quotes, May 2018
31 Sculpteo, Units and Size: Understand your 3D Printing Dimensions, December 2016
In addition, print axis is a large limitation and limits the complexity of the print. Currently there is an arms race to print in five and six-axis which will allow more complex prints such as complex motherboards and PCBs, or computer parts that can curve around surfaces. However, increasing the axis also requires significant advancements in the CAD software which will requires significant R&D thus slowing down the competitiveness and rate to the market.\(^\text{32}\)

3. **Issues with accuracy, precision, tensile strength and tolerances:** The industry is still not sold on the reliability of 3D Printing techniques. Currently 3D equipment manufacturers attempts to close the gap thus far reach as much as 90% accuracy for printed objects. Objects printed that are not ‘accurate’ to design specifications occur when the materials quality is not consistent, print size is not consistent (some print techniques require post-processing techniques to strengthen the object such as sintering, which results in shrinking of the object), or there are just simply print flaws. Of course, these do not occur in casting and injection molding techniques.

Interventions are still being designed today to increase the accuracy of prints. Specifically, within the workflow management (MES) of a print machine. Several advancements in this area include visual sensors and software that monitor a print and automates control to take corrective action real-time.

4. **Not fully automated, assembly (still) required:** 3D Printing still requires skilled labor. Whereas a technician can queue up prints for production, all prints still require post processing steps which require manual intervention and adds additional steps in the manufacturing processes which drastically diminishes its value proposition. These vary depending on print type but can include curing a print, polishing surface, cutting object from the print plate, and removing and preparing print area for the next print job.

In addition to these steps, most prints today are not end products – they are commonly pieces for a product that requires assembly with other objects to create a complete product therefore still requiring assembly and not completely displacing the manufacturing process.

5. **Lack of certified and tested material properties:** As eluded to in accuracy and precision is the durability of a printed products. This depends on the quality of the printing equipment but also heavily dependent on the sources materials. Though generic commoditize materials like plastics and resins are available in the marketplace, if 3D printing were to integrated in production, an industry

\(^{32}\) 3DPrinting.com, Why 3D Printers With 5 or 6 Axes Will Be the Next Big Milestone for 3DPrinting, March 2017
manufacturer would require a higher quality of material to ensure consistency, durability, and strength. Materials with advanced properties are always proprietary and charge a market premium which will be the main driver in higher operating expenses for a manufacturer.

A significant barrier to market adopters are that most of these new materials have not been previously tested in the market for a long period of time thus exposing them to risk on how the material will perform under pressure and the life of the product. Therefore, companies are unlikely to adopt (i.e. printed metals for automotive or aerospace industries).

In response, materials companies have been applying certification tactics to help potential customers get past this issue. These companies have uniquely been ‘certifying’ their own alternative materials in the market for strength and quality (though similar properties to the commoditized material) and reaping positive sales growth while commanding higher premiums.

6. **Selling a process increases customer acquisition costs:** The single largest expense for 3D Equipment manufacturers is the customer acquisition costs. Startups and the industry giants such as 3D Systems and Stratasys are spending an enormous amounts of capital to educate them on the value proposition of 3D printing. Often these efforts require equipment manufacturers being in-house with a potential client to conduct pilot programs and tests on which items in their production process can be 3D printed. As a result, a company will need to further convince the customer to change their entire production process, which requires very costly change management, and process management – something manufacturers do not take lightly.

Given that 3D Printing is not just selling a product, but selling a process – sales requires a champion within the organization which is open and educated on the advantages of 3D printing in their processes. Once adopted, these will require a very specific skilled labor to install and operated the new 3D Printed process which is a scarce resource in the market – often leading to a trend we see with end verticals in the market making acqui-hires (bringing in the skilled workforce simply through an acquisition of a company).

7. **High implementation costs and risk of disintermediation:** Companies that consider adopting 3D printing techniques must weigh the cost and benefits of this new process. Included in the cost of a new process is the machine costs, maintenance costs, facility cost and skilled labor costs. In addition of the various 3D Printing techniques a company will have to commit to only one – especially during a time where incremental advancements in precisions, accuracy, speed and post-processing is going
the incremental and evolutionary changes. In addition, some processes, like laser sintering with powder-based materials to fuse the material together requires a lab-like environment to minimize explosions and pristine ventilation. For these reasons, it makes for a very difficult decision for a company to commit to such a significant capex expense and process & organizational change.

Another key consideration is potential disintermediation from competitors. Adopting 3D printing techniques will leave companies susceptible to market attacks from competition. For example, given a significant operating expense will be wrapped up in material costs. If a competitor were to acquire your material suppliers, they will likely increase the prices to drive up your manufacturing costs which will depress your margins or even force you to transmit the costs directly to their end customers of their products by raising prices.

8. **Powerful incumbents with deep pockets**: Many of the novel 3D Printing patents have been expiring in the past decade which has opened the market for new copy-cat products which has been poking the incumbents of these original patents.

Currently the market for 3D printed equipment and corresponding software is dominated by two incumbent companies who divide the market share, 3D Systems and Stratasys. These two were the original pioneers to selling 3D Print machines to businesses since the early nineties through their IP protected techniques. It has been very common for these two firms (especially 3D Systems) to protect their space through heavy litigation – to drive a message for new rising competitors and even forcing many to tie up their capital in litigation, resulting in bankruptcy.

In addition to protectionism techniques, incumbents with deep pockets have been consolidating the industry for new incremental techniques that simplify their product offerings and increase the speed, reliability, or accuracy.

For new entrepreneurs to win market share and scale is unlikely given the customer acquisition costs. As incumbents control the customer and are well known in the industry – potential customers will drive towards their products. Any new equipment startup in this space can hope for an acquisition from two market leaders or from strategic end-users.
SYNOPSIS OF FINDINGS IN GROWTH FINANCING

The value proposition is still not strong enough. The value proposition is strong for end market users (manufacturers) with advantages of meeting demand in a Just-In-Time (JIT) method thereby reducing carrying cost, waste, and with in-sourcing can be printed and distributed locally — increasing the efficiency of the distribution process for product orders, ultimately moving the supply chain closer to the consumer.

The attraction of build-where-you-sell (i.e. insourcing) not only decreases distribution costs but lowers the currency exchange (devaluation) and tariff exposure of the manufacture. Unfortunately, Additive Manufacturing is a process change, not an equipment change, thus requiring significant organizational and process changes. Lastly, today the equipment is not advanced enough to print complete integrated parts, thus still requiring assembly.

For these reasons, in addition the absence of new techniques on the horizon that will grow the customer base (aside from Desktop Metal), and current processes today leverage alternative techniques with better unit economics (casting & injection molding). We are unlikely to see major advancements.

Investors only look for novel advancements in high margin business models: As we analyze the value chain characteristics, the highest growth potential is solely in two areas with the largest potential profit margins, novel material IP and design software. These two areas have the potential to produce returns expected of a Venture Capital investments.

• Materials Business ~ 90% profit margins, but look for an already novel I.P., not simply a material’s shop. Often these IP’s can also reside with a unique printing technique and also develop the corresponding equipment. The key is to find a novel material that will increase adoption and reduce barriers to adoption (i.e. increases tensile strength and prints resolution for metals), and unlock recurring revenue to equipment manufacturers and end-users.

• Equipment Business – Very Low profit margins, eating margins include high cost in sales (including marketing and distribution) and continued services for the equipment. All with overlapping technologies vying for the same market share with subtle differences in technology and trade-offs in value propositions. A company attempting to drum up market share here will effectively need to be
loss-leaders with the additionally threat of the incumbent’s hard responses of litigate to set an example for every new entrant.

- Design Software ~ 90% profit margins, with recurring subscription revenue model can fund the carrying capital of a business, in addition being able to control the customer experience is optimal and can compete not just on innovative advancements to test the market (new axis design, API plugins and workflow mgmt.) but additionally there is a lot of room for advancements here and can further compete on design and interface. After-all, most engineers within R&D are using CAD software to create and visualize their products.

- Service Bureaus – Very Low profit margins with heavy capital costs, could be beneficial for PE growth financing as they work to reduce the adoption barrier for small/mid-sized companies as Service Bureaus help reduce the cost barrier but not at full production levels and therefore are unlikely scale production from parts (single pieces) to complete products especially when there are alternatives that are more economically feasible (casting & injection molding).

**Incumbents will respond by protecting their turf:** Today incumbents like 3DSystems and Stratasys are heavily capitalized and are no-longer innovating and their original patents have long since expired, opening the market to copy-cat alternatives to their techniques and competing for the same market-share. For these reasons, incumbents today (and historically) have been protective of their market share through steadfast litigation, likely to bankrupt a budding new company encroaching on their hard fought, and very expensive turf. In addition, any novel advancements that will reduce barriers to their products will be quickly acquired and removed from the market as the dominate players compete.

Through the past twenty years, these large incumbents have shifted their business models – from solely selling through resale to owning the sales process, to offering service bureau-like services for potential customers. The reason for this transition is largely in-part of educating the customer on the advantages of additive manufacturing. Incumbents have learned sales and marketing activities is extremely expensive and laborious process as they need to not only sell an equipment but an entire new manufacturing process. This, of course, is the advantage for new startup entrants.
Industry end users will lead innovation and shop it in the market: The trend for the past several years has been massive M&A activity for those companies that are looking to innovate their supply-chains through additive manufacturing. Some in the industry argue they are paying too much, however given large fortune 500 companies are well capitalized, this can easily be absorbed and still seen as a market leader.

Given this shift in activity, corporate innovation is being brought in-house, closer up the value chain so they can more easily experiment within their own supply chains and thus circumvent single equipment purchases and service bureaus all-together through acquisitions of equipment and talent. Additionally, it is expected that corporations will fully integrate their additive manufacturing needs all the way back to the materials providers as to eliminate the exposure risk of disintermediation of the competition, thus sabotaging their innovation advancements through acquiring their core materials provider (with the IP) and driving up price.

As corporate innovations will never-the-less drive new requirements and advancements of materials and equipment, it is expected that corporations will seek the market to develop solutions to their Additive Manufacturing processes, also known as the “pull method”. Leading the innovation in the 3D Print industry will result in the equipment and materials providers to compete on price. However, this will likely be a slow moving evolution process as corporate culture is typically cautious and well measured.

Novel Advancements

Additive Manufacturing

The Additive Manufacturing ecosystem is largely going through an evolutionary stage in materials, equipment, software, and business models – each aiming to reduce the barriers of production-level adoption. Though there are still some revolutionary advancements that are expected to gain buzz in the area of 3D Printing, for example;

- **Advancements in metal printing** – Currently the company Desktop metal is generating a lot of buzz (though no sales, yet) with their new techniques in metal printing. Desktop metal promises 100x reduction in costs, 10x the print speed, and increased strength, resolution, and reliability.
• **Integrated material techniques and PCB chipset advancements** – New processes have been coming out on pushing out print capabilities for integrated materials. Given the day when assembly will not be required for multiple materials by integrating plastics and conductive materials, new applications can be profound, especially in PCB Chipsets.

• **Applications in construction, new materials on additional axis** – It is very plausible that 3D Printing can begin having a significant impact in the construction business. New advancements in materials quality and more flexible techniques can allow for uniquely printed structures (ex., curves). Though unlikely to totally displace construction techniques anytime soon but may first evolve into printing certain inputs on-site, reducing high logistics costs.

**Mass Customization & New Marketplaces**

Not all breakthrough technologies in 3D Printing will apply to the manufacturing marketplace, therefore reducing many of the adoption challenges within the market. Through Mass Customization/on-demand print services, custom anything that brings the supply chain closer to the consumer will be a significant advancement in the industry, the following are several areas showing promise today;

**Mass Customization**

• **Biotech** – Further advancements in driving healthcare advancements that printed objects are unique to the consumer, whether it be cell based organ or bone-like structures. There is without a doubt a large market, however limited by the slow regulatory FDA testing and approval processes.

• **Printed Food** – Today several startups are printing hamburgers to customized pastries with designs. There is potential that other food alternatives may be printed for novel and personalized enhancements to your dinning out experiences.

**New Marketplaces**

• **Printable File libraries** – As printable file libraries become more accessible, this can drastically reduce the need for companies to keep slow moving assets on-hand while incurring high carrying costs. For example, emergency repair parts on a freighter, or automotive parts replacements for expired, vintage models. This will only require either access to a local fab-lab print facility with a print-per use and service charge or a company owning the 3D Print equipment in-house.
CONCLUSION

Much like the relationship with Venture Capitalists and Clean-tech, we cannot expect an economic windfall in Additive Manufacturing. While there are many skeptics 3D Printing will break out of prototyping and pre-production processes, there are, however, many others that believe that 3D printing is enjoying a new renaissance and is currently at an inflection point.

The largest underlining deterrent to market adoption is the simple fact the industry is not only selling enterprises a machine or service – but rather an entirely new design and manufacturing process all together. Additional adoption challenges including:

1. Alternative techniques with economies of scale
2. Scale and print axis limitations
3. Issues with accuracy, precision, tensile strength and tolerances
4. Not fully automated, assembly (still) required
5. Lack of certified and tested material properties
6. Selling a process increases customer acquisition costs
7. High implementation costs and risk of disintermediation
8. Powerful incumbents with deep pockets

In addition to just overcoming these challenges, for companies to secure growth funding – they will have to consider the following market forces.

1. The value proposition is still not strong enough
2. Investors will only look for novel advancements in high margin business models
3. Incumbents will respond by protecting their turf
4. Industry end users will lead innovation and shop it in the market

Although 3D Printing is unlikely to revolutionize additive manufacturing in the near future, there are still some novel advancements investors should take a second look at for opportunity and return.

1. Advancements in metal printing
2. Integrated materials techniques and PCB chipsets advancements
3. Applications in construction, new materials on additional axis
4. Mass customization in the way of bio-tech and printable food techniques
5. New marketplaces and printable file libraries
BIBLIOGRAPHY


### Exhibit: Additive Manufacturing Ecosystem Research

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<td>- Managed Networks</td>
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<td>- Cast</td>
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**Notes:**
- Forecasts indicate global market for 3D prints will hit $12B by 2020.
- Consolidations with Material Providers: Carbon Technology / Form (access to titanium powder)
- Acquisitions for Materials Advantages: 3D Systems
- New Material Breakthroughs: 3D printing with polymer-derived ceramics
- New Technologies & Processes: Rapid Process Deposition (Metal)

**References:**
- Various sources including 3D Printing World, Forbes, and Industry Week.