Key Trends and Developments in the Additive Manufacturing Startup and Technology Landscape

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ABSTRACT

Innovation in additive manufacturing has expanded in recent years with major developments arising in printable materials, printing technologies, and software. Startups are the most indicative group of innovators in additive manufacturing. Tracking and analyzing the startup landscape helps identify emerging technologies and market dynamics in order to develop strategic plans that best leverage additive manufacturing. By getting detailed information from startups and analyzing them on a range of quantitative and qualitative factors, innovation grids are created that detail startup activity in a particular segment. Grouping startups in this fashion shows leaders and laggards, indicates the maturity and promise of a technology category such as stereolithography, and reinforces or refutes partnership considerations. Major trends including material feedstock form factor, the emergence of desktop professional printers, and printable composite materials are illustrated with examples, and their strategic implications are discussed.

Keywords: additive manufacturing, 3D printing, printable materials, startup, innovation

1 INTRODUCTION

Advanced materials, design tools, and manufacturing technologies are perpetually in pursuit of producing better parts and products, faster, and at lower cost. Predicting which emerging technologies will be successful in these categories early on gives business leaders, investors, and other stakeholders time to develop strategies that leverage impending innovations. Startup companies form to use innovation in two different ways to generate profit: first, there is a technical innovation that can disrupt an existing market or help create a new one, or second, there is a recognized market demand that needs an innovation to be addressed appropriately. These approaches are not mutually exclusive, but can be used to delineate the two general categories by which Lux Research assesses startups.

This study considers the additive manufacturing landscape primarily from the perspective of key strategic and financial stakeholders in corporate, government, and non-profit organizations. The additive manufacturing value chain is complex with intricate tiers of material and chemical suppliers as well as end users of the systems. For the purposes of defining the value chain in a straightforward manner, the key players are simplified by category and illustrated in Figure 1 below.

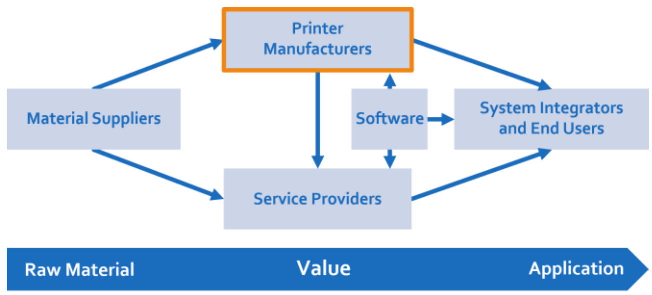

Figure 1: Simplified Additive Manufacturing Value Chain

The printer manufacturers are the most prominent and technically differentiated category in the value chain, and as a result are used as the lens through which this research organizes additive manufacturing startups.

2 METHODS

Lux Research, an independent research and advisory firm, provides strategic advice and ongoing intelligence on emerging technologies across Materials, Digital, Energy, and Health sectors. A foundational aspect to researching emerging technologies is based on a validated framework for assessing startup companies. The process involves a technical analyst-conducted in-depth interview with a startup founder or executive, follow-up discussions and secondary research analyzing competitors, funding, and patent data, and writing a company profile with a detailed scorecard rating system. The scorecard metrics and other profile components take into account the technical value, business execution, maturity, and stage of commercial development that is summed up in an overall Lux Take. The scorecard metrics are on a least favorable to most favorable one to five scale, and the overall Lux Take is similarly described as Strong Caution, Caution, Wait and See, Positive, or Strong Positive [1].

The data and analysis carried out on select startups is represented on a Lux Innovation Grid, which plots startups based on composite technical value and business execution scores, and represents each with a colored circle where the diameter represents a maturity score and the color represents the overall Lux Take as seen in Figure 2.

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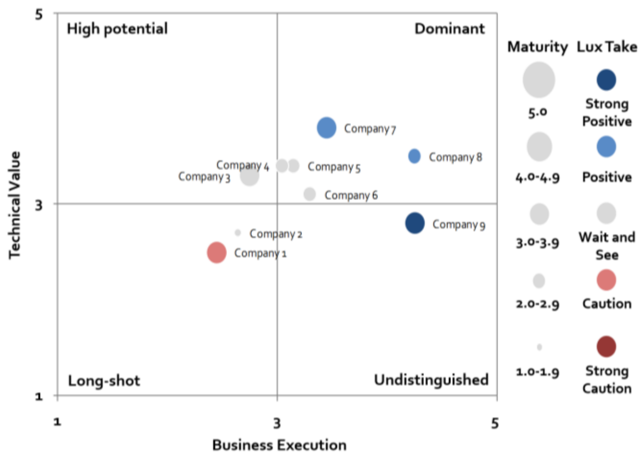

Figure 2: Lux Innovation Grid

Each of the quadrants characterizes a startup according to its position on the grid, with high potential being more desirable from an investment standpoint, and undistinguished or dominant from a partnership or acquisition standpoint depending on maturity.

3 RESULTS AND DISCUSSION

The additive manufacturing landscape continues to expand and diversify in an effort to capture a wider range of market segments through application specificity and price differentiation. There are numerous dominant as well as high potential companies that give additive manufacturing its present day technical and market diversity. The companies depicted in Figure 3 maintain either sales, service provider, or some combination of the two business models. Neither business model presents a significant advantage in terms of position on the grid or on Lux Take. The average circle diameter increases for companies from left to right in accordance with business execution. Similarly, Positive companies are found in the high-potential and dominant quadrants because they tend to have high business and technical scores.

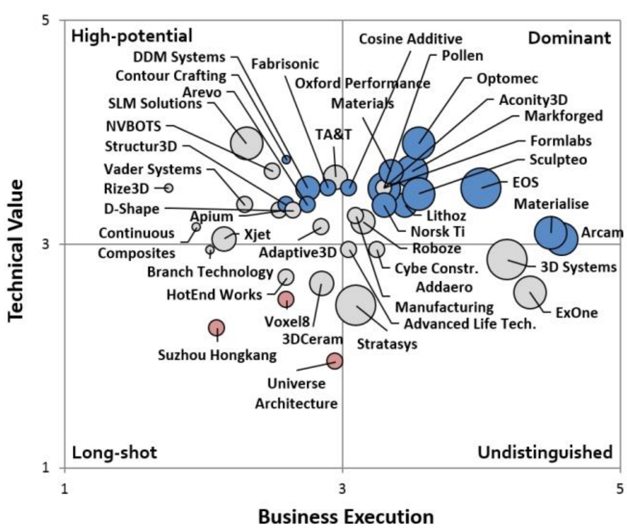

Figure 3: Additive Manufacturing Landscape (selected companies)

From an aggregate standpoint, less mature companies such as NVBOTS, Pollen, or Cosine Additive with a Wait and See or Positive Lux Take are likely to be appealing early-stage technology partners or technology-motivated acquisition targets. Companies clustered in the middle of the grid like Advanced Life Technologies, Voxel8, or Roboze are not as well differentiated, making them less attractive from an acquisition standpoint but may be well suited to grow through business development partnerships with corporate partners. A few established additive manufacturing players such as Stratasys, 3D Systems, Arcam, and Materialise are included as a point of reference for the promising overall startup landscape. This positive landscape has emerged due to a combination of technical and business trends that enabled startups to grow and compete with established players.

3.1 Desktop Professional 3D Printers

Additive manufacturing companies have traditionally catered to two types of customers: industrial users demanding dependable and capable equipment, and hobbyists looking to tinker and print items for personal use. Technology providers aligned with these two use cases have positioned equipment offerings at a sub-$2,000 price point, or in the $50,000 to $1,000,000 range with typical systems priced in the bottom quartile of this range. In recent years, a decrease in the cost of high-end hardware in conjunction with the availability of cloud software services has reduced the development costs associated with bringing a complex hardware plus software system such as a 3D printer to market. As a result, 3D printing startups pushing the limits of available technologies are finding it more economical to develop quality hardware and software that performs nearly as well as, or in some cases better than, the industrial systems yet at two to ten times lower cost.

A desktop professional system is priced between $2000 and $15,000 to target small business and industrial users that do not require large build volumes or very high throughput capabilities. The lower cost allows users to buy printers as needed, saving significantly on the upfront capital investment. Applications benefiting from these systems include dental surgical guides and appliances, investment casting for jewelry, aesthetic model making in entertainment, and a range of prototyping, molds, and tooling use cases in product development and education. A prime example of a desktop professional 3D printing company is Massachusetts-based Formlabs. The company's $3500 Form 2 is priced in the sweetspot of what has emerged as the desktop professional 3D printing segment, and offers nearly identical layer resolution, consistency, and print speed to industrial printers priced an order of magnitude higher.

Formlabs has doubled in sales and employee count annually for the last three years, and is just one strong indicator of the growing demand for affordable, capable, and reliable printers. There are a number of startups, and some established players like 3D Systems, that have developed systems priced to compete in this growing market segment (see Table 1).

Manufacturer	Model	Price	Technology
Apium	P155	$ 30,160	FFF
Roboze	One	$ 7,570	FFF
Roboze	One +400	$ 43,240	FFF
Markforged	Onyx One	$ 3,500	FFF
Markforged	Onyx Pro	$ 7,000	FFF
Markforged	Mark Two	$ 13,500	FFF
Pollen	Pam	$ 17,300	FFF
Rize3d	Rize One	$ 24,000	FFF
NVBOTS	NVPro	$ <20,000	FFF
Structur3D	Discov3ry	$ 5,000	FFF
Voxel8	Developer Kit	$ 9,000	FFF
Stratasys	BST 1200es	$ 24,900	FFF
Stratasys	uPrint SE	$ 13,900	FFF
Stratasys	Mojo	$ 5,600	FFF
3D Systems	Cubepro	$ 4,399	FFF
3D Systems	Projet 1200	$ 4,900	SLA
Formlabs	Form2	$ 3,500	SLA
Autodesk*	Ember	$ 7,500	SLA (DLP)
Asiga*	PICO2	$ 7,000	SLA
Stratasys	Objet24	$ 18,000	Material jetting
Stratasys	3Z Studio	$ 24,600	Material jetting
Sintratec*	Kit	$ 5,390	SLS
Mcor*	Arke	$ 9,000	SDL
Printing Technologies: FFF = fused filament fabrication, SLA = stereolithography, DLP = digital light processing, SLS = selective laser sintering, SDL = selective deposition lamination			
*Not shown on innovation grid			

Table 1: Desktop Professional 3D Printers by Technology [2]

Other notable companies include Markforged, which has developed chopped fiber-reinforced and/or continuous fiber reinforced nylon 3D printers, and Mcor, which has developed a lamination deposition process using paper and adhesive. Some systems in Table 1 are clearly outside the desktop professional price range but are listed as points of reference when considering what the next tier is in terms of price and specifications. Roboze had its model One FFF 3D printer on the market for well over a year before it released a second printer with a wider range of material capabilities, but at a significant price increase. There are no desktop professional metal printers on the market to date because the equipment and extreme processing conditions required in sintering or otherwise binding metal together are still cost-intensive and pose a larger safety concern than FFF or SLA systems do to end users.

Some of the most promising desktop professional startups and their more established direct competitors are plotted in Figure 4. With the exception of Voxel8, all the

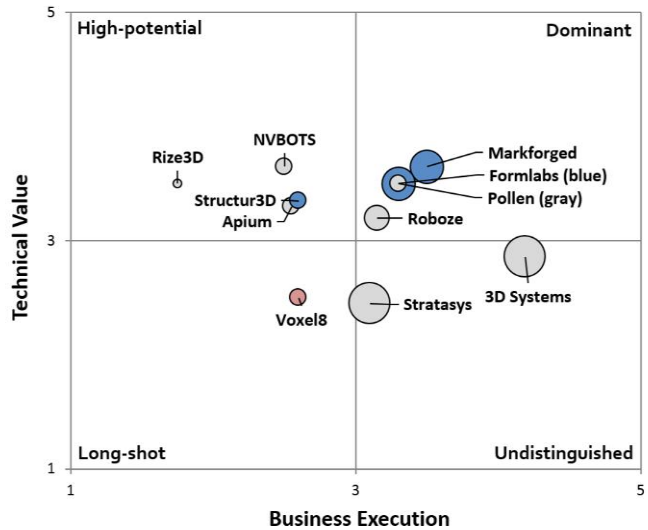

Figure 4: 3D Printing Companies Offering Desktop Professional Printers

startups interviewed have a technical value score above three, but are distributed across the business execution spectrum. This particular combination of trends suggests that the desktop professional market segment is near the midpoint of its growth cycle. The early entrants have led this market segment's growth and staked out their claims with intellectual property and respectable sales, while others are still finding product-market fit with their promising technologies. Stratasys and 3D Systems are participating in this segment to try and maintain their market dominance, while Autodesk's open source 3D printer and software provide a truly development-friendly platform for the desktop professional market.

3.2 High Performance Thermoplastic and Composite 3D Printing Capabilities

The same reasons that the desktop professional 3D printer came about (quality low-cost hardware and cloud-based software services) have also driven startups to develop unique value propositions around printable materials. Thermoplastics have long since been the most popular printable material, with low cost options such as polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) becoming the default for many prototyping and less mechanically demanding applications. Two key materials trends have emerged to deliver additional value in the FFF 3D printing technology category: high performance thermoplastics (HPTP) (those with a glass transition temperature above 150 °C) and fiber-reinforced polymer matrix composites. Figure 5 illustrates the relatively high technology value for startups innovating in either category, with composite materials leading in terms of companies with a Positive Lux Take.

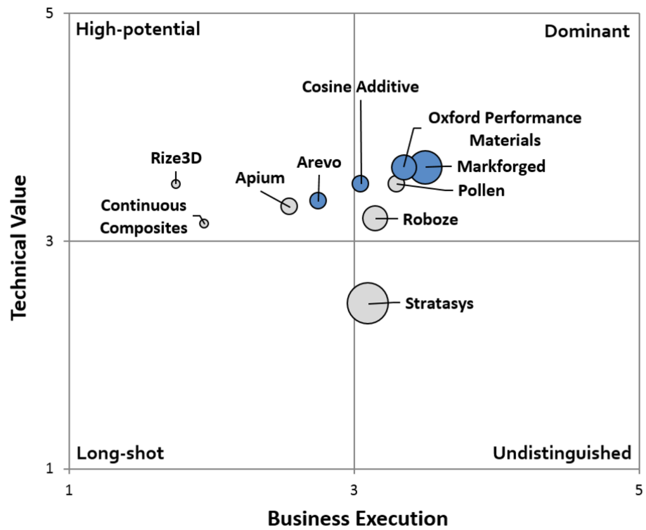

Figure 5: HPTP and Composite 3D Printing Material Developer

HPTPs such as polyetheretherketone (PEEK), polyetherketoneketone (PEKK), and polyetherimide (PEI) are often used in high strength and/or higher temperature applications in aerospace, medical, and the oil and gas industries. Some of these HPTPs require extrusion temperatures approaching 400 °C and precise control to maintain desired properties such as percent crystallinity. Startups offering FFF systems using HPTPs include Roboze, Apium Additive Technologies, and Stratasys (for PEI only). Oxford Performance Materials uniquely offers selectively laser sintered PEKK parts as a service provider. Pollen offers a somewhat unique multimaterial 3D printing technology that can combine up to four materials using a single nozzle, intended for multimaterial consumer products such as customized sunglasses.

Fiber-reinforced polymer matrix composites have become increasingly popular because the use of a low cost chopped fiber filler imparts improved mechanical properties and significantly reduces warping of lower grade plastics during printing. Cosine Additive offers a larger format printer that is possible thanks to up to 10% chopped carbon fiber inclusion in its thermoplastic filaments. To further increase mechanical performance for molds, tooling, and final part applications, Arevo Labs, Continuous Composites, and Markforged each have developed continuous fiber-reinforced 3D printing technologies that reinforce a polymer matrix with carbon, glass, or Kevlar fiber. While Markforged uses nylon as the matrix polymer, Arevo Labs uses HPTPs such as PEEK for aerospace applications, and Continuous Composites uses a fast-curing UV thermoset that allows for printing without supports and the inclusion of conductive or optical fibers for sensing applications.

3.3 Material Form Factor Diversification

In addition to new printable materials options, startups are looking to further differentiate their offerings through reduced material costs. The first group of startups are using standard materials in a less expensive form factor directly in their systems. For example, Vader Systems and NVBOTS are developing wire feedstock metal printers because the cost per kg of powder is two to ten times that of the equivalent metal wire. Both companies are still developing their systems, but look to compete with more established direct metal laser sintering systems from established players such as EOS. Within polymers, Pollen's nozzle design enables use of thermoplastic pellets directly in its printer, saving on material cost.

The second group of startups have developed small scale thermoplastic filament extruders. For \$700 to \$3500, 3devo and Redetec enable end users to buy pellets in bulk and produce their own filaments for FFF 3D printing. This disrupts the traditional supply chain and saves the user from paying the mark-up put on ready-to-use filaments, but cannot be used on all FFF systems because some manufacturers void equipment warranties when third party resins are used.

4 STRATEGIC OUTLOOK

Assessing additive manufacturing startups using technical and business metrics gives insight into emerging technology and market trends. The desktop professional market segment is growing and will continue to expand into new markets, like dental, that are not ideally suited to more expensive industrial printer models. Innovation in printable materials differentiates startup value propositions, and expands 3D printing's applicability to include structural aerospace composites and multimaterial product manufacturing. Cost savings from less expensive form factors reduces per part costs and the payback period for a printer, also expanding the number of cost-effective applications for 3D printing.

For those looking to employ additive manufacturing's benefits in supporting part development, or for final part or product printing, there are now more performance-oriented options and more reduced cost options available. For those looking to invest, consider startups in the high potential quadrant due to their high technical value and earlier stage of development. For those looking to partner, consider startups in the undistinguished or dominant quadrants only after taking into account maturity Lux Take, and the above trends.

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