Brian Cleary
3D Systems and Additive Manufacturing
NAICS Code: 334111, Electronic Computer Manufacturing

Overview and Introduction Additive Manufacturing:

In the sixteenth century, Michelangelo said, 'every block of stone has a statue inside it and it is the task of the sculptor to discover it (BrainyQuote.com). Michelangelo's process of chipping away pieces of marble until David revealed himself is like traditional manufacturing techniques. Additive manufacturing (AM or 3D printing) offers an alternative. In the Economist's *The Printed World,* the article describes how AM begins by with a 3D image created with computer-aided design software (CAD). The CAD program slices the 3D image into thin layers—this allows a 3D printer to begin replicating this item by adding layer-by-layer of material in an additive process (Diagram I). This is unlike the subtractive methods of cutting and drilling because the printed object is ready-made. Software programs allow designers to instantly send digital designs to 3D printers anywhere in the world—requiring less transportation, component assembly and raw materials.

In *Economic Implication of Additive Manufacturing and the Contribution of MIS*, Thiesse describes flexibility and efficiency as the two major dimensions of traditional manufacturing. Flexibility describes how quickly a company can react to changing demand or produce a wide arrange of products. Efficiency refers to the maximization of output while minimizing inputs (cost and time). To maximize flexibility for customizable products, manufacturers begin production after the customer places an order as each item is unique. To maximize efficiency, manufacturers rely on standardization and automation to produce items in bulk at the lowest cost. Manufactures can choose production strategies between the extremes or at the extremes; however, a trade-off between efficiency and flexibility is inevitable.

Additive manufacturing offers the potential to simultaneously increase both constraints. In *Additive Manufacturing: Making Imagination the Major Limitation,* Zhai describes consequences of this paradigm shift—superior design, geometric flexibility, multi-material fabrication, reduced retooling, shorter lead time, instant local production at a global scale and material, energy and cost efficiency. Superior design and geometric flexibility can be achieved because the digital models are free form and allow for complex shapes to emerge as the printer head deposits the material where needed, layer-by-layer. Lead time attributed to molds and re-tooling drop sharply because printer heads do not require molds or retooling with design change. Printers have increased efficiency by reducing material usage by up to 75% and local production allows ready-made products to be produced anywhere (808-810). For example, GE announced that it would use AM to build up to 25,000 fuel nozzles for Airbus Group's A32 panes' LEAP jet engines. GE used AM to design more complexity into the fuel nozzle while reducing it from a 20-piece unit that required assembly to a one-piece unit that does not. This 'design-to-process' allowed for weight reductions per unit, and decreased material and labor costs, while improving performance (Wray, pg. 20).

Industry Characteristics:

The roots of additive manufacturing can be traced back 150 years to the fields of photo-sculpture and topography (Zhai, 809). In *The History of 3D Printing,* the first 3D printing patent was issued in 1986 to the co-founder of 3D Systems for stereo lithography apparatus (SLS). In the 1990's, Stratasys developed fused deposition modeling process, which allowed for freeform fabrication of metal objects. Beginning in the 1990's the industry began to diversify between expensive commercial printers capable of high value, highly engineered, complex part production and lower-end printers designed for functional prototyping. AM is a relatively new industry as the commercialization of AM did not even begin until 1986—although it is beginning to move beyond the experimentation by early adopters to industry-specific solutions and applications (Silver).

Market Structure:

The classification for 3D Systems is either electric computers (SIC 3571) or electronics computer manufacturer (NAICS code 334111). In *Managerial Economics,* Hirschey defines several characteristics of oligopoly markets that are found in AM—few sellers, blockaded entry, imperfect dissemination of information, and the opportunity for economic profits in the long run. Few firms' indeed produce the bulk of output in the AM industry—3D Systems and Stratasys made up 85% of the 2014 revenues (see Table I and Chart I). These two companies are effectively the AM market and I compare them rather than use all companies in computer manufacturing because most have nothing to do with AM.

According to Silver, barriers to entry in AM include printer technology and patents—3D systems holds 1,300 patents. In *Additive Manufacturing—Turning manufacturing inside out,* Peter Wray attributes the recent popularity of AM to a reduction in a key barrier to entry. In 2009, Stratasys' patent for fuse deposition modeling expired which lowered a key barrier to entry for competitors. Makerbot, a producer of desktop machines, reduced system prices by as much as 90% upon expiration. Information for customers is not easily available in AM due to rapidly changing technology—early adopters cannot know the long-term durability of the finished products yet. The opportunity for long run, economic profits are possible as brand and product differentiation, patent protection and first-mover advantage are distinct competitive advantages. Wray quotes industry expert Terrence Wohlers to put AM's recent growth into perspective, 'It took the 3D printing industry 20 years to reach $1 billion in size. In five additional years, it generated its second $1 billion (18-19)'.

3D Systems:

According to Silver, 3D Systems offers the "broadest array of commercial 3D Printing technologies by a wide margin". In 3D System's 2014 Annual Report to shareholders, the firm details the breadth of materials its printers can utilize—plastics, ceramics, metals, and even, edibles. Multiple product lines offer printers of varying quality and prices that range from $1,000 to over $1M, respectively. Management is pursuing a growth strategy in five key business areas—manufacturing, metals, medical, materials and Main Street. In 2014, the company's manufacturing business unit launched several industrial 3D printers with increased speed, print capabilities and material selection (10-K, 28-32). According to Silver, a competitive weakness is within the metal-based printing business unit; however, the company acquired Cimatron and LayerWise to improve the designed-for-manufacturing CAD/CAM software and increase its metal-based printing material patents, respectively (Silver). The healthcare business, which provides end-to-end simulation, modeling services, digitizing scanners, and simulation products, was the fastest growing business unit in 2014. The acquisitions of Medical Modeling, Simbionix and LayerWise improved the competitive advantage in personalized surgery and personalized medical and dental devices (2014 10-K, pg. 31).

Financial Performance 2010-2014:

3D systems financial performance over the five-year period (2010-2014) reveals a mixed bag. For example, revenues in the last 5 years grew from $112 to $653 million (Chart 5). From 2009-2014 revenues from all four geographic areas increased (2014 10-kK, Pg. 16). Asia Pacific showed the most promise by leapfrogging Germany and Other EMEA countries to move from 4th to 2nd place (Table II and Chart II). Approximately 50% of revenues occur internationally, which increases the diversification of the revenue stream and allows for a global reach; however, this increases exchange rate risk. The recent strengthening of the US Dollar relative to other currencies made 3D Systems products and services more expensive for international customers (2014 10K, F-13). A bright spot was that the debt ratio improved from 36.36% to 15.27% over the same period—therefore liabilities have paid for a much smaller percentage of the assets.

Year-over-year revenue growth has grown at a decreasing rate over the past 5 years from rate of 41.68% in 2010 to 27.23% in 2014. Since it is more difficult to grow by the same rate year-over-year as any company becomes larger, ROE and ROA are better measurement. According to Hirschey, ROE tells us how profitable a company is and ROA tells captures the effect of managerial decisions (452). Discouragingly for shareholders, over the 5-year period, ROE decreased from 16.46% to 1.05% and ROA decreased from 10.89% to .89%. To put this into perspective, Hershey states that an ROE needs to consistently fall above 10% to compensate investors. Over the 5-year period, revenues grew and COGS decreased from 53.73% to 51.44%; however, soaring operating expenses had a negative effect on earnings (Table II and Table III). Net profit margins decreased from 12.24% to 1.78% due to increased operating expenses for sales, general and administrative (SG&A) and research and development (R&D)—SG&A increased from 26.48% of revenues to 33% and R&D increased from 6.71% of revenues to 11.53% from 2010-2014. From 2013–2014, SG&A increased by $74 million due to increased sales and marketing expenses and higher staffing costs ($34 million labor and $18.7 amortization). From 2013-2014, R&D increased by $31.9 million due primarily to $17.7 million related to R&D labor and talent acquisition costs (Table III). Since Stratasys and 3D Systems make up 85% of the industry revenues, a comparison to Stratasys reveals industry challenges rather than company specific issues. By comparing revenues, net income and ROE for the two companies, we see both firms had similar increasing revenues, decreasing net incomes and decreasing ROE in 2010-2014 (Charts III, IV, V).

Aggressive merger and acquisition strategies help to explain the recent challenges faced 3D Systems. To dominate the AM market, the firm has attempted to fill gaps, upgrade technology, and improve R&D to become a one-stop solution (Silver). A growth strategy has led to a flurry of acquisitions—according to Sharma in *3 reasons for 3D printing stocks' correction,* 3D systems acquired 48 companies in the past 5 years. Although 3D Systems has not yet written down goodwill from the 2012-2014 acquisitions, it is too early to know if the company priced the acquisitions properly (2014 10K, pg. F-11).

3D systems will need to maintain customer relationships inherited from the acquired companies, while simultaneously controlling policies and procedures for a global company comprised of different cultures (2014 10K, pg. 14-15). Part of the attraction to the one-stop shop AM provider is that 3D systems can offer clients printers at lower margins then charge higher margins on services and materials. Materials generate a consistent future revenue stream and gross margins are 20-30 percentage points higher than hardware (Silver).

Future Competition:

Although Stratasys and 3D Systems currently enjoy high market dominance, competition is intensifying. A risk to the incumbents is that competitors, existing or future, will patent better technology that results in superior 3D printers. In 2014, some of 3D Systems patents expired which lowered a barrier to entry for imitators. Unlike Stratasys's expired patents, 3D System's expired patents relate to high-end commercial printers that are at less risk than the low-end desktop models (Silver). R&D spending has increased as the company attempts to develop patents that can help the company sustain long-term economic profits by creating barriers to entry with intellectual property rights.

In *HP's 3D Print Breakthrough Could Push Rival 'Out of Business',* Anders describes Hewlett Packard's intention to manufacture 3D printers. HP, a behemoth of 2D printing, will enter the 3D printing market in 2016. By tinkering with its existing inkjet technology, HP's 3D printers are 10 times faster and maintain precision equal to half the width of a strand of silk (Anders). Unlike HP, another deep-pocketed incumbent in 2D printers, Cannon Systems, decided to form an alliance with 3D Systems rather than build hardware itself (Hipolite).

Future Macroeconomic Challenges:

In *3D Systems Announces Preliminary, First Quarter 2015 Results,* President and CEO Avi Reichental describes macroeconomic forces influenced the 2015 1st quarter results. According to Reichental, customers deferred planned capital expenditures for 3D printers due to a strengthening U.S. dollar that made hardware relatively more expensive for non-domestic clients. With the Federal Reserve Bank ever more likely to increase interest rates from historic lows, the US Dollar is likely to strengthen. Furthermore, Reichental described lower oil prices as a reason for decreased capital investment of 3D printers by clients in the aerospace and automotive industry. Unfortunately for Reichental, there is no indication that oil prices will rebound anytime soon. In the *"Oil Prices: What's Behind the Drop? Simple*

Economics", Krauss describes that ever since a 2014 meeting in Vienna, the OPEC cartel has opposed reducing production. With a surplus of oil, prices have halved—if OPEC members chose to reduce supply, prices would increase, as the reduction would shift the supply curve left along the demand curve.

Estimates for long-term annual growth in the 3D printing industry is 25% or more (Silver). Despite 3D System's historical market share in the 3D printing industry and the growth potential of this fledgling industry, the next few years will be critical. If 3D systems can fend of existing competitors (Stratasys) and new competitors with deep pockets (HP), rewards to shareholders will be generous. To do so would require integrating numerous acquisitions successfully and reestablishing establishing barriers to entry (patents), while simultaneously confronting macroeconomic headwinds (strong dollar and cheap oil).

3D Printing will continue expand as prices decrease and technology allows forever-greater possibilities. Cost saving from less wasted material will be an important factor should material or transportation prices rise sharply. For example, in *3D Printing Helps Robotic Marble Sculptors Push the Limits of Digital Manufacturing,* Sher describes a marble-based filament that can be used with 3D printers. If Michelangelo were alive today and faced increasing marble or transportation costs, he could e-mail a CAD design of David to a 3D printer anywhere in the world to offset material and transportation costs. The printer would locally create marble statue with a marble-based filament of David starting at the feet and working his way up to the head—resulting in the same statue but with hollow chamber inside reducing inputs and transportation costs.

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Appendix

Diagram I

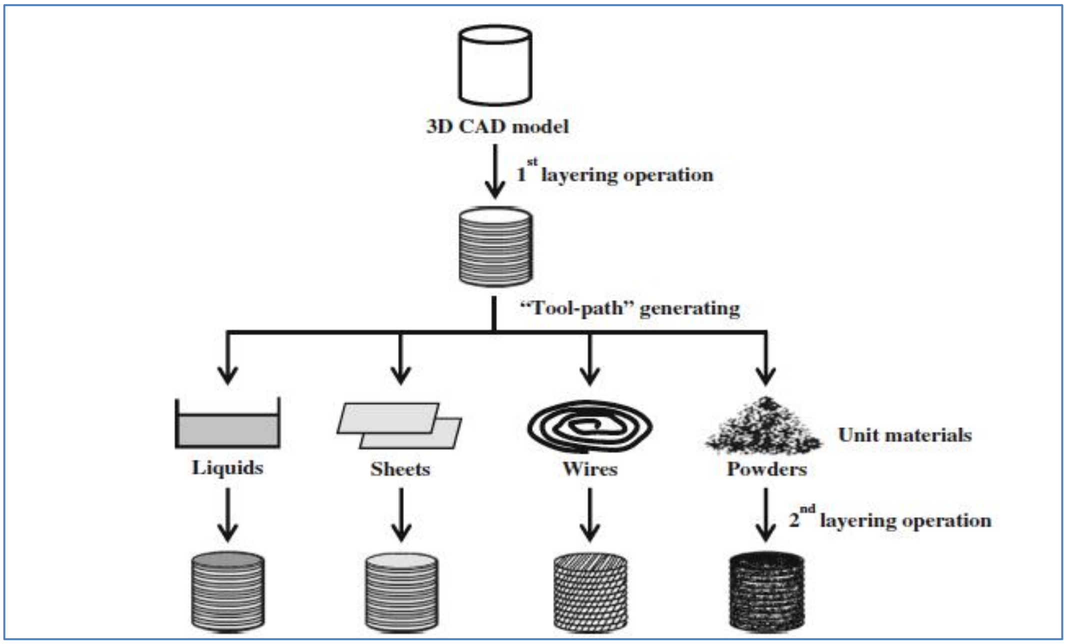

Chart I

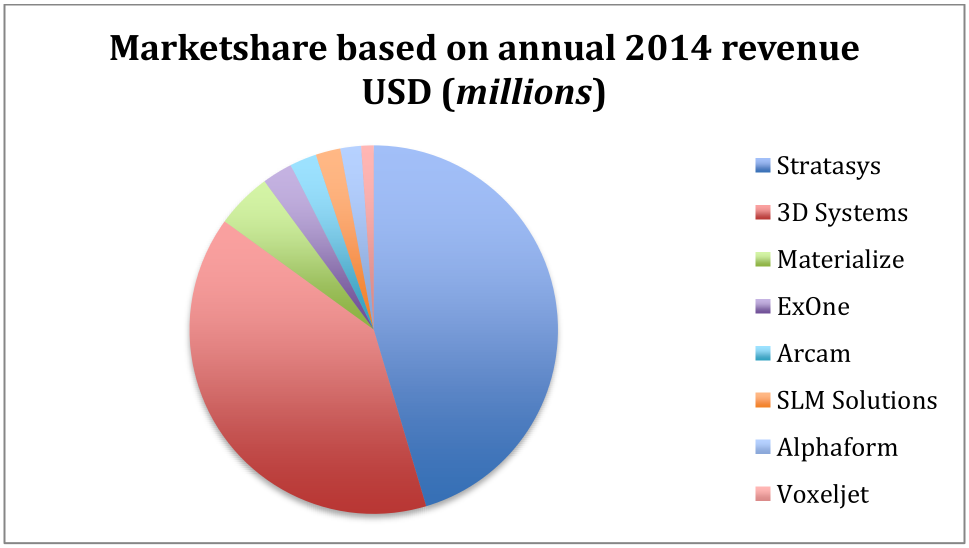

Table I

Revenues 2014		
Market Share	*(Million)*	
Stratasys	$750	45%
3D Systems	$654	40%
Materialize	$81	5%
ExOne	$44	3%
Arcam	$39	2%
SLM Solutions	$36	2%
Alphaform	$30	2%
Voxeljet	$18	1%
Total Revenue	$1,652B	100%

Chart II

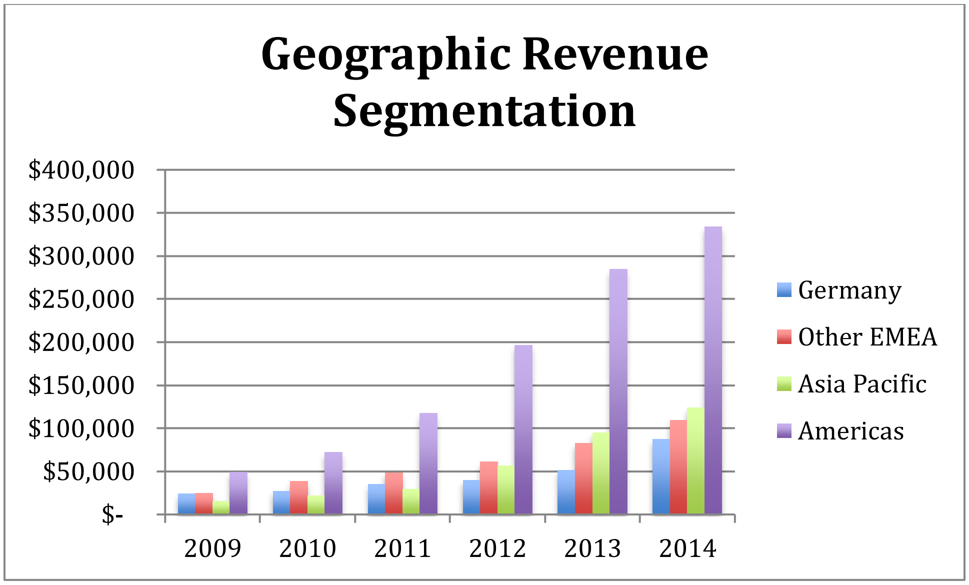

Table II

Geographic Percentage of Revenue Segmentation 2009-2014
Market Share (Thousands)

	2009	2010	2011	2012	2013	2014
Americas	31%	45%	51%	56%	81%	51%
Germany	15%	17%	15%	11%	14%	13%
Other EMEA	15%	24%	21%	17%	23%	17%
Asia Pacific	9%	14%	13%	16%	27%	19%
Annual Revenue	71%	100%	100%	100%	145%	100%

Table III

3D Systems - Ratio Analysis

	2010	2011	2012	2013	2014
Profitability	%	%	%	%	%
YOY Revenue Growth	41.68	44.13	53.47	45.18	27.32
SG&A (% of revenue)	26.48	25.95	27.55	27.90	33.00
R&D (% of revenue)	6.71	6.22	6.56	8.47	11.53
COGS (% of revenue)	53.73	52.68	48.76	47.88	51.44
Operating Margin	13.09	15.15	17.13	15.75	4.03
Net Profit Margin	12.24	15.37	11.01	8.59	1.78
ROE	16.45	18.26	10.59	6.24	1.05
ROA	10.89	10.55	6.83	4.97	0.89
Liquidity					
Current Ratio	1.74	4.43	3.82	4.77	3.91
Debt Ratio	36.36	44.92	29.1	15.03	15.27

Chart III

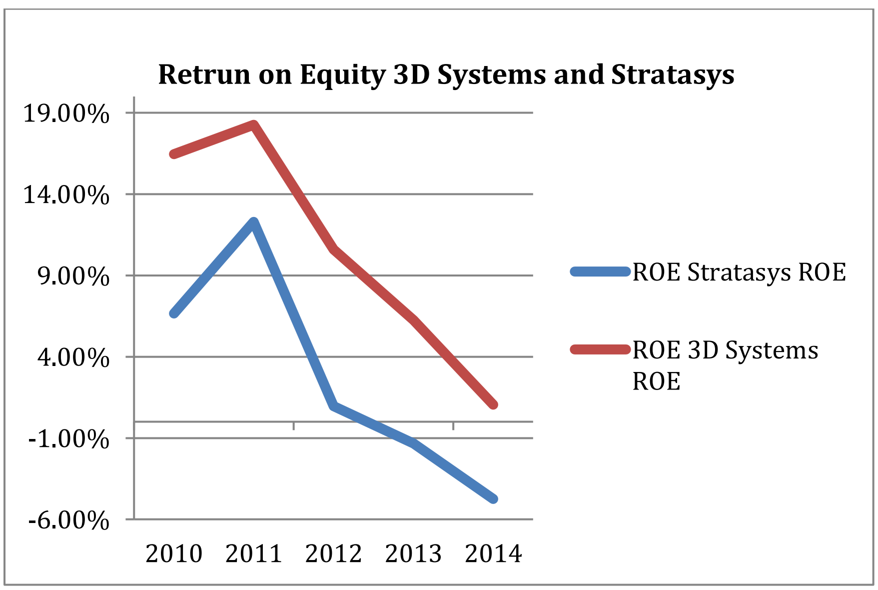

Chart IV

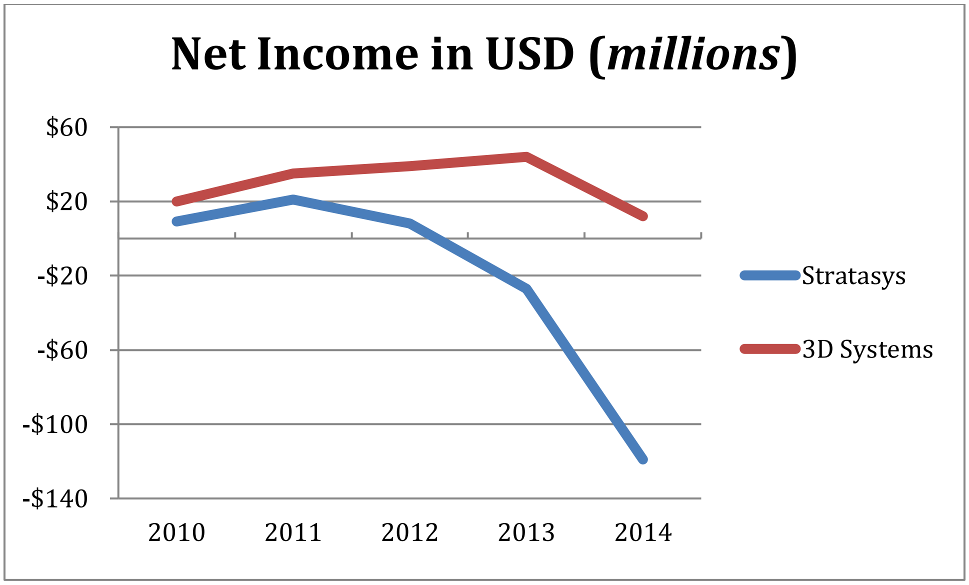

Chart V