U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON ENERGY AND COMMERCE

February 24, 2016

TO: Members, Subcommittee on Commerce, Manufacturing, and Trade

FROM: Committee Majority Staff

RE: Hearing entitled "The Disrupter Series: 3D Printing"

I. INTRODUCTION

On February 26, 2016, at 10:00 a.m. in 2123 Rayburn House Office Building, the Subcommittee on Commerce, Manufacturing, and Trade will hold a hearing entitled "The Disrupter Series: 3D Printing."

II. WITNESSES

- Alan Amling, Vice President, Global Logistics and Marketing, United Parcel Service, Inc.;
- Dr. Edward Herderick, Additive Technologies Leader, GE Corporate Supply Chain and Operations;
- Neal Orringer, Vice President, Alliances and Partnerships, 3D Systems Corp.; and,
- Ed Morris, Vice President and Director, America Makes, the National Additive Manufacturing Innovation Institute National Center for Defense Manufacturing and Machining (NCDMM).

III. BACKGROUND

Three-dimensional (3D) printing, or additive manufacturing, refers generally to the process of taking a digital, computer aided design (CAD) model and instructing a printing device to recreate the model by adding material together. This is distinct from typical part manufacturing, which typically involves a process of reducing raw material down to a desired shape using machine tooling and casting methods.

The first 3D printing, or additive manufacturing, methods took shape in 1984.[1] Since then, additive manufacturing has taken off, especially in recent years, due to advances in printing processes and the software that enables the printing process. These advancements in turn have fueled an expanding set of uses for additive manufacturing. Surveys have shown that a large

[1] "A Brief History of 3D Printing," T. ROWE PRICE CONNECTIONS, *available at* http://individual.troweprice.com/staticFiles/Retail/Shared/PDFs/3D_Printing_Infographic_FINAL.pdf.

percentage of manufacturers are using or experimenting with additive manufacturing[2] and the 3D printing industry itself has experienced a compound annual growth rate of 33.8 percent in recent years.[3] The global industry is estimated to grow from about $6 billion this year to over $21 billion by 2020.[4]

Unlike 2-dimensional printing, 3D printing software and hardware is not standardized. For example, in order to print an object, it must first be designed using CAD software.[5] Then, it must be exported to a separate software file (the most common file type for 3D printers now is '.stl' or STL) that is compatible with the printer's software.[6] Finally, in order to print the item, the STL file may need to be imported into a proprietary software program specific to the printer's manufacturer.[7] However, software companies have begun to develop programs that are easier for consumers to use.[8] Since its beginning stages, several distinct methods of 3D printing have been developed to serve a variety of different types of uses.

Printing Methods

Stereolithography (SLA) is one of the first additive manufacturing techniques to emerge, and comprises a process wherein figures are produced layer-by-layer using polymers cured with ultraviolet lasers.[9] In this process, SLA printers use a laser to cure photosensitive liquid polymers into hardened objects layer-by-layer as instructed by STL software files.[10] Similar to 2D printing, the quality of FDM printed items is expressed in terms of "resolution."[11] Horizontal resolution is dictated by how small the printer's movements can be along the X-Y axis and vertical resolution is dictated by how thin each layer can be.[12] Current SLA printers are very high resolution and can produce layers with a minimum thickness of under 0.05mm, or 25 microns.[13]

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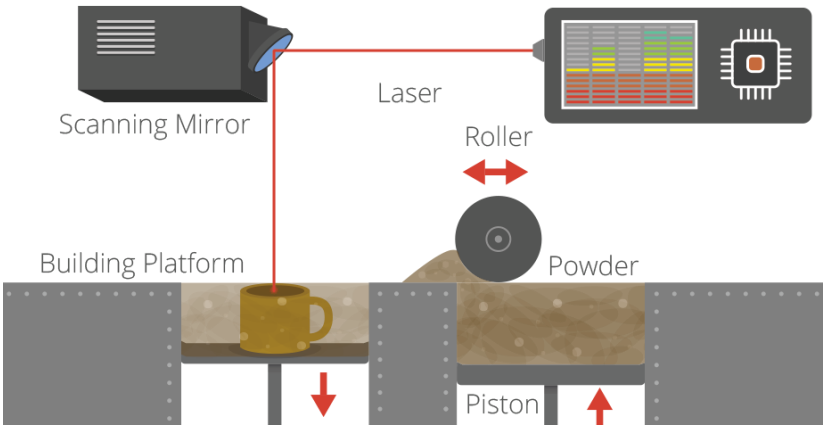
[2] IS 3D PRINTING RIGHT FOR YOU? 3D PRINTING MAKES HEADWAY INTO THE HEART OF U.S. INDUSTRIAL MANUFACTURING, ACCORDING TO PWC US AND THE MANUFACTURING INSTITUTE, PRICEWATERHOUSECOOPERS, *available at* http://www.pwc.com/us/en/press-releases/2014/is-3d-printing-right-for-you.html.
[3] "Wave of Future: 3D Printing industry to quadruple by 2020," RUSSIA TODAY, *available at* https://www.rt.com/business/253785-3d-printing-industry-growth/.
[4] Louis Columbus, "2015 Roundup of 3D Printing Market Forecasts and Estimates," FORBES (Mar. 31, 2015), *available at* http://www.forbes.com/sites/louiscolumbus/2015/03/31/2015-roundup-of-3d-printing-market-forecasts-and-estimates/#76dfb4f01dc6.
[5] FREQUENTLY ASKED QUESTIONS: GET TO KNOW FDM TECHNOLOGY, STRATASYS, available at http://www.stratasys.com/3d-printers/technologies/fdm-technology/faqs.
[6] *Id.*
[7] *Id.*
[8] *See* Valentina Palladino, "Kids will soon make their own toys with Mattel's $300 ThingMaker 3D printer," ARSTECHNICA (Feb. 15, 2016), *available at* http://arstechnica.com/gadgets/2016/02/kids-will-soon-make-their-own-toys-with-mattels-300-thingmaker-3d-printer/.
[9] STEREOLITHOGRAPHY, STRATASYS DIRECT MFG., *available at* https://www.stratasysdirect.com/solutions/stereolithography/.
[10] *Id.*
[11] 3D PRINTER RESOLUTION: FACTS AND FIGURES, ALL3DP, *available at* https://all3dp.com/3d-printer-resolution/.
[12] *Id.*
[13] STEREOLITHOGRAPHY, 3D SYSTEMS CORP., *available at* http://www.3dsystems.com/resources/information-guides/stereolithography/sla.

Another additive manufacturing technique that began in the 1980s is fused deposition modeling (FDM).[14] This method uses plastic filaments extruded (squeezed) at high temperatures through a tiny nozzle, which is guided to produce layers of the substance according to the design.[15] Like SLA, FDM uses STL files, which calculate the printer nozzle's precise path based on the layer-by-layer design of the item to be printed.[16] Currently, FDM printers produce lower resolution objects than SLA and the minimum thickness of a layer is 0.005 inches or 0.127mm.[17] Similar to FDM and SLA, material jetting technology sprays tiny droplets of liquid plastic onto a build tray, where they are instantly cured by ultraviolet light.[18] This method is able to achieve higher levels of resolution than FDM and the raw material inputs can be variably mixed to allow different parts of a single printed item to have differing levels of flexibility.[19]

Laser sintering (or laser melting) uses powdered input material and a laser beam heats and melts the powder, fusing it into a shape dictated by the software file.[20] Variations of this process can use a variety of materials beyond polymers, including metal and food grade ceramic. However, laser sintered metal items can be porous and lack strength.[21]

Laser Sintering



Electron Beam Melting (EBM) has taken the laser sintering method a step further. Using the same basic process, EBM uses an electron beam rather than a laser, allowing it to produce fully-dense parts in a variety of metal alloys, including medical grade.[22] As a result, the technique has been used in the aerospace and automotive sectors to make finished parts, and in the healthcare sector to produce medical implants.[23]

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[14] *Id.*
[15] *Id.*
[16] *Id.*
[17] *Id.*
[18] POLYJET 3D PRINTING, PROTOCAM, *available at* https://www.protocam.com/additive-manufacturing-services/polyjet-3d-printing/.
[19] POLYJET MATERIALS, STRATASYS, *available at* http://www.stratasys.com/materials/polyjet.
[20] 3D PRINTING PROCESSES: THE FREE BEGINNER'S GUIDE, 3D PRINTING INDUSTRY: THE AUTHORITY ON 3D PRINTING, *available at* http://3dprintingindustry.com/3d-printing-basics-free-beginners-guide/processes/.
[21] *Id.*
[22] *Id.*
[23] *Id.*

Prototyping

Prototyping is perhaps the most popular use of 3D printing today.[24] Using 3D printing software, designers can quickly and accurately convert digital 3D models into figures. This process eliminates imperfections resulting from handmade models and drastically reduces costs and the time needed to produce prototypes from designs.[25] For example, larger manufacturers may have the resources to use large-scale metal casting machinery to produce prototypes.[26] But these production tools are expensive and not necessarily designed to convert one-off designs into models.[27] This cost reduction is important because the less time it takes for prototypes to reveal design flaws, the more quickly the design process can be concluded and transition to the production stage.

Healthcare

The 3D printing healthcare market is projected to grow from $579 million in 2014 to about $2.4 billion in 2020.[28] Additive manufacturing has already become a popular method for constructing prosthetics. Using CAD software, in some cases aided by scanners, manufacturers can create prosthetics custom fitted for patients.[29] But an especially important advance 3D printing brings to prosthetics is lower cost: whereas a traditionally manufactured prosthetic limb can cost between $5,000 and $50,000, bionic 3D printed limbs range well under $5,000.[30] In addition to prosthetics, 3D printing is now being used to produce highly accurate replicas of a patient's body using special software-enhanced CT scans.[31] This aids the surgeon by providing either a practice model or a surgery template to overlay directly on a patient, reducing the risk of

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[24] Louis Columbus, "2015 Roundup of 3D Printing Market Forecasts and Estimates," FORBES (Mar. 31, 2015), *available at* http://www.forbes.com/sites/louiscolumbus/2015/03/31/2015-roundup-of-3d-printing-market-forecasts-and-estimates/#76dfb4f01dc6.

[25] "3D Printing Scales Up," THE ECONOMIST (Sept. 3, 2013), *available at* http://www.economist.com/news/technology-quarterly/21584447-digital-manufacturing-there-lot-hype-around-3d-printing-it-fast.

[26] *See* Testimony of Peter Weijmarshausen, CEO & Co-Founder of Shapeways, "The Rise of 3D Printing: Opportunities for Entrepreneurs," Hearing before the U.S. House of Representatives Committee on Small Business (Mar. 12, 2014), at 3, *available at* http://smbiz.house.gov/uploadedfiles/3-12-2014_final_weijmarshausen_testimony.pdf.

[27] *Id.*

[28] WORLD 3D PRINTING HEALTHCARE MARKET - OPPORTUNITIES AND FORECASTS, 2014 – 2020, RESEARCHANDMARKETS (Jan. 2016), *available at* http://www.researchandmarkets.com/research/fn5vhg/world_3d_printing .

[29] "World First for 3D Printing and Bionics," blog post, OPEN BIONICS (Nov. Nov. 4, 2015) http://www.openbionics.com/blog/world-first-for-3d-printing-and-bionics.

[30] Sarah Griffiths, "The cheap robotic hand set to revolutionise prosthetics: 3D-printed device performs advanced tasks for a fraction of the cost," DAILY MAIL (Aug. 26, 2015) http://www.dailymail.co.uk/sciencetech/article-3211347/The-cheap-robotic-hand-set-revolutionise-prosthetics-3D-printed-device-performs-advanced-tasks-fraction-cost.html; Varun Nayar, "Open Bionics is Developing a Cheap 3D-Printed Prosthetic Arm," Tech Times (Aug. 25, 2015) http://www.techtimes.com/articles/79273/20150825/open-bionics-3d-printing-prosthetic-arm-indiegogo.htm.

[31] "Healthcare Solutions," 3D SYSTEMS, *available at* http://www.3dsystems.com/solutions/healthcare; "ClearView Anatomical Models," 3D SYSTEMS MEDICAL MODELING, *available at* http://www.medicalmodeling.com/solutions-for-surgeons/tactile-medical-imaging/clearview-sup-reg-sup-anatomical-models.

errors.[32] Similarly, 3D printing is being leveraged to create accurate surgical implants as well as customized surgical implements.[33]

While 3D printing is advancing healthcare using typical 3D printing inputs such as metal alloys and polymers, groundbreaking methods are being developed to print biological materials as well.[34] These methods are known as bioprinting, a process where a printer deposits living cells in a determined pattern layer by layer.[35] Each layer is held in place by soluble paper-like layers of hydrogel. As each layer dissolves, the printed cells slowly fuse together.[36] Although bioprinting is in experimental stages, bioprinters have been able to print kidney tissue for drug testing; brain tissue; and fully vascularized ear tissue in a large enough structure for "clinical application."[37] In a handful of cases, various bioprinted materials including muscle, bone, and cartilage has been successfully implanted in mice and rats.[38] Scientists hope that bioprinting will one day lead to the ability to produce organs and other implants on-demand using the patient's own cells.[39]

Manufacturing

In addition to rapid prototyping, manufacturers use 3D printing to produce finished parts and tools. Small manufacturers use 3D printing services to fabricate parts and products for end use. The availability of additive manufacturing has been attractive for small businesses due to its increasing availability at lower costs.[40] The ability to print items reduces inventory costs because the manufacturer need only send the design to a 3D printer as the product is ordered, instead of storing the item in case it might be ordered.[41] This process can also reduce transportation costs by allowing a manufacturer to print an item closer to its destination than if it were produced elsewhere and stored.[42]

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[32] *Id.*
[33] "Healthcare Solutions," 3D SYSTEMS, *available at* http://www.3dsystems.com/solutions/healthcare.
[34] *See* "Bioprinting," Explainingthefuture.com, *available at* http://www.explainingthefuture.com/bioprinting.html.
[35] *Bioprinting: A Beginning*, TISSUE ENGINEERING Vol. 12, no. 4, at 632 (2006), *available at* https://www.researchgate.net/profile/Brian_Derby/publication/7107177_Review_Bioprinting_A_beginning/links/00b4952645111cc5ee000000.pdf.
[36] *Hydrogels as Bio-Ink*, BIOPRINTING IN REGENERATIVE MEDECINE 91, ed. by Kursad Turksen (2015).
[37] Arielle Duhaime-Ross, "This 3D Bioprinter can make human-sized ear, muscle, and bone tissues," THE VERGE (Feb. 15, 2016), *available at* http://www.theverge.com/2016/2/15/10995730/3d-print-human-tissue-ear-muscles-bone.
[38] *Id.*
[39] "Could Star Trek's Replicator Become Reality with 3D Printing Technology," National Law Review (Jan. 28, 2016), *available at* http://www.natlawreview.com/article/could-star-trek-s-replicator-become-reality-3d-printing-technology.
[40] *See* 3D PRINTING, THE UPS STORE, *available at* https://www.theupsstore.com/print/3d-printing.
[41] Rakesh Sharma, "Can 3D Printing Reshape Manufacturing in America?" FORBES, Tech Section, available at http://www.forbes.com/sites/rakeshsharma/2014/06/17/can-3d-printing-reshape-manufacturing-in-america/#16b16aad4f10.
[42] *See* Lindsay Ellis and Laura Stevens, "UPS Tests a 3-D Printing Service," WALL STREET JOURNAL (Sept. 18, 2015), available at http://www.wsj.com/articles/ups-tests-a-3-d-printing-service-1442618648?cb=logged0.2966617050115019

Manufacturers have found that additive manufacturing is especially useful for short-run parts, pieces that must be customized, and parts that require frequent replacement.[43] 3D printing is especially well suited to the oil and gas industries and aerospace. Additive manufacturing allows manufacturers to produce designs using less material without sacrificing strength—making certain parts lighter and more aerodynamic.[44] In particular, the LEAP jet engine produced by GE uses 3D printed nozzles and brackets, which are lightweight and optimally designed to reduce drag.[45]

Consumer Products

3D printing allows consumers to customize all or portions of certain products. For example, manufacturers are now able to print customized toys for children based on their color and design preferences using a variety of materials.[46] Mattel has also unveiled a 3D printer for children to print their own designs at home, priced at only $300.[47] Aside from the uniquely low price, a significant aspect of this product is how easy the design software is to use, whereas most 3D printing design software to date has been relatively inaccessible for consumers.[48] In addition to toy printing, myriad 3D printing services are available for consumers to have their own designs or pre-made designs printed and shipped or printed at a local destination.[49]

IV. ISSUES

The following issues may be examined at the hearing:

- Which types of additive manufacturing are poised to revolutionize manufacturing the most and how?
- What are the most significant barriers to investment in 3D printing technology? What can be done to promote investment?
- What are the legal and regulatory hurdles to the further adoption of additive manufacturing?

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[43] "3D Printing for Mass Production," AMERICAN SOCIETY OF MECHANICAL ENGINEERS, AMSE.org (Feb. 2015), *available at* https://www.asme.org/engineering-topics/articles/manufacturing-processing/3d-printing-for-mass-production.
[44] *See* "Custom materials enables ESD-safe printed aerospace parts," 3D Printing Progress (Feb. 10, 2016), *available at* http://www.3dprintingprogress.com/articles/9076/custom-materials-enables-esd-safe-3d-printed-aerospace-parts.
[45] *See* "Advanced Manufacturing is Reinventing the Way we Work," GE, *available at* http://www.ge.com/stories/advanced-manufacturing.
[46] PieceMaker Teams with Ford Motor; brings metal 3d printing into retail personalization kiosk, by Tess (blog post), 3DERS.ORG (Feb. 15, 2016), *available at* http://www.3ders.org/articles/20160215-piecemaker-teams-with-ford-motor-brings-metal-3d-printing-into-retail-personalization-kiosk.html.
[47] Sarah Perez, "Mattel Unveils ThingMaker, A $300 3D Printer That Lets Kids Make Their Own Toys," TECHCRUCH (Feb. 15, 2016), *available at* http://techcrunch.com/2016/02/15/mattel-unveils-thingmaker-a-300-3d-printer-that-lets-kids-make-their-own-toys/.
[48] *Id.*
[49] *See* https://www.theupsstore.com/print/3d-printing; http://www.shapeways.com/; https://www.3dhubs.com/; https://www.makexyz.com/.

V. STAFF CONTACTS

If you have any questions regarding this hearing, please contact Paul Nagle or Graham Dufault of the Committee staff at (202) 225-2927.