TESTIMONY OF

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Before the

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HOWARD COUNTY MARYLAND
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Chairman Graves, Ranking Member Velázquez, and Committee Members, I am honored to have the opportunity to speak with you about technologies that are significantly impacting how we make and manufacture, across industries. From product development to manufacturing additive manufacturing (AM), also known as 3D printing, give us new capabilities that will alter how we compete in an increasingly global marketplace. Whether getting tangible prototypes faster and cheaper, hybridizing existing production methodology, or completely transforming industries, after 30 years of development and a CAGR of 29.4%, AM technologies are coming of age and are already shifting paradigms for manufacturing and supply chain models. "Using AM to break the constraints of these (existing performance) trade-offs creates opportunities for companies to improve performance, grow, and innovate."[1] The paradigm shift is proving to be especially valuable to small business and entrepreneurs--the generation point of much innovation and the backbone of the American economy.

I'll start with a real-world example. 3D Maryland is located within the Maryland Center for Entrepreneurship (MCE), which has approximately 95 clients in its business incubator. A new client came to visit me within two weeks of joining the MCE, having heard that I was the 3D Printing Person. He started talking about his product, having prototypes made, having sent $2500 to someone in China and not hearing anything from them. He asked if I could help. My first question: "When do you need it?" His answer: "Yesterday." My response: "Send me your files and I'll see what I can do." He promptly emailed the 2-dimensional product drawings and I immediately had the necessary 3-dimensional computer aided design files created. When the hopeful entrepreneur knocked on my door two days later to check in, saying nothing, I gestured toward the build platform of the 3D printer across my office. He looked at the object on the build platform, looked at me, looked back at the printer, speechless. I said," That's your prototype." Eventually, he said, "This is like magic." Well, it isn't magic, but it is a tool that can get all kinds of parts and products developed locally, significantly faster and cheaper. It is a tool that allows us to optimize and adapt products and processes much more efficiently. The efficiencies are expected to expand, assuming the trends in adoption and development continue[2].

To budding entrepreneurs and small business owners alike, parting with $2500 to invest in capital is already risky, regardless of physical manufacturing location. Why might someone take the risk of having less oversight/control of their capital investment by choosing to manufacture at such a distance? The answer is that the perceived risk was minimized by the fact that in order to be cost effective enough to compete and survive while using traditional manufacturing, one has had to utilize the efficiencies produced in the global supply chain. Additive Manufacturing reverses efficiencies of scale and standardization—dramatically reducing required capital investment and risk in manufacturing, while creating opportunity for complex and personalized designs –effectively reducing the barriers to new entrants across industries.

Background

I am the Executive Director of 3D Maryland: a state-wide leadership initiative created to raise the awareness of 3D printing and the concomitant business benefits, and to facilitate engagement and implementation of these technologies among business, industry, and entrepreneurs as a driver for innovative economic growth. Prior to 3D Maryland, I built and directed Object Lab along with the Object

[1] Deloitte University Press, "3D opportunity: Additive manufacturing paths to performance, innovation, and growth." Pg 6: http://dupress.com/articles/dr14-3d-opportunity/

[2] Econolyst, "Building Small Business Around 3D Printing" http://www.econolyst.co.uk/resources/documents/files/Presentation%20-%20Oct%202012%20-%203D%20printshow%20London%20UK%20-%20Building%20a%20small%20business%20around%203D%20printing.pdf

Design program @ Towson University, Baltimore, Maryland, where I am a full professor. The Object Design program was designed to include an internship program focused on working with small business and entrepreneurs to engage 3D printing and digital fabrication/rapid technologies. Object Lab is a comprehensive, state-of-the art digital fabrication lab that today includes seven 3D printers in addition to laser cutting, CNC milling, 3D scanning, and high end computer aided design capabilities. A finalist in the Volt Awards in the Technology Implementer Category, the Object Lab @ Towson University spawned a digital fabrication lab that bridges the academia and business at East Stroudsburg University, Stroudsburg, Pennsylvania for which I have been a primary consultant.

Paradigm Shifting Technology

3D printing and additive manufacturing (3DP/AM) is a disruptive 21st century technology. It is changing what we make, how we make it, where we make it, and who makes it. It is disrupting economies of scale, current business models, and democratizing who can make and manufacture across industries. Engagement with these technologies is notably accelerating. Innovation and entrepreneurial opportunities are at the heart of these technologies.

- The benefits from economies scope are still being explored, but appear to have immense potential. We are seeing new and unfamiliar complex geometries that might not have been possible or practical with traditional manufacturing. For example, newly developed AM products proved to be capable of achieving efficient lighter and stronger properties, delivering drastically improved results over the product's lifecycle. We are seeing products with more organic structures and re-entrant features. We are able to print assemblies. We are manufacturing for design rather than designing for manufacturing. New tools bring new capabilities.

- Additive manufacturing's inherent flexibility further increases the technology's advantages from economies of scope. While each of the seven 3D printing technologies has specific applications, within those applications the tool can virtually produce an unlimited range of products without any tooling adaptation. Multiple functionality allows for unlimited customization are very minimal, if any, cost.

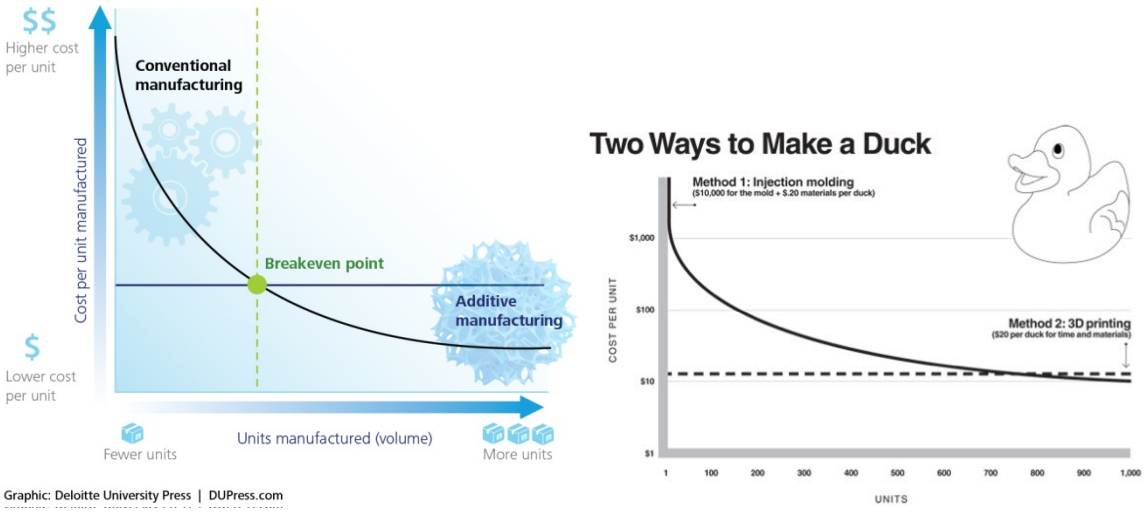
  3DP/AM is a decentralized, distributed ecosystem reliant on digital data which can be transmitted anywhere making localized production a reality. 3D printers can virtually run 24/7 unassisted thus it is referred to as lights-out manufacturing, and print-on-demand technology. Printing what we need, where and when we need it disrupts the supply chain and lowers inventory costs in numerous ways: lead time, storage, shipping, loss of control, tied up cash—all contributing to lowering cost to entry.

- The sweet spot for 3DP/AM today is in low volume/high value parts and products from end-of arm tooling to hearing aids. We are beginning to see manufacturing without traditional tooling and on-off tooling, and concepts such as mass customization are a reality. It costs no more per unit to run one unique part, small batch production, or 15,000 one-offs, as in the case of Invisalign aligners. Traditional manufacturing required large capital investments and standardization in order to produce large quantities to benefit from economies of scale. Economies of scale are reached at the point of minimum efficient point (where the average cost of producing each unit is the lowest). The lowest marginal cost to produce of additive manufacturing is very low, potentially 1. Figure 1 shows the cost structure of production where the cost of each additional unit is the same with AM (the lowest minimum efficient point is one).

The required investment for AM is substantially lower than with traditional manufacturing, and reduction in price is expected to continue.

- Lots of people have ideas. Now people have myriad access points to rapid technologies that can help them realize their ideas *encouraging innovation and entrepreneurship*. Garage invention reinvented. The significance and accessibility of these technologies is not to be overlooked.

Figure 1. Breakeven analysis comparing conventional and additive manufacturing processes



Graphic: Deloitte University Press | DUPress.com

Impact of 3D Printing for Small Business and Entrepreneurs

The significance of small business and entrepreneurs to the economy are widely recognized with familiar statistics such as 'the approximately 23 million small businesses in the US account for 55% of jobs and 66% of all net new jobs since 1970s'[3]and '89.8% firms are businesses with less than 20 employees.[4]It is unfortunate that, typically, small business owners and entrepreneurs have the most difficulty competing with large entities because of the lack of funds required to reach efficient production. AM/3DP offers opportunities for both groups to effectively compete, globally even, and innovate.

The **primary advantages** of 3D printing are significant to small and large business alike, but they level the playing field so that small businesses have opportunity to compete and develop solutions. Proof of concept models and more efficient iterative prototyping lead to optimized products prior to commercialization. Cost savings can be captured with faster and cheaper prototypes. More importantly for small business, 3D printing allows for less expensive process improvement and innovations. When a business culture permits, if employees can envision a tool that can make a process work more effectively, and the company has the expertise to create CAD drawings of the improvement, chances are that tool can be made. Improvement leads performance improvement, growth and/or innovation and result in added business value of either profit or time.

Small business has distinct advantages when adopting additive manufacturing technologies and may be in a better position to develop entrepreneurial solutions. Small businesses tend to be more agile in terms of structure, focus, and culture. There are certain barriers to entry in this space that small

[3] Small Business Association, SBA.gov
[4] U.S. Census, Statistics of U.S. Business, http://www.census.gov/econ/susb/

businesses may not struggle with as much as larger established businesses. Larger enterprises tend to have large sunk costs (investments in capital) and, after many years, following a successful standardization/large-scale supply chain model, may be resistant to transition into a new framework. Enabling small business to develop advancements and solutions that feed into and support the larger economic pipeline is an important piece of advancing the American economy. Even larger companies are seeing the value in utilizing a smaller structure for innovation: companies spin out start-ups in order to make advancements in specific areas.

Small Business Maryland Case Studies

Danko Arlington Foundry, Baltimore, Maryland, Baltimore County

A 94-year old family owned foundry in Baltimore City serving primarily the aerospace and defense industry turned to 3D printing and rapid technologies when they started having a hard time finding skilled workers in legacy technologies. With an eye on the downward trends of vocational training, general discouragement of trade work and manufacturing, lack of meaningful internships and apprenticeships, and the retirement of the labor code of this specialized skill, John Danko sought new solutions landing on 3D printing technologies. In 2010, Danko Arlington purchased its first 3D printer for $500,000, the largest on the market. Danko Arlington began using 3D printing to print the masters for the sand molds, a process that required Danko Arlington to invest substantial time and money into adapting the technology for this purpose. There was no roadmap for John Danko, he created his roadmap. A true success story, Danko Arlington credits the adoption of these technologies with not only increasing profit but also creating jobs.

Danko Arlington attributes the inclusion of 3D printed prototypes with bids as part of the key to winning proposals. Tooling is a required part of federal contracts. Danko Arlington uses 3D printing technologies to create their foundry tooling, which in one example tooling costs were 1/5th that of traditional tooling. CEO John Danko says, “Additive manufacturing brings new opportunities to a ninety-four year old company, and is helping to create jobs.” In 2013, Danko Arlington purchased its second large-scale 3D printer as a result of securing a year-long federal contract. They sell excess 3D printing capacity to other companies from small entrepreneurs to General Motors of Whitemarsh, and John Danko generously shares his lessons learned with the Maryland rapid tech ecosystem. John Danko is the epitome of the American spirit: hard work, a can-do attitude, and an entrepreneurial edge.

UAV Solutions, Jessup, Maryland, Howard County

UAV Solutions manufactures unmanned aerial vehicles. Established in 2007 with eleven employees, UAV Solutions is currently a 55-employee, hybrid manufacturer utilizing five industrial grade 3D printers 24/7.

Dixon Valve & Coupling, Chestertown, MD, Eastern Shore

Dixon Valve manufactures industrial fittings, joints, gears, locks and clamps.

Dixon Valve created an Innovation Center in early 2000 and made its first 3D printing capital investment at a $160,000 to accelerate its innovation efforts. ROI was realized in 18 months.

Barriers to Engagement
An informal survey of small businesses in Maryland returned the following as barrier to adoption which was presented to the Office of Advocacy February 2014.

Access to knowledge. One of the biggest barriers is access to accurate information about the technologies from knowledgeable and trusted sources. There are seven primary 3D printing technologies, over 200 materials can be printed from tool steel to biological cells, and there are more than 75 different machines not including the desktop class of printers of which there are many. Knowledgeable and trusted information sources are important as people seek to understand what the technology can and cannot do, how others have strategized the challenges, and how and where to start.

Overcoming Industrial Era Thinking. 3D printing and additive manufacturing are paradigm-shifting technologies. Two of the barriers to entry are getting our industrial era brains to think differently about ways to make and manufacture, as well as developing a digital culture and workflow within established businesses. Some engineers are on board, some designers are on board, and some are not. New tools allow for new capabilities, but first we must recognize the opportunities. New tools are leading us to new and unfamiliar geometries; geometries that are stronger and lighter; geometries that are optimized for the job they are to perform, while proving to have a lifecycle worth well over its traditionally manufactured counterpart. With some level of frequency engineers--especially managing engineers/mid-level engineers—report resistance from C-level decision makers. When the Gutenberg press came out people thought it was pretty cool but few could predict its impact it.

***Cost of Entry*.** The allocation of resources whether capital costs or human resources can be a barrier. There are three primary classes of 3DP hardware: consumer: <$5,000, professional: $5,000-150,000, industrial: $150,000- 1 million. It is worthwhile noting that consumer-grade desktop printers have a role in business and industry adoption; business and industry can get in the game between $10,000-$50,000; and it is only the highest end, highest grade printers that are in the $500,000- $1 million range. Industry standard software can be a barrier for the small business and entrepreneur both in terms of cost per license and also interoperability between functionalities.

Position of the Technology. With thirty years under its belt and recent accelerated growth3d printing and additive manufacturing is here to stay. Rapid prototyping is here to stay, the cost savings are proven. While we do have high end case studies of direct digital manufacturing where 500 certified production parts are printed on one printer overnight, with lead times decreased from 3-4 weeks to 3 days from order to delivery, and per piece part reduced by 5% and tooling costs eliminated5 this is the exception not the norm. Enterprise companies have the resources to advance the application of the technology and they should. Boeing has been 3D printing non- critical parts for decades. Key drivers for the industry include the hardware getting faster, materials more closely matching traditional materials, and reliable repeatability. The $1 million question for most companies is not whether to get in, it is when is the right time to get in? Scaled direct digital manufacturing is coming. There is a learning curve with these technologies at each point on the continuum. Companies that purchase equipment and have it in house generally apply the new technology efficiently across business units, since they tend to find more applications when the equipment is on site.

[5] Stratasys, "A Turn for the Better: Direct Digital Manufacturing Reduces Instrument Part Cost 5% and Lead Time 93%,": http://www.stratasys.com/~/media/Case%20Studies/Aerospace/SSYS-CS-Fortus-KellyManufacturing-08-13.ashx

3D Maryland

Maryland is poised to be a hub in the mid-Atlantic region for 3D printing and additive manufacturing drawing on and expanding the region's significant core competencies and assets. In recent white paper by the Economic Alliance of Greater Baltimore, the Alliance highlights the potential for the adopting AM and 3DP in the region:

"Greater Baltimore claims a number of distinctive qualities that creates a fruitful region, poised for a position of leadership in the growth of 3D printing. The region produces some of the most innovative minds in the country, and when combined with Washington, DC, the corridor is arguably one of the best educated regions in the country. The Baltimore Metropolitan Statistical Area offers strengths and opportunities to innovators in or seeking to enter the 3D printing industry. No region is better positioned for improving, refining, and creating new methods and uses for 3D printing."[6]

3D Maryland is an innovative and entrepreneurial initiative addressing barriers to entry and advancing the business advantages of 3D printing for business, industry and entrepreneurs. 3D Maryland is identifying and addressing opportunities to strengthen and advance the rapid tech ecosystem in Maryland in order to build a loosely coupled system of collaborative relationships and partnerships across sectors to innovate and accelerate the region's economic competitiveness. The initiative is already engaging in practices in order to achieve these goals. The Maryland rapid tech ecosystem interactive online map on 3D Maryland's web site indicates an overall level of engagement, as well as sector engagement with delineation of private sector users, service providers, educational programs, federal labs, etc. The 3D Maryland Expert User group brings together a diverse group of practitioners and stakeholders that work together to accelerate commercial application of AM technologies through cross-pollination and collaboration. The user group is open to firms of any size that are currently exploring additive manufacturing. The initiative is planning to create a general user group in order to address the needs and engage with potential users. An online platform, www.3DMaryland.org, provides users and interested parties throughout the state with information on resources and opportunities within the 3D printing space. In combination with the knowledge resources offered, 3D Maryland offers a physical facility for learning that encourages efficient, educated adoption. The Innovation and Prototyping Lab is a technology agnostic knowledge center where people can learn computer aided design through a variety of software packages, 3D printing, and 3D scanning. Based on a fee-for service model, target audience can access the Innovation and Prototyping Lab for small batch printing.

Call To Action

- Encourage and support initiatives, such as 3D Maryland, that have a focus on multi-sector, cross-disciplinary, pre-competitive collaboration, building on strengths and core competencies to advance current practices, foster innovation, and grow regional ecosystems, while taking advantage of public funding resources. This would build on the momentum created by the National Additive Manufacturing Innovation Institute, now known as America Makes, which is an example of private-public partnerships.

  There is multi-directional concern about the loss of America's production/manufacturing base. The MIT task force on the Production in the Innovation Economy, states, "We saw reasons to

[6] Economic Alliance of Greater Baltimore, "3D Printing: The Future of Manufacturing in Greater Baltimore," http://www.greaterbaltimore.org/portals/_default/publications/3dprint.pdf

fear that the loss of companies that make things will end up in the loss of research that can invent them." "The PIE taskforce believes that one objective is the most urgent: rebuilding the industrial ecosystem with new capabilities that many firms can draw on when they try to build their new ideas into products on the market." "Research suggests that it's the co-located interdependencies among complementary activities, not narrowly specified clusters that produce higher rates of growth and job creation, and they do so across a broad range of industries…" "The key functions are…convening, coordination, risk-pooling and risk-reduction, and bridging."[7]

- Address creating an adaptive workforce at all points on the spectrum: work at the grass-roots level, locally with users with proven track records, from both industry and education to institute changes in K-16, vocational training and apprenticeship programs, retraining programs, etc. Wider adoption is inevitable; we need ensure that the workforce is prepared to increase engagement. The current value of the AM technology and service industry is $1.7 billion, with an overall compound annual growth rate of 29.4%. At current levels of growth, the industry is forecasted to be worth $8.4 billion by 2020—assuming organic growth based only on today's technologies. Additive manufacturing sector analysts accept that penetration is currently 8% of the potential market opportunity. With technically development and far-reaching adoption (>8% penetration), the industry could be worth $105B by 2020[8].

  "Studies have shown that students who are educated in AM processes are among the first to bring the advanced hands-on technologies to their employers."[9]

- Continue small business incentives such as low interest loans and tax cuts but also incentivize small businesses to adopt leading edge technologies

- Continue to support for research funding and programs to facilitate technological transfer. Technological progress with 3DP and AM has accelerated rapidly recently, primarily due to increased investment. The technologies are becoming more accurate, versatile, and accessible (financially)—promising movement towards leveling the playing field in modern manufacturing.

- Incentivize private investment in small businesses that utilize proven leading edge emerging technologies.

[7] MIT PIE Task Force, "Report of the MIT Taskforce on Innovation and Production," http://web.mit.edu/press/images/documents/pie-report.pdf
[8] Econolyst, "Building Small Business Around 3D Printing" http://www.econolyst.co.uk/resources/documents/files/Presentation%20-%20Oct%202012%20-%203D%20printshow%20London%20UK%20-%20Building%20a%20small%20business%20around%203D%20printing.pdf
[9] Wohlers& Associates: Wohlers Report 2013: pg261