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THE RISE OF 3D PRINTING: OPPORTUNITIES FOR ENTREPRENEURS

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UNITED STATES
HOUSE OF REPRESENTATIVES

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Questions for the Record:
- None.

Answers for the Record:
- None.

Additional Material for the Record:
- None.

THE RISE OF 3D PRINTING: OPPORTUNITIES FOR ENTREPRENEURS

WEDNESDAY, MARCH 12, 2014

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SMALL BUSINESS,
Washington, DC.

The Committee met, pursuant to call, at 1:00 p.m., in Room 2360, Rayburn House Office Building. Hon. Sam Graves [chairman of the Committee] presiding.

Present: Representatives Graves, Luetkemeyer, Schweikert, Bentivolio, Collins, Rice, Schrader, and Payne.

Chairman GRAVES. I will go ahead and call the meeting to order. The ranking member is going to be delayed for just a little bit, but we also have a vote coming up at any moment which will delay the hearing slightly, which I apologize for. We never know for sure when they are going to schedule votes. And unfortunately, they are going to schedule them right in the middle of our hearing. But we will go ahead and get started and see how far we can get before they do call that vote.

3D printing or additive manufacturing is a process of creating objects from a digital model, typically through the deposit of a material layer upon layer until an object is formed. Today, we are here to discuss how 3D printing is spurring innovation and entrepreneurship all across the country.

While the technology has been around since the 1980s, it has traditionally been used by large companies in industrial settings for rapid prototyping. But in the last 10 years, 3D printers have become more affordable, which is opening the door for smaller businesses and entrepreneurs to begin benefitting from the technology. For instance, some models are now available for under $1,500, and analysts expect prices to continue to go down.

Small businesses and entrepreneurs are using 3D printing in a variety of ways. It has the ability to save time and costs during the creation of prototypes, make highly-accurate parts that assist in product production, and produce finished products that may be sold directly to end-users. 3D printing has become, and will increasingly be, a critical component of the operations of many small businesses. While a number of entrepreneurs and at-home innovators are using it to print models of products that they intend to manufacture with traditional methods, others are using the technology to create products from start to finish, sometimes that can be done right there in the garage. As 3D printers continue to become more affordable and advanced, the number of small businesses that begin as "household manufacturers" is likely to skyrocket.

While some embrace and capitalize on new technologies, others are very wary and cautious about the technology. As Congress and other regulatory bodies consider policies applicable to this and other technological advances, it is important that we must not be hasty and do not unduly restrict the ability of small businesses, entrepreneurs, and other innovators to help grow our economy.

We are fortunate to have with us a very interesting group of makers and users of the technology, which includes entrepreneurs that use 3D printing in their development of products. I look forward to hearing your insights on how small businesses are using this technology to grow and obviously create jobs, which is what this Committee is all about.

So we will move right on into our witnesses. Our first witness today is Patrick O'Neill, who is the founder and CEO of olloclip, a clip-on lens for iPhones and other Apple products. Prior to founding olloclip, he was product manager and VP of product development at Premier Systems, which is an information technology resaler and consulting organization. Mr. O'Neill was named Entrepreneur Magazine's 2013 Entrepreneur of the Year. Welcome to the Committee, and we look forward to hearing your testimony.

STATEMENTS OF PATRICK O'NEILL, CEO, OLLOCLIP, LLC; JONATHAN COBB, EVP, PUBLIC AFFAIRS, STRATASYS, INC.; PETER WEIJMARSHAUSEN, CEO, SHAPEWAYS, INC.; JAN BAUM, EXECUTIVE DIRECTOR, 3D MARYLAND, MARYLAND CENTER FOR ENTREPRENEURSHIP

STATEMENT OF PATRICK O'NEILL

Mr. O'NEILL. Chairman Graves, Ranking Member Velázquez, and members of the Committee, I am Patrick O'Neill, CEO and founder of olloclip, the mobile photography company. I invented the olloclip, a clip-on lens for the iPhone. I am very grateful for the opportunity to speak with you regarding our use of 3D printing and how it has helped a small business go from a kitchen startup three years ago to selling a product in every Apple store worldwide.

In have spent my whole career in the technology industry. I hold over 30 patents, and 3D printing has enabled us to innovate at a rapid pace. This pace is required for us to be at the forefront of mobile technology, as well as keep jobs in America.

In creating the olloclip, I wanted to create a photo lens that would give people the ability to use the iPhone to capture photos artistically, creatively, and spontaneously. The olloclip design was inspired by the philosophies of Steve Jobs, founder of Apple, and Colin Chapman, the English founder of Lotus cars, for clean, simple designs.

Since the start, we employed this "simple and light" design philosophy. At the beginning, when the design studio was in my kitchen, we used a local 3D printing company to produce hundreds of prototypes. I would ask myself, "Would Steve Jobs think this product was good enough?" The answer wound invariably be "no," and we would keep refining it until we felt the result would meet Steve's demanding standards.

After a year of development, we launched olloclip through the Kickstarter crowdfunding platform in May 2011. Olloclip received

funding within four weeks from backers in more than 50 countries and achieved almost five times our funding goal.

Since our start three years ago, we have moved three times to larger offices, and now employ more than 50 people in Huntington Beach, California, including seven full-time designers. Today, olloclip is considered the leader in mobile photography products. Olloclip products are now sold in more than 90 countries.

The olloclip has attracted a legion of passionate users and received numerous awards. I am also fortunate, as you mentioned, to be named "Entrepreneur of the Year" by Entrepreneur Magazine. 3D printing enabled me to innovate quickly and turn my idea into a commercial product. Design and 3D printing are still the core of our development. In just the past six months, we created six new products to enhance our line of photography tools thanks in part to 3D printing. We have invested more than $50,000 in 3D printing to prototype our own products.

We also print models of rumored devices, so lenses can be designed quickly each time Apple releases a new version. We sketch an idea in the morning, model it in the afternoon, send it to the 3D printer and have a prototype that evening. Fast turnaround is key for companies in this space. We finished and validated an iPhone 5 version within days of the device's announcement. I cannot imagine doing this without our own 3D printer.

Here is the process of developing our products. We first start with brainstorming and concept generation. Then, sketch ideas and create cab models of those ideas in the computer. Then, print the models on the 3D printer. Next, we evaluate the prototype for functionality, proportions, and aesthetics. Changes are made, if needed, and then reprinted. If the prototype is approved and everything looks good, we move forward to mass production.

The mobile device market changes so quickly. To stay competitive, we use the 3D printer every day to develop new ideas. We have found it is the best way to innovate quickly and get to market faster. We can now develop products in a week or two. Without 3D printing it could take months for development. As Apple launches products, we would miss critical launch time and market opportunities. This could result in a potential loss of millions of dollars of sales, perhaps even failure.

Small and mid-sized companies like ours need the ability to compete on the world stage, especially in rapidly changing, innovation driven industries, like consumer technology. As 3D printing evolves, we would like to use it for bridge manufacturing to produce finished products so we can get to market even faster.

At olloclip, we continue to think differently and are not afraid to try new things. We will only build products if we can innovate. 3D printing allows us to take more risks because it shrinks the opportunity cost. We are able to test and validate new designs within a day or two, rather than a month or two. If they are unsuccessful, we can quickly move on to try something else.

Our success has come from our passion and perseverance, our ability to take risks, and blaze new trails when it comes to product innovation. As Congress and others consider policies that will apply to 3D printing, it will be important to ensure entrepreneurs like

myself are able to continue using the technology in innovative ways.

I am honored to be here today. Many thanks to Chairman Graves, Ranking Member Velázquez, and this Committee.

Chairman GRAVES. Thanks, Mr. O'Neill.

Our next witness is Jonathan Cobb, who is the executive vice president of Public Affairs for Stratasys, a global leading manufacturer of 3D printers. Mr. Cobb has served in several positions at Stratasys, including Executive Vice President of Global Government Relations and Global Marketing, and he serves as the company spokesperson. He has also held the position of vice president and general manager for the Dimension 3D printing business unit of Stratasys. Today, he is testifying on behalf of the National Association of Manufacturers.

Welcome to the Committee.

STATEMENT OF JONATHAN COBB

Mr. COBB. Thank you, Chairman Graves, Ranking Member Velázquez, and Committee members. Thank you for the opportunity to tell you about 3D printing and how our company, Stratasys, is helping small businesses grow and thrive in this economy.

My name is Jonathan Cobb, and I am executive vice president for Stratasys, which is based in Eden Prairie, Minnesota.

Stratasys is a member of the National Association of Manufacturers (NAM), and I am honored to testify on behalf of the organization. As the nation's largest manufacturing trade association, the NAM represents 12,000 small and large manufacturers in every industrial sector in every state.

Manufacturers are the world's leading innovators and perform two-thirds of all private sector R&D in the nation, producing more innovative breakthroughs than any other sector. I am proud to say that 3D printing and Stratasys are part of this innovative American industry.

You may be asking what is 3D printing and why should I care about it? Simply put, 3D printing is a process of turning digital blueprints into tangible objects within a matter of objects. It works by sending digital schematics to the printer, which then shapes very thin layers of plastic, metal, or other materials into physical objects.

I brought a couple of samples that hopefully we can talk about a little bit later on if there are some questions.

Although the concept may be new to many of you here today, this technology has existed for decades. 3D printers were originally created to help engineers test designs before spending money on expensive factory tooling for production. Today, 3D printers are not only just used to make prototypes; they are also used for low-volume manufacturing, items such as prosthetic limbs and interior components of aircrafts.

3D printing is also found in the classroom. In fact, since 2002, nearly one-quarter of Stratasys's business has been in education. By helping students learn design and manufacturing through 3D technology, we are hoping build a strong hiring pool for businesses in America.

This brings up an important point. 3D printing will not replace traditional manufacturing process. It will serve as another tool in a toolbox for manufacturers, to deliver products to markets in efficient and customized ways.

Stratasys was started in 1988 and has been growing ever since. In 2005, we started a separate business unit called RedEye, which is a service that can produce 3D printed parts for those who do not own a 3D printer. We also acquired Solidscape of Merrimack, New Hampshire, which helps jewelry designers and dental markets adopt 3D solutions.

Last year, we merged with Brooklyn-based MakerBot, a 3D printing company whose user-friendly products are designed for prosumers and entrepreneurs with basic technical skills.

The growth of our business has helped others as well. When musician Chris Miles was performing at events with his band, he used a popular credit card reader to process payments when he sold his CDs. The credit card reader plugged into his laptop, but he found that the reader tended to swivel or spin when used, instead of remaining stable. That made it sometimes difficult to use. Borrowing from his children's Lego pieces, Chris built an accessory that kept the card stable. With a successful design, Chris wanted to bring his new innovation to market. It would have been costly and inefficient using traditional production methods, so instead, Chris invested in a consumer-level 3D printer, which has literally become a factory on his desk, enabling him to produce his invention from home for a couple thousand dollars and sell thousands of them.

We take pride in stories like this. To us, they demonstrate that we are not just a business of producing 3D printing machines; we are also helping empower entrepreneurs by bringing manufacturing into their homes and workspaces.

Our presence here today shows that the interest in 3D printing is strong and the future is infinite. Our industry is experiencing rapid growth and is giving domestic manufacturing a new competitive edge in this global economy. The best thing Washington can do is to encourage further growth and investment. As President Obama noted in his recent speech touting 3D printing hubs, if we want to attract more good manufacturing jobs to America, we have to make sure that we are on the cutting edge. Our company could not agree more.

I would like to thank the Committee for holding this hearing, and I would be happy to answer any questions that you have.

Chairman GRAVES. Thank you, Mr. Cobb.

Our next witness is Peter Weijmarshausen.

Chairman GRAVES. Weijmarshausen, founder and CEO of Shapeways, the world's leading 3D printing marketplace and community. Prior to Shapeways, Peter was the chief technology officer at Sangine, where he and his team designed and developed satellite broadcast modems. He is also director of engineering at Aramiska, where he is responsible for delivering a business broadband service via satellite. He was born and raised in the Netherlands and moved to New York in 2010.

Thanks for being here.

STATEMENT OF PETER WEIJMARSHAUSEN

Mr. WEIJMARSHAUSEN. Good afternoon, Mr. Chairman, and members of the Committee. My name is Peter Weijmarshausen. I am CEO and cofounder of Shapeways. I am honored to be here today to discuss how 3D printing is fueling small business growth, enabling anyone to create a business with physical products at low capital costs.

As a kid in the Netherlands, I loved coding and playing with computers, resulting in a passion for open source software. Driven by this and my entrepreneurial spirit, I spent much of my early career at various software startup companies. One of these was Blender, the first company to publish a free 3D modeling software. This turned out to be important.

In 2006, much later, I learned about the technology called 3D printing, which prints physical objects based on 3D computer designs.

I immediately thought of the Blender community, a large group of 3D modeling enthusiasts. They, like other designers, were using 3D software, but never imagined it would be possible to hold their own designs in their hands. So I asked some of them for their designs to print, and when I showed the 3D printed "products" to them, they were completely blown away. They immediately agreed it was a good idea to build an online service where people could print their 3D designs, and I knew there could be a business opportunity. How big was yet to be seen.

I started working at Shapeways in March 2007, with in the Lifestyle Incubator of Phillips Electronics, who shared the vision that 3D printing could be very disruptive. At the time, 3D printing was used mostly for prototyping by large companies and was very expensive.

By 2008, we launched Shapeways.com to enable anyone to make and get products they want. We started 3D printing products, not prototypes.

In 2010, we spun Shapeways off as an independent company and moved their headquarters to New York City. New York is perfect for Shapeways, providing us with high-caliber, tech-savvy talents, who are hungry for innovative solutions. It is also the creative epicenter, so we have the ability to talk to so many of our customers and learn from them firsthand. At that point, we had fewer than 20 employees. Today, we have over 140, in New York, Seattle, and in our factories in Eindhoven and Long Island City. These factories are transforming old industrial hubs into factories of the future, with new and innovative processes and machinery.

Shapeways is now the world's leading marketplace and community to make, buy, and sell custom, 3D printed products, unlocking design opportunities for entrepreneurs and creative consumers. Shapeways itself is already a success story in terms of a small business growing out of endless possibilities of 3D printing, but the opportunities created by 3D printing for entrepreneurs are immeasurable.

When I think about what we can achieve, I relate it to how the Internet has enabled software engineers to become entrepreneurs. Before the Internet became mainstream, bringing new software to market was extremely difficult. You had to know what users want-

ed, build the software, test it, then produce a lot of CD-ROMs for floppy discs, bring it to retail, and hope that people would buy it.

Today, using the Internet, any software engineer can become an entrepreneur. The Internet has removed the barriers. Launching a website has become incredibly easy, and this is one of the reasons why companies like Google, Amazon, and Facebook became successful so quickly.

Similar to how the Internet removed barriers for software development, 3D printing is removing barriers for manufacturing products. Designers can create their products, have them printed with little cost; create and update their designs quickly so there is no need for marketing research in advance; build products without costly upfront payments for manufacturing or molds; and distribute their products direct online, with no retail investment. Plus, they can continuously evolve their products since they do not have to keep any inventory.

There is no question that entrepreneurs are taking notice. From 2012 to 2013, product uploads increased from 40,000 per month to 100,000 per month, and the number of new people creating products on Shapeways has doubled.

3D printing transforms how we think about launching products and enables the garage entrepreneur in ways we could never conceive of in the past.

To understand this in detail, let me quickly share with you how Shapeways works. Anyone can upload a 3D design to Shapeways.com. There are many free and open source software programs available to use for 3D modeling, so literally anyone can do it. After the design is uploaded, the user selects the material in which to print and make it available. Shapeways offers over 40 materials and finishes, including precious medal, bronze, ceramic, plastic, and full-color sandstone. Designs are reviewed by our engineers. They are then uploaded to our printers, and then they are printed, after which they are cleaned by the engineers, sorted, and put in the boxes and sent to anyone.

On-demand 3D printing as described above is at the core of Shapeways. People have used it to create endless types of products for their hobby or business, including model trains, jewelry, funny Internet memes, home décor such as lamps, dishware, cups, plates, et cetera. I have brought a few samples as you can see over here.

Let me share one of the examples of a successful business on Shapeways. GothamSmith is an example. Four friends who were working in creative industries in New York City wanted to create something more tangible and lasting than a website or app. Starting with designing cufflinks and eventually into other jewelry, GothamSmith used 3D modeling applications to develop unique ideas. Shapeways gives them the ability to quickly turn these ideas into physical prototypes and then final products at scale, without relying on large and costly metal casting machinery. They sell their products on Shapeways.com directly or through other channels and are emphatic that their business would not exist without Shapeways or 3D printing.

The ability to easily create one-of-a-kind, customizable products is another phenomenon spurred by 3D printing. An otherwise extremely costly and labor intensive process, 3D printing and

Shapeways make it seamless. One company that is leveraging the technology is called Nervous Systems, a design studio that uses a novel process, creating computer simulations inspired on natural phenomena such as the growth of coral. Their process generates products such as jewelry and light fixtures. All of these products are one-of-a-kind and 3D printed by Shapeways, sold on our site, and multiple retail channels, including the MoMA Store in New York. They are another example of a successful business that is rapidly growing and employing more people every day as demand grows.

I would like to conclude with the fact that even the president of the United States has acknowledged that this great opportunity. Shapeways is working with the White House to partner on the first ever White House Maker Fair, dedicated to showcasing and celebrating the Maker movement. The goal is to support a culture of making, and use it as a call to action for stakeholders, and Shapeways has committed to help the White House use this moment in time to facilitate entrepreneurship.

And, in his State of the Union last month, President Obama spoke about a facility in Ohio, saying that a once-shuttered warehouse is now a state-of-the-art lab where new workers are mastering 3D printing, which has the potential to revolutionize the way we make almost everything.

It is true. 3D printing does have the potential to revolutionize the way we make everything. I am passionate about helping others see that, and I hope that I have effectively demonstrated to you the positive impact I can have on small businesses, creating many jobs in the future.

Moving forward, it will be critical that accessibility to 3D printing remains uninhibited.

Thank you for your time today and allowing me the honor of speaking about 3D printing, a technology that I am sure will change the world.

Chairman GRAVES. Thank you, Peter.

Our next witness today is Jan Baum, who is the director of 3D Maryland, which has been charged with bringing the 3D printing and rapid technology agenda to the Greater Baltimore region. Ms. Baum is also a full professor at Towson University and the founder of the university's Object Lab, a comprehensive, state-of-the-art rapid technologies and digital fabrication lab. In 2012, Ms. Baum cohosted the first Rapid Tech and Additive Manufacturing Conference in the Greater Baltimore region, and in 2013, was named Innovator of the Year by the Maryland Daily Record.

Ms. Baum, thanks for being here.

STATEMENT OF JAN BAUM

Ms. BAUM. 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 carry out our work across industries. From product development in manufacturing to skull surgery and bioengineering, 3D printing gives us new capabilities that alter how we compete in an increasingly global marketplace.

I would like to start with a real-world example. I am the executive director of 3D Maryland, a statewide leadership initiative to advance the engagement and implementation of 3D printing and additive manufacturing as an innovative, economic driver for Maryland, but also for America. 3D Maryland is located within the Maryland Center for Entrepreneurship, which is a business incubator in Howard County, Maryland. Within two weeks of a new client joining the Maryland Center for entrepreneurship, he sought me out and he said, "I hear you are the 3D printing person." I said, "I am." And he started telling me about his product that he was innovating and wanting to prototype and how he had sent $2,500 to China and had not heard anything and could I help. And I said, "Well, when do you need your prototype?" And he said, "Yesterday." And I said, "Well, send me the 2D drawings and I will see what I can do." He promptly did, and I immediately turned them around, had the 3D digital files made, and two days later, hopeful, he knocked on my door to check the progress, I am sure not expecting what he found. He put his head in the door and I pointed to the build platform on the 3D printer across my office. He looked at his prototype sitting on the build platform, looked at me, looked back at the printer, looked at me speechless, and I said, "That is your prototype." And he looked at the printer, and looked back at me, and he said, "This is like magic."

Well, it is not magic, but it is a tool that helps us do our work better, more efficiently, locally, and many times, most times, faster with optimized solutions across industries, whatever work it is we are carrying out.

3D printing and additive manufacturing is a disruptive 21st century technology. It is changing the who, why, when, why, and importantly, the what of what we make and how we solve problems. If we can imagine it and we have got the skill to design it, the 3D printers will print it. We are making things we could have never made before. And there are tons of examples on the table here today. It is disrupting economies of scale, current business models, and democratizing production across industries. Innovation and entrepreneurial opportunities are at the heart of this technology.

There are some barriers to engagement. Access to knowledge, both trusted knowledge sources and understanding what the technology can and cannot do. Overcoming industrial-era thinking is a huge one. We have made things subtractively for a very long time and we are very good at it.

Cost of entry. The allocation of resources, whether capital or human, is a challenge for small businesses and entrepreneurs? And then the position of the technology. Are we there yet is a question that we all receive regularly.

The leadership of Howard County in Maryland, county executive Ken Ulman, the Howard County Economic Development authority CEO, Larry Twele, and the executive director of the Maryland Center for Entrepreneurship are a very strong leadership team for Howard County, and they very easily saw the vision and the opportunity that these technologies brought and how it fit in with and supported small business and the entrepreneurial ecosystem.

3D Maryland itself is an innovative and entrepreneurial initiative addressing barriers to entry and advancing the business ad-

vantages of 3D printing for business, industry, and entrepreneurs. Those are our target audiences. We are raising awareness and facilitating engagement and implementation. 3D Maryland is identifying and addressing opportunities to strengthen and advance the rapid-tech ecosystem in Maryland, and we are building a loosely coupled system of collaborative relationships and partnerships across sectors to innovate and accelerate the region and the country's economic competitiveness.

I respectfully recommend that this Committee encourage and support initiatives such as 3D Maryland that have a focus on multi-sector, cross-disciplinary, pre-competitive collaboration. Building on the strengths and core competencies to advance current practices, foster innovation, and grow regional ecosystems while taking advantage of public funding sources.

Supporting initiatives like 3D Maryland builds on the momentum created by recent initiatives, such as the National Additive Manufacturing Innovation Institute. Addressing and creating an adaptive workforce at all points on the spectrum is also critical to our engagement of these technologies. I would recommend working at the grassroots level locally with users with proven track records from both industry and education so we can institute some changes in K–16, vocational training, and apprenticeship programs, retraining programs, et cetera.

Wider adoption is inevitable. We need to ensure that the workforce is prepared to increase engagement. Studies have shown that students who are educated in additive manufacturing processes are among the first to bring the advanced hands-on technologies to their employers, and that is something that I have told my students at Towson University since I established that lab. You are workforce leaders. Continuing to support research funding and programs that facilitate technology transfer, 3D printing, and additive manufacturing are just getting started.

I thank you very much for your attention and your consideration of these technologies.

Chairman GRAVES. Thank you very much. We will recess just until after this series of votes.

How many are there? Three?

And then we will come back and start with questions.

The Committee is in recess.

[Recess]

Chairman GRAVES. We will go ahead and call the hearing back to order, and we will start questions with Mr. Luetkemeyer.

Mr. LUETKEMEYER. Thank you, Mr. Chairman. And thank all the panelists for a very impressive testimony. It is interesting stuff. I know on the way over to votes a while ago I was talking to Mr. Bentivolio here who has got some experience in your field, and it is fascinating to talk about the possibilities and what all you are doing. So as a small business guy it is very rewarding to see the entrepreneurial aspect of this and see that folks are really doing some good stuff.

One of the concerns that I have is getting startups like what you do, and because it is a rather new product and new process from the standpoint of not widely used, I guess, are there regulatory problems that we need to be aware of here in Congress that we

need to put a stop to? Are there ways that we can enhance your ability to do your job better? Just go down the line of whoever has got some comments or concerns about it. Everybody has got concerns about Washington these days. Trust me. And rightly so.

Mr. O'Neill, do you want to start? Have you got any problems with us?

Mr. O'NEILL. I do not yet have any problems with you.

Mr. LUETKEMEYER. Not yet. Key word "yet"; right?

Well, obviously, the healthcare law is something that concerns a lot of small business people, and you are at that 50 if I recall.

Mr. O'NEILL. Yes, we are.

Mr. LUETKEMEYER. So that may be a concern to you. But from the standpoint of producing your products, that is the kind of regulations I am thinking about right now.

Mr. O'NEILL. I figure if we just keep working hard, designing great products, and making money, everything else will figure it out.

Mr. LUETKEMEYER. So far you guys are so far ahead of regulations that you have outrun them, so therefore, you are probably okay for a while until somebody figures out, well, we need to stop these guys and regulate them. So we have to make sure that does not happen.

Mr. O'NEILL. No, I do not want that to happen. I mean, our feet have not hit the ground. We shipped our first order to Apple out of our house less than three years ago, and you know, now we keep moving. We have got a 17,500 square foot facility now and that is not big enough. We need to get a bigger one.

So I understand that there are some complications, and I let other people in our business worry about those things. That is probably why I do not seem concerned. I am sure I should be, but——

Mr. LUETKEMEYER. You hire people to worry for you; right?

Mr. O'NEILL. I really do, because I do not like to worry.

Mr. LUETKEMEYER. I understand.

Mr. Cobb?

Mr. COBB. Thanks.

Yeah, if you go back to the beginning of Stratasys, which really started, like I said, in 1988, we have shipped about 50 percent of our business overseas, and we continue to do that at this point in time. It has been a big piece of our business. So if you look at areas that we are concerned about or could be concerned about, it would be any export laws that would restrict this technology from moving out from the U.S. I mean, if you look at the bulk of our business, we manufacture in New Hampshire, we manufacture in New York, and we manufacture in Minnesota. And so all these products are being exported. So anything that would harm that export——

Mr. LUETKEMEYER. At this point there is no problem then here? That is not a barrier yet?

Mr. COBB. It is not a barrier yet, but I know there has been some discussion about that. So since I had the opportunity to address the question, yes.

Mr. LUETKEMEYER. Flake stuff here so we can be watchful for that. I mean, that is the purpose of the hearing today, to make sure that we know those things ahead of time.

Mr. Weijmarshausen?

Mr. WEIJMARSHAUSEN. Well, we are not really concerned about things that are currently in place but there might be something that you could help, however, think of. Shapeways has a large community of designers that make their own ideas come to life using our platform. They upload them to our sight and then they have them printed and we ship it back to them. And the other element of Shapeways is that we enable people to open shops where they can start selling these products. And I brought a few that you can see right in front of me.

Now, if some of these products currently infringe copyrights, which very rarely, but it does happen, then the DMCA gives a very nice process where the copyright holder can send us a notice, we take down the product from our website and the story or the discussion then is between the copyright holder and the person that is allegedly the infringer. And that process kills very well. You have to realize we have 400,000 community members, and that is growing very quickly. We get 100,000 new designs every month. So these numbers are really large. And DMCA helps with the copyright end of the spectrum.

However, there is no such process for patents. So if someone would infringe a patent, there is no clear process akin to the DMCA that would enable the patent holder to notify us so we can take it down, and then the discussion becomes between the copyright or the patent infringer and the patent holder. In that case, platforms like Shapeways are party to the discussion, which, of course, is really hard for us because we get so many new designs that it is completely impossible for us to check. Also, given the fact that in most cases we only print things once, for us it is completely impossible to check whether there are patent infringements going on at the time.

So, of course, we are open to build compelling technology to help solve this, but since the DMCA works so well for copyrights, I would suggest maybe think about having a similar-type process for platforms like Shapeways—and there are others coming up as well in the United States and also abroad—to have such a process that can help these platforms stay scalable and flexible.

Mr. LUETKEMEYER. Do you have disclosure statements that you have to sign whenever you are sent a drawing of some kind by an individual or a company that says if you produce this object that you are restricted from showing it to anybody else or anything like that?

Mr. WEIJMARSHAUSEN. So the idea about Shapeways, since it is a community, is openness. However, our terms and conditions do ask people, do you own the copyrights? Do you own the rights to use this product and upload it to Shapeways, for one. Do you have the rights to have it manufactured for yourself? And do you have the rights, if you want to, to sell it to others? And people have to state that they have those rights, of course. However, some people might not read that.

Mr. LUETKEMEYER. Very good.

My time is up, otherwise, I would let Ms. Baum answer. Thank you.

Chairman GRAVES. Mr. Bentivolio?

Mr. BENTIVOLIO. Thank you, Mr. Chairman. Thank you for coming in.

Yes, we had an interesting discussion on the way to votes about the possibilities of 3D printing, and I explained to my colleagues that I was a vocational education teacher as well as general ed and was in the automotive design business for almost 20 years. And I am very familiar with 3D printing and proud to say that many of my female students went on to Case Western to study biomechanical engineering because of CAD and some of the things they got to make in my classroom using a 3D printer from Fair State University. At the time, we just sent the design to them. They printed it for like $35. They sent it back in a nice package. Instead of putting something on the refrigerator door, "Hey, mom and dad, look what I did in class," they got to put it on a table, which was kind of interesting.

But in that regard, I am wondering, the possibilities, we are looking at some things like, for instance, one of my questions is if I could scan something, can I digitize that and have it made; right? So, for instance, hip replacements, that kind of thing, could I use an X-ray data and convert it to digital and then have a custom made hip for a patient if I was a doctor? And there are some regulations that would have to come with that, too; right? I mean, it has to be sterile, made from specific material? So we could do that with bone as well. If somebody crushed a bone, we could replace that using a 3D printer. And how long would that take, for instance? I am not a doctor so I could not even name a bone in my wrist.

Ms. BAUM. Both of those examples are a current practice today, so most of that—to my understanding, most of that work is being done abroad in Germany and Sweden. Arcam is one of the OEMs in Sweden who is producing hip replacements. And right now, while we can take the personalized data from a CT scan or an MRI scan and we can digitize that, we can build that into a 3-dimensional model, my understanding is right now what we are doing is creating those hip replacements in small, medium, large, three or four sizes, because that does the job and does the job most effectively. I may not remember the name of the university that is doing the bone planting—I think it is in Texas—that are growing bone structures, but biomedical engineering is huge.

I mean, what I would say is I would share with you that at Johns Hopkins University there is as skull surgeon there by the name of Dr. Amir Dorafshar and he uses 3D printing to create 3D prints to do pre-op planning. So they know before the team ever goes into the operating room exactly what the cuts are, what is removed, where the staples are. Everything is done in order to simplify that process. I think that is fantastic. The doctor is working less hours in a stressful situation, the patient is under anesthesia less time, and the operating room costs are a huge contributor to healthcare costs, and that is lower. This is disruptive technology.

Now, that is going to upset the apple cart in many directions, so the business model for hospitals is now going to be disrupted. They may not be so happy about operating room costs, operating room times being declined because now they have to go back and rework

the numbers again. But healthcare, medical is one of the first industries to engage 3D printing and additive manufacturing.

Mr. BENTIVOLIO. Great. For instance, if there was somebody that needed plastic surgery, a plastic surgeon could use the X-rays and know where his cuts are going to be, know how he is going to repair the patient's face, if you will?

Ms. BAUM. Absolutely. And they also use 3D printing for surgical guides. So they put the 3D print right on the patient's body and then they know the tool, they know the cut, they know the angle. It takes a lot of the guesswork out.

And I would just also volunteer that in terms of what 3D Maryland is doing, one of our first initiatives or first activities was to create an expert user group, so to gather all the expert users in Maryland around these technologies and cross-pollinate them. And so the Applied Physics Lab is actually collaborating with Dr. Dorafshar to build robotics to make that surgery even better. To make it even smoother. We are also printing cells. And I am not sure again, like, who the doctor is that is printing skin, but they are printing skin during surgery from the patient itself. And when you print cells from a patient, you really limit the risk of rejection or the body rejecting whatever you are putting in it or on it.

Mr. BENTIVOLIO. Okay. So now we have that. And it also reduces 3D printing prototype build time; correct? No longer are we doing the giant clay models; we can actually design parts, for instance, for a motorcycle. I could design everything on that motorcycle using a 3D printer, put it together, make sure it all fits, and probably reduce my build time and prototype costs to—do you have any numbers?

Ms. BAUM. Well, when I see the case studies roll through and Jon can probably speak to this even more clearly, but when I see the case studies roll through and I go, okay, what am I going to present like a baseline, I think many times it is at least a third or a fifth of both the cost savings and the time savings.

And then the other thing, too, is you have those savings but when you put those parts together and they are not quite right, you are not going back to square one; you are tweaking.

Mr. BENTIVOLIO. So how long would it take—real quickly, how long would it take for me, for instance, once I have that information digitized and I am going to do the surgery, to have maybe a model that I can practice or look at, how long would that take to have that 3D print?

Ms. BAUM. Really, those are hard questions because you do not know how much data, what the scale is, and scale is a factor. I would say from thinking about Dr. Dorafshar's skulls, and he uses SLA technology, I think those skulls probably take three or four hours.

Mr. BENTIVOLIO. Three to four hours.

Ms. BAUM. Maybe six hours. And what I am advocating for Maryland—I think it is a model that we could all look at—is that Maryland create a consortium-based model where we have state-of-the-art medical facilities so that Dr. Dorafshar can see a patient from shock trauma and then zip files right over to a local center and get them. We do not have to worry about FedEx anymore, and

then we will start to really see improvements in the technology as well.

Mr. BENTIVOLIO. And I started in the business, Mr. Chairman, when we took a body side molding on a car, sent it to the shop, and waited three months for a prototype model, and now we can get it done in a matter of hours. Right?

Thank you very much. I really appreciate you being here.

I yield back, Mr. Chairman.

Chairman GRAVES. Mr. Collins?

Mr. COLLINS. Thank you, Mr. Chairman.

I am sorry I missed the opening part. I was caught up in another hearing, but thank you all for coming. So I may well be asking questions you answered, and if that is the case, I apologize.

I will go back. I have a little experience in 3D. We have been using that for five or six years in one of my companies to make small-scale models of fairly complex machinery as part of our sales proposal. If it is a $6 million proposal, it is well worth delivering that, and maybe others are going to catch up, but early on we were the only one doing it. And there was a wow factor there. And when we got the order, everyone in the customer's company wanted another one. So it is great. It is great for a lot of things. We used it as a sales tool.

I guess my question comes to, as this takes off, are there any quality control issues on repeatability and all the things you do in ISO and other quality things for repeatability, and CNC machines and whatever. I am a machine shop guy. Are there quality control issues? And once you get into production and out of prototyping? I am not sure who to ask, so if somebody wants to jump in.

Mr. WEIJMARSHAUSEN. So since we are building hundreds of thousands of products on a yearly basis, and actually over 100,000 a month now at Shapeways for our customers, we see these kinds of problems pop up. We make, for instance, very popular iPhone cases. And of course, for them to fit, and to make clear, Shapeways does not provide prototyping only, we print final products. My iPhone case that I use myself is 3D printed. And many other people buy from Shapeways just to get a unique iPhone case. But they need to be an exact fit. And since 3D printing was used for a long time as a prototyping technology, there is definitely a need for technology to improve from a quality perspective, from a price, and even from a speed perspective to meet the needs of today's consumers. From a prototyping perspective, you always have somewhat of an option if the prototype does not come out right to do it again, but if you have a consumer who has a birthday party where he needs to bring a present, you have only one shot to get it right and get it out the door in time.

So the technology has come a long way, and it is really great that we can make final products using 3D printing and enable so many people, but I think the technology is still, to my opinion, in its infancy and it will keep growing. As the big consumer market engages, there will be large jumps in how the technology will mature.

Mr. COLLINS. So, you know, as you are layering this, you know, plastics I understand. I am sure powdered metals are probably being used. Some ceramics.

Mr. WEIJMARSHAUSEN. Yes.

Mr. COLLINS. Is that the place? And what happens when you get into the need for some really high alloy steel, stainless steels, et cetera? Is that like way out or is that never?

Mr. WEIJMARSHAUSEN. We are printing in metals already, and several types. We print in silver, which is the same type quality that you would find in a jewelry store. We print in ceramics. We print in stainless steel, brass, bronze. We are adding other precious metals pretty soon. It is already possible.

Mr. COLLINS. Carbon steel, too?

Mr. WEIJMARSHAUSEN. Not yet.

Mr. COLLINS. Okay. Is that coming, do you believe?

Mr. WEIJMARSHAUSEN. Yes.

Mr. COLLINS. Okay. So as this takes off, what is the thought on the cost? You know, today you have got a lot of machines running unattended. Labor cost is all but zero. You set a machine up and they just pop those out even in a dark factory. Is this similar? What would be the labor cost to make a part using 3D versus automated equipment today in a factory that the machine just does it without manpower?

Mr. COBB. Sure. I think you look at where 3D printing is being utilized today. And as was mentioned before, it is being utilized in a manufacturing environment. Aerospace companies, automotive companies. A number of people are using 3D printing today. So I think where it makes sense is not the things that we are maybe thinking about where you are making tens of millions of bottle caps or something like that, but where it makes sense at this point in time is when you have a short production type of a run or maybe a custom run, or maybe something where because of regulations or other reasons the part is constantly changing. And so when you look at the cost of a piece part, the piece part cost you are going to get utilizing 3D printing is going to be more than say injection molding. However, you are not going to have to build that tool. So as a small business owner, a couple cases that were mentioned here today, you are not going to have that upfront cost, so you are also probably not going to have to have that upfront knowledge as well because you can design something, you can test it with a prototype, and then start printing that as your real part. So it is a little bit different as far as high volume versus mid to low volume, I believe.

Mr. COLLINS. Thank you very much. My time has expired, so I yield back.

Chairman GRAVES. Mr. Payne?

Mr. PAYNE. Thank you, Mr. Chairman. I would like to thank the panel for their testimony today.

With the rapid growth and accessibility of 3D printing, there is room for great innovation as has been stated. As many of you testified, 3D printing creates endless opportunities for entrepreneurs. However, with companies like MakerBot increasingly reducing the cost to own and operate 3D printers, do you feel eventually consumers will become their own manufacturers, making the services that many small businesses offer obsolete?

Mr. COBB. Certainly, MakerBot and products like that really enable a lot of people to do work as far as design work and then some production-type of work that we were talking about. And I think

for certain products, yeah, you could see where a product like MakerBot would actually be used in a home environment.

I think though that where some of the big opportunities for 3D printing comes in is really in the manufacturing process. As we talked about before, it allows current manufacturers to build things in a different manner, to customize things in a different way. So I think there are certainly some products that are absolutely geared toward that, but if you look at the use of 3D printing and all the different materials that are going on today, I think the bigger advances are going to come in the manufacturing area. And with that comes a whole area where students today or people that are in the workplace today are used to manufacturing in traditional methods. And so training of people that are currently employed or training of students to design utilizing 3D printing is one thing, but then to manufacture using 3D printing is vastly different. It is different than injection molding. But it can be used, in fact, and that is one of the big inhibitors I think in getting 3D printing into small and medium sized companies is because the characteristics of a 3D printer are different than the characteristics of injection molding, for instance.

Mr. PAYNE. And on another note, I serve on the Homeland Security Committee as well, and the potential of creating weapons through 3D printing technology is a real concern. What is the possibility of someone coming along and creating a nondetectable firearm or some other harmful weapon using 3D printing technology?

Mr. COBB. We have been staunch supporters of the plastic gun legislation that just got reenacted, I think, at the end of last year, as a matter of fact. So it is something that has been demonstrated at some point, but we have certainly been a supporter of the legislation that has taken place up to this point, looking at the restrictions on that opportunity.

Mr. PAYNE. Okay. But couldn't someone potentially, not follow the guidelines and regulations for this type of product and create something that is not detectable and cause a problem?

Mr. COBB. I am not an expert in it, but I think that you need some type of metal, either a bullet or the firing mechanism, for the firearm. So again, I am not an expert on that but from what I know I think it would be difficult.

Mr. PAYNE. Okay. Thank you.

Chairman GRAVES. Mr. Schweikert?

Mr. SCHWEIKERT. Thank you, Mr. Chairman.

It always makes me nervous when a technology like this is here in Congress because it means we are paying attention to you, and let us face it, when the bureaucracy pays attention to a technology, we often try to regulate it or screw it up. And I say this in the context of someone that believes one of the great successes of the Internet was the fact that it grew and grew and grew before sort of the bureaucratic mechanisms truly understood it and were able to slow down the investments, the capital, the creativity. So what is, whether it be 3D printing or even the thing that maybe you and I have not even found out to define yet, which may be the large scale or the high speed production of such, what is the systematic threat to the industry? Is it copyright? Is it the source files having patent litigation or copyright litigation chasing? Or is it those of us

in government and the bureaucracy? If I came to you right now and said over the next decade this is one of the great disruptive technologies that is going to make us a more efficient society but we have to conquer these risks to that expansion, for each of you, start with Mr. O'Neill, what are the systemic risks to the technology?

Mr. O'NEILL. Well, I am an entrepreneur, so I am not representing the manufacturers. We use the technology to create innovation in our own business. So these kind of questions do not really apply to us but I would sincerely hope that no legislation comes in that would restrict our ability to innovate.

Mr. SCHWEIKERT. What about the discussion—I know we have all been running in and out so I have not heard—copyright?

Mr. O'NEILL. Well, copyright is a concern to us as a copyright holder. And as a holder of 30 patents, I am concerned that people will infringe our patents and our designs and they will print them. And we have had that happen. I mean, we had that happen with Shapeways, but we worked with them and they were able to deal with it. But it is a concern. I mean, it seems like it is something that needs to be addressed but I am not sure it is a 3D printing specific concern because it is still IP is IP, whether it is 3D printed or it is made in some other way. And we have people in China that are making counterfeit products all the time of ours. And they are not doing that with 3D printing. They are doing it with traditional manufacturing.

Mr. SCHWEIKERT. And Mr. Cobb, sort of the same. What is the systemic risk? And on the IP, I think there has been the discussion of saying, well, if I change just a bit of the source code, does that relieve me of a copyright?

Mr. COBB. Well, I guess as a manufacturer, the laws in this country, you have the patent protection. From a manufacturer, what we do is we spend 10 to 12 percent of our overall revenue on trying to be more innovative, trying to stay ahead of things that are going to fall out as far as a patent goes. I think looking at—you talked about what can be an inhibitor. I think one of the things, and maybe it is a little off base here, but I think one of the things that will not help the industry as much as possible is people, young people and traditional workers not being educated in this technology. And I think it is a real opportunity at this point in time to have education at a high school level, at a grade school level, and even workers that are displaced because of manufacturing. I think manufacturing is starting to come back into the U.S., and I think 3D printing is a portion of that. And I think there is a real opportunity for the Federal Government to get more involved in training of new students and traditional workforce.

Mr. SCHWEIKERT. But understand, as we get involved, there are also certain risk profiles that come with that.

Mr. COBB. I understand.

Mr. SCHWEIKERT. What would be a systemic risk to your business?

Mr. WEIJMARSHAUSEN. Well, I already laid it out briefly, and as you mentioned, Shapeways is a platform, a service, so what we want to do is create as many products for people as they like and make it possible for them to create things that were not possible before, in that way democratizing how people think about products.

Everybody can now make things instead of only big companies. But we are taking very serious the responsibility that we need to take that we can only make things that are original. And the good thing is Shapeways has made over 2.5 million products to date that the amount of products that we had to take down, the amount of products that we actually made using the printers that were infringing in hindsight were extremely small—like counting on one hand or two hands, less than 10 that we actually made. And that is, I think, a good thing. Because people grasp that they now can make anything they want. It is not the first inclination. Actually, the technology is much more expensive also than mass manufacturing, so it is much easier to copy something popular with traditional manufacturing technologies, as mentioned in China, perhaps, than you can do it on a 3D printer. But this—yes?

Mr. SCHWEIKERT. And forgive me because I know I am up against time. But academia has always an interesting world where it sits there where what is sort of in the public domain, what is—xxx@ 0:29:06xxx?? So you may have to navigate some more interesting discussion there.

Ms. BAUM. Well, I guess my response to that question, it may bridge academic, it may not. I am an advocate of the technology for business, industry, and entrepreneurs. And what I hear from my expert users is one of the things that is going to hold the industry back or is holding the industry back is the proprietariness of both the hardware and the materials. So the expert users that I see using the technology in the most advanced way say to the OEMs, I do not care about your warranty. I want "under the hood." And they will hire a third-party contractor that provides the warranty so that then they can put in any material they want and they can tweak the parameters. If you do not do that, then you are paying about $25,000 per set of parameters to be under the hood. And I know Peter agrees with me. Keeping the technology open, just like your example, your leading example of the Internet, we have got to keep it open. The U.S. is not a leader in this technology. I think the Western World is leading it.

Mr. SCHWEIKERT. And I know I am way over time, so real quick. The code, the underlying code, proprietary to each manufacturer or sort of a common script?

Ms. BAUM. Proprietary. The parameters that you run the machine on and the materials that you put into the machine.

Mr. SCHWEIKERT. So if I were to hop online right now and want to start design and actually do some coding, and I am a decade old, out-of-date SQL programmer——

Ms. BAUM. I am going to let Jon jump in on that one.

Mr. COBB. Well, I think, if I understand your question correctly, the capability of sending a file——

Mr. SCHWEIKERT. Well, how proprietary is the software for each manufacturer?

Mr. COBB. Okay, the software to actually allow you to print a part?

Mr. SCHWEIKERT. Correct.

Mr. COBB. Okay. So I will answer two ways.

The software that allows you to have access to the printer is common. It is called an STL file. Okay, and that is common to all the

different companies that are out there. Then what is proprietary would be actually how the printer prints. Each one of them uses a variety of different technologies and parameters, so that would be proprietary, if that answers your question.

Mr. SCHWEIKERT. Thank you. And Mr. Chairman, thank you for your patience with me. Thank you.

Chairman GRAVES. Could each of you, you all brought a variety of things, starting with Mr. O'Neill, can you kind of tell us about what you have got in front of you, or show it off?

Mr. O'NEILL. Sure. Well, as I said before, we have to bring products to market very quickly because the iPhone refreshes every year and it usually refreshes around September or October. So to get the products into the stores for the holiday season we have to be very quick. So whenever there are rumors on the Internet, we will take those rumors and take the specification and actually print a copy of an iPhone, a 3D one based on the rumors. And then we will print a product that would hold our lenses, a clip, to see how it fits, see how well it works, and evaluate whether we are happy with that. We will keep working on this all through all the rumors. Every time there is a new rumor we will do a new one, and we will do hundreds of designs of the product to get it right. So when Apple actually does release the phone, then we have got this product that we can put on there and we can test our lenses on the new device. We can test the fit and see how it is. And then if we are happy with everything, we send it out to manufacturing and have the tooling made so we can do injection molding. And then we are in production and that whole process takes about six to eight weeks.

Chairman GRAVES. Mr. Cobb?

Mr. COBB. Picking up on what Patrick was talking about, this particular part was a part that really gets the idea of taking a prototype into a realistic area. What we have done is utilized a printing process somewhat similar to an ink jet printer, but it gives you really the realism that you get from a part. And that is what a manufacturer or designer is looking for. In the particular process that we are using here called PolyJet, what it allows us to do is mix materials. So you have something very durable that is called a digital ABS, the white part, but at the same time you are printing this flexible material here as well. This was printed all as one part. Then, just recently, we introduced the capability of the multiple material and then we have also added color to that. So you can actually then print a very real—in this case it is a prototype shoe—but a very realistic prototype shoe that to most people coming in here looking at this, you would probably think it was the real thing.

And then getting towards the idea of real things, this particular part is a different technology that we have called FDM or fuse deposition modeling. This particular technology takes real thermal plastic. So nylon, polycarbonates, ABS, and ULTEM, that are being used today in manufacturing, typically in injection molding process. But in this particular case, this is an ABS part that we are seeing here. This was printed, again, there were about 18 different components here. This was all printed in one particular piece. So from a prototyping standpoint, it allows you to look at a lot of different

things that are going on because it is not just an individual part; it is an assembly. And this particular prototyping allows you to look at those assemblies testing for form, fit, and function. And then as you go a little bit further, you can also, because it is real thermal plastics, these are the types of materials that are being used in real life today for end-use parts in aerospace, automotive, some consumer goods.

Mr. WEIJMARSHAUSEN. Well, I brought a variety of products. It is so hard to choose if there are so many people creatively active. So in my testimony I used an example of a design collected from New York called GothamSmith. They make men's jewelry. And these are cufflinks that are made in sterling silver designed by them and they are for sale on our platform and they also sell it in a different way. So that is one example.

Another that is really cool is an indie game. So it was just almost an organic movement, crowd funded, the Kerbal Space Program. They made a little game and a very passionate community behind it, and a few guys figured out, hey, can we take our assets from the game and turn them into real things? So they uploaded it to Shapeways and I was working. So now this is people ordered them through pictures, went on the Internet, went viral, and everybody now wants to have them. Two very different examples.

I mentioned Nervous Systems. They use algorithms, so they do not even design the products anymore by hand. There is no CAD software involved. They write computer codes that mimic nature. And by doing that they can create unique items all the time. This is an example of a lightshade with an LED light inside. And you can go on their website. You can go on Shapeways. You can find these products and they are for sale. And Ms. Baum has actually brought another product from Nervous Systems, which is a customizable necklace. And this is also from Nervous Systems. So you can see that it is a wide variety from jewelry to lighting fixtures to gadgets and game accessories. And I can keep going for hours but I will not.

Chairman GRAVES. Ms. Baum?

Ms. BAUM. Right now I am wishing I had selected my samples a little bit differently. I had some skulls sitting up here, and the face transplant model that Dr. Rodriguez did a year ago. The other thing that I wish I had brought is an example of 3D printing with traditional metal plating over top of it. And so one of the companies in Maryland, Repliform, they plate specifically on 3D printed objects, extending the life of the plastic prints. And some of the work that they do is highly classified, but what is in the knowledge center at 3D Maryland is a one-tenth scale thruster that they made for Boeing, and those objects are really impressive.

What I have in front of me are some soles, some prototype soles from Under Armour. Under Armour is an anchor business for Baltimore for sure. That is probably as much as I am able to say. I am close friends with Under Armour and frequently behind the door with them. So right now they are prototyping soles.

This is a watch, and this is off of one of Mr. Cobb's systems, and it is the same idea of the gear shifter. So a very flexible material and very rigid material at the same time.

This is an end-use product from Northrop Grumman, which is also located in Maryland, and this is an end-use part. So prototyping and use parts. And this is a metal-printed part that then had some post-production matching done on it.

And then I guess I would just tag on with Peter about this little guy. This particular printer prints in full color. And we talk about entrepreneurs and we talk about the uses of the technology. If you take a 3D photograph of yourself or maybe your daughter or your grandchildren and you want to have that replicated into a doll, your kids can have dolls that look like them if that is what you want to do. Mixee Labs is doing the UK. Stanley Black and Decker, also located in Maryland, uses this to color code the parts of their tools as they put it through production. So orange is one division, green is another division, or they code the parts accordingly. And that is not an extra. That is just inherent to the technology.

And the last sample that I have that I will talk about is this architectural model. And we are all probably old enough to understand that architectural models before 3D printing were made very painstakingly with X-Acto knives and map board, and today we can actually print the prototype of the building. And there is a saying in the industry that if a picture is worth a thousand words, a prototype is worth a thousand pictures. And I think as our society gets more and more visual, our literacy maybe declines a little bit, but we become more visual, that is more and more true.

And then lastly in my testimony I included a really nice profile of a company in Baltimore by the name of Danko Arlington, and it is a traditional foundry. It is a wonderful American story. A 94-year-old family-owned business, three or four generations, and they started losing their pattern makers. And they said how are we going to solve this problem? They do not want to see this successful business change. And so they adopted 3D printing in 2010. They have a number of Stratasys machines, the highest machine that Stratasys makes, and they say that they win bids because they send a prototype of the object that they are going to create for the defense industry with the bid and that is how they get successful bids.

Chairman GRAVES. You all bring up an interesting point, too. In terms of your different mediums that you print with, how does that translate into durability or strength or whatever the case may be? I will let any one of you answer that want to.

Ms. BAUM. I am going to point the finger to Mr. Cobb because he has got the highest-end materials.

Mr. COBB. The bulk of our business is in the thermal plastic area. I talked about the nylons and polycarbonates, ABS. And traditional manufacturing would be utilizing an injection molding process to bring those parts. We do not quite do that. We do not melt it and we do not put pressure into it. We actually use the layer technology that we all talked about in the past. And so the characteristics of that are different than the traditional injection molding.

Now, we are using real ABS, real nylon, and real polycarbonate. There is a wide variety of manufacturers around the world; we just select one of those. So the difference is not in the material itself, but the difference is in the way the part is actually manufactured.

And so when I was talking a little bit earlier, we talked about having the knowledge from a designer, the knowledge from a toolmaker, and the knowledge from a manufacturer to understand that a 3D printed part is, in our case, a real thermal plastic, but it is made differently than the traditional injection molding. Injection molding has been around for a long period of time. There is a handbook that really talks about injection molding, the principles, to make sure that you build a durable part. There is no such thing for 3D printing or additive manufacturing today. And as the technology evolves, new materials evolve, and they are evolving every single day. Having that knowledge to understand the differences between an injection molded part in the case of a thermal plastic and a 3D printed part is going to be important in producing more and more parts for end-users because they can be used utilizing 3D printing. They are being used in 3D printing today. But it is a different design criteria. It is a different manufacturing method, and it is different.

Chairman GRAVES. Let us say you do not have a drawing and you do not have, you know, you are just in the restoration industry, out of curiosity, can you take an existing or wore out part and create data points and then turn around and reproduce that? And how expensive is this for somebody to, like if they employ or call somebody, they obviously do not want to buy the technology themselves. They would just as soon have somebody do it for them. How expensive is it to create that part as a model to be able to fit up?

Mr. WEIJMARSHAUSEN. So you can use scanning technologies that are getting more and more powerful today. And we actually were just at South by Southwest where we were scanning people at parties which was a big party hit. In the same way, you can take a part, and if it is still in one piece, you could scan it. Not all parts can be scanned, however. You need to be able to see all items of it. It is going to be very hard to scan this part Mr. Cobb brought with him, but more simple products you could very easily scan. And those scanners are getting very affordable. They turn the pictures basically they take into a model you can print and then you can print it in a wide variety of materials.

To your point of questions around what does it cost, the scanners are available from a few hundred dollars up to like tens of thousands if you want to have high-end, professional stuff. The printing itself, again, depending on the material you want to use, items the size of an iPhone case would cost you $20–$30. Things that are getting bigger, they are $50–$100 in plastics. If you talk about metal objects the size of this are around $100–$200. But this is like real stainless steel. So you can make things in silver, all kinds of materials based on scans if you wanted to for repairing stuff. And it has been done.

Chairman GRAVES. So you can build up in metal?

Mr. WEIJMARSHAUSEN. Sorry?

Chairman GRAVES. You can build up in metal?

Mr. WEIJMARSHAUSEN. Yes, metals are possible, just like ceramics and plastics. Yeah.

Chairman GRAVES. Fascinating.

With that I want to thank you all for participating today. And again, I apologize for the vote series that happened during the

hearing, but your testimonies obviously helped us to better understand how 3D printing is spurring economic growth and creating a lot of opportunities, a lot of opportunities out there for entrepreneurs around the nation.

With that, I would ask unanimous consent that all members have five legislative days to submit statements and supporting materials for the record. Seeing none, that is so ordered. And without objection, I would say the hearing is adjourned.

[Whereupon, at 2:45 p.m., the Committee was adjourned.]

APPENDIX



Testimony of

Mr. Patrick O'Neill
CEO and Founder
olloclip, LLC.

before the

House Committee on Small Business

March 12, 2014

Chairman Graves, Ranking Member Velázquez and members of the committee, I am Patrick O'Neill, CEO and founder of olloclip®, the mobile photography company. I invented the olloclip lens, a clip-on lens attachment that takes fisheye, wide-angle and macro photos on the iPhone. I'm very grateful for the opportunity to speak with you regarding our use of 3D printing and how it has helped a small business go from a kitchen start-up three years ago to selling product in every Apple Store worldwide.

I have 25 years of experience in the technology industry. I hold over 30 patents because 3D printing has enabled our innovation at rapid pace. This pace is required for us to be at the forefront of mobile technology as well as keep jobs in America.

As an inventor of computer accessories for more than 25 years, and smartphone accessories for the past 10 years, I've always wanted to develop a product that melded my profession with my love of photography. The iPhone lens idea percolated for years and was inspired by the philosophies of Steve Jobs, founder of Apple, and Colin Chapman, the English founder of Lotus cars, for clean, simple designs.

When the first smartphone cameras came out, I thought wouldn't it be cool to put different lenses on those cameras. The problem was: how do you elegantly mount the lens on the smartphone? I then let that idea percolate for a few years. When the iPhone 4 launched, I felt the camera was great and could benefit from a lens.

Designing the olloclip

In creating the olloclip, I wanted to create a photo lens that would give people the ability to use the iPhone to capture photos artistically, creatively and spontaneously.

Since the start, we employed a "simple and light" design philosophy. At the beginning, when the design studio was my kitchen, we used a local 3D printing company to produce hundreds of prototypes. I would ask myself, "Would Steve Jobs think this product is good enough?". The answer would invariably be "no", and we would keep refining until we felt that the result would meet Steve's demanding standards.

Kickstarter

After a year of development and hundreds of designs later, we launched the olloclip quick-connect, 3-in-1 Photo Lens through Kickstarter, a crowfunding platform, on June 6, 2011.

olloclip received funding within four weeks from backers in more than 50 countries. We achieved almost 5x of our $15,000 funding goal, finishing among the top-40 highest funded projects for that time period.

Success

Three years ago, we were a kitchen startup. Since then, we have moved three times to consecutively larger offices—and now employ more than 50 people in Huntington Beach, California, including

seven full-time designers, allowing us to make our products in the United States.

Today, olloclip has helped accelerate the transition of the smartphone as the primary camera. By providing mobile photography tools similar to those used for larger DSLR cameras, we have achieved phenomenal success in a short amount of time. olloclip has created a new category for mobile photography with award-winning products that are fun and easy to use.

olloclip products are now sold in more than 90 countries and growing. The olloclip has attracted a legion of passionate users, and has received awards from WIRED Magazine, Mashable, and the Consumer Electronic Association to name a few.

The ease with which it allows photographers to take creative shots and share them has also had a major impact on social media sites like Instagram, Twitter and Facebook.

This past January, I was also fortunate enough to be named **Entrepreneur of the Year** by Entrepreneur Magazine.

olloclip Product Development

3D printing enabled me to innovate quickly and turn my idea into a commercial product.

Design and 3D printing are still the core of our product development. In just the past six months, we created six new products to enhance our product line of mobile photography tools for Apple devices, thanks to 3D Printing. These include the new 4-in-1 photo lens system, macro 3-in-1 Lens, iPhone 5c 3-in-1 Lens, Telephoto + Circular Polarizing Lens (CPL), the Quick-Flip™ case with Pro-Photo Adapter for iPhone and iPod touch, and the olloclip photo and video app.

olloclip lenses clip on quickly and easily to the iPhone and iPod without any need for adjustment and the device's camera auto focuses normally through the olloclip to instantly capture photos or videos. Choosing the lens—fisheye, wide-angle or macro lens—is as simple as flipping it over.

> Every olloclip photo lens is made of high-quality components, including aircraft grade aluminum and precision ground coated glass optics. The design is clean and simple—and the product is half the size and weight of the average car key. An olloclip photo lens fits in a pocket making it a easy-to-use camera accessory.

olloclip and 3D Printing

We have invested more than $50,000 in 3D printing, not only to prototype our own products, but also to create mock-ups of rumored iPhones so that lenses can be designed quickly each time Apple releases a new version.

We can literally sketch an idea in the morning, model it in the afternoon, pop it in the printer and have a sample made that evening. Fast turnaround is key for companies in this space.

We finished and validated an iPhone 5 version of the Apple product within days of the handset's announcement. I can't imagine doing this without owning our own 3D printer.

The olloclip Process

The process of developing our products starts here:

1. Brainstorming, concept generation.
2. Sketching of ideas.
3. Modeling chosen concepts in the computer.
4. Printing the concepts of the 3-D printer.
5. Evaluating the prototype for functionality, proportions, aesthetics.
6. Making changes if needed and reprinting.
7. Re-evaluating.
8. If concept is approved and everything looks good, move forward to mass production.

3D Printing - Staying Competitive

The mobile device market changes to quickly. To stay competitive, we use the 3D printer every day to develop new ideas. We've found that it's the best way to innovate quickly and get to market faster. What we can now create in week would have originally took 1–2 months for development.

Without 3D printing, the more traditional model of designing and prototyping would take much longer and the process would slow us down considerably. As Apple launches products, we would miss critical launch timing and market opportunities. This could result in a potential loss of millions dollars of lost sales, perhaps even failure.

Small and mid-size companies like ours need the ability to compete on the world stage—especially in rapidly changing, innovation-driven industries like consumer technology.

Fending off Counterfeits

Fending off counterfeiters is one of our challenges. Poorly made, fake counterfeits flood the markets. Thanks to 3D printing, we can keep our computer-aided design files in-house.

Future of 3D printing with olloclip

olloclip is thinking of investing in a new Conex3 printer that is 7x the cost of our current one. The printer will allow us to make more advanced prototypes in different colors, transparencies and material.

As 3D printing evolves, my small business would like to get to the point w3here we can use it for bridge manufacturing. When we finalize a new design, it takes six to eight weeks to produce the tooling to do the injection mold. It would be nice to use 3D printing to deliver products in that in-between time, so we can get to market faster.

Protecting Small Business

At olloclip, we continue to think differently and are not afraid to try new things, and will only build products if we can innovate. 3D printing allows us to take more risks because it shrinks the opportunity cost. We are able to test and validate new designs within a day or two, rather than a month or two. If they are unsuccessful, we can quickly move on to try something else. Our success has come from our passion and perseverance, our ability to take risks and blaze new trails when it comes to product innovation.

As Congress and others consider policies that will apply to 3D printing, it will be important to ensure entrepreneurs like myself are able to continue using the technology in innovative ways.

I am honored to be here today, and many thanks to Chairman Graves, Ranking Member Velázquez and this committee.

NATIONAL ASSOCIATION OF
Manufacturers

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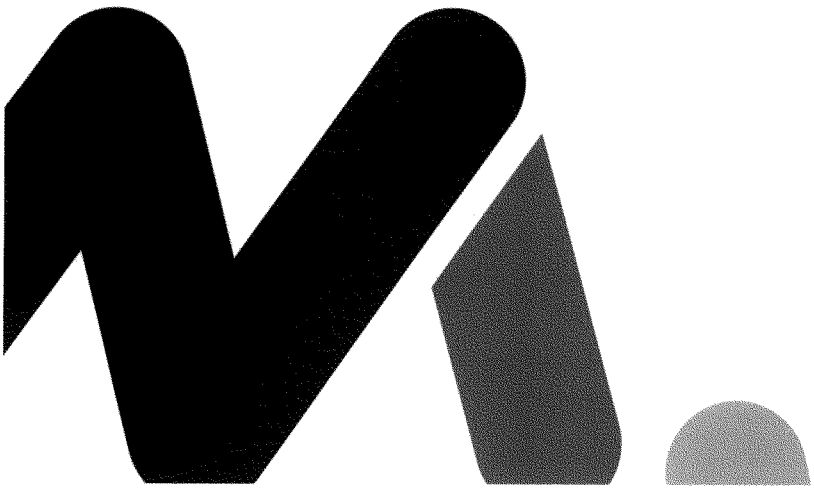
Testimony

of Jonathan Cobb, Stratasys, Inc.

before the House Small Business Committee

on "The Rise of 3D Printing: Opportunities for Entrepreneurs"

March 12, 2014



TESTIMONY OF JONATHAN COBB

BEFORE THE

HOUSE SMALL BUSINESS COMMITTEE

Hearing on: "The Rise of 3D Printing: Opportunities for Entrepreneurs"

MARCH 12, 2014

Chairman Graves, Ranking Member Velázquez, and Committee Members, I am excited to have this opportunity to speak with you today on behalf of the National Association of Manufacturers and to share with you some background on 3D printing innovation, its role in reviving America's manufacturing industry, and how our company—Stratasys—is helping other small businesses grow and thrive in this economy.

My name is Jonathan Cobb and I am Executive Vice President of Corporate Affairs for Stratasys, which is based in Eden Prairie, Minnesota.

Stratasys is also a member of the National Association of Manufacturers (NAM) and I am honored to testify on behalf of the organization. The nation's largest manufacturing trade association, the NAM represents 12,000 member companies consisting of small and large manufacturers in every industrial sector and state. As the voice of manufacturers who employ 12 million men and women who work in manufacturing in America, the NAM is committed to achieving a policy agenda that helps manufacturers grow and create jobs.

In 2012, manufacturers contributed $2.03 trillion to the economy; up from $1.93 trillion in 2011. This represents 12.5 percent of our nation's GDP. Manufacturing supports an estimated 17.4 million jobs in the United States—about one in six private-sector jobs—and offers high-paying jobs. In 2011, the average manufacturing worker in the United States earned $77,505 annually, including pay and benefits—22 percent more than the rest of the workforce.

Manufacturers are also the world's leading innovators. Manufacturers in the United States perform two-thirds of all private-sector R&D in the nation, leading to more innovative breakthroughs than any other sector. I am proud to say that 3-D printing and Stratasys are part of that innovative leadership in the United States.

For many manufacturers in the United States, the economy is showing definite signs of improvement. Manufacturing has added about 600,000 jobs since the end of 2009, but it still has a long way to go. Manufacturing lost more than 2 million jobs during the past recession, and output remains below its 2007 peak.

Nearly 95 percent of all manufacturers in the United States have fewer than 100 employees, and the Small Business Administration (SBA) defines manufacturers with fewer than 500 employees as small. To compete on a global stage, manufacturing in the United

States needs policies that enable companies to thrive and create jobs. Growing manufacturing jobs will strengthen the U.S. middle class and continue to fuel America's economic recovery.

Because of the significant challenges affecting manufacturing, the NAM developed a strategy to enhance our growth. The NAM Growth Agenda: Four Goals for a Manufacturing Resurgence in America, is a policy blueprint for the Administration and Congress that sets four goals with bipartisan appeal for enhanced competitiveness and economic growth: (1) The United States will be the best place in the world to manufacture and attract foreign direct investment; (2) Manufacturers in the United States will be the world's leading innovators; (3) The United States will expand access to global markets to enable manufacturers to reach the 95 percent of consumers who live outside our borders; and (4) Manufacturers in the United States will have access to the workforce that the 21st-century economy demands. To achieve these goals, we need sound policies in taxation, energy, labor, trade, health care, education, litigation, and regulation.

You may be asking yourselves: "What is 3D printing and why should I care about it?"

Well, quite simply, 3D printing—otherwise known as "additive" manufacturing—is the process of creating a digital blueprint using Computer-Aided Design. These blueprints can also come from MRI, or scanned data. These digital files are then sent to the 3D printer, which builds them from the group up in very thin layers of plastic, metal, or other materials. The printing allows the creator to test for form, fit, and function.

With 3D printing technology, a user can take a digital design and turn it into a solid, tangible part within a matter of hours.

Although the concept may be new to many in this audience, the technology has actually existed for decades.

Our company was started in 1988 after our founders, Scott Crump and Lisa Crump, developed and patented the Fused Deposition Modeling (FDM) process. Scott Crump remains active with the company and serves as the Chairman of the Board.

3D printers were originally created to help engineers prove out their designs and perfect them before spending money on expensive factory tooling for production. This creates better quality products and allows companies to bring those products to market faster. Today, manufacturers are not just using the machines to produce prototypes. They are also using 3D printers for low-volume manufacturing of items from prosthetic limbs to the interior components of aircraft.

This brings up an important point that is relevant for this Committee: 3D printing will not replace traditional manufacturing processes but, rather, it serves as another "tool in the manufacturing toolbox" to complement how a good portion of manufacturers are delivering products to market in a more efficient and customized way.

Like the internet in the 1990's and smart phones in the last decade, 3D technology is becoming highly accessible, and poised to usher in a new world of "mass customization."

As the industry is changing, our company is changing as well. In 2005, we started a separate business unit called RedEye, which allows people to acquire 3D printed parts. We also added Solidscape of Merrimack, NH, which helps jeweler designers and dental markets adopt 3D solutions.

Last year we merged with Brooklyn-based MakerBot, a 3D printing company whose user-friendly products are designed for entrepreneurs with basic technical skills. MakerBot's growth since its inception in 2009 has allowed more small companies to receive the true benefit of 3D printing.

This growth in our business has helped other small businesses grow as well. When musician Chris Milnes was performing at events with his band, he used a popular credit card reader to collect sales proceeds for his band's CDs and merchandise. He loved the card reader, which plugged into his laptop, but he found that the product tended to spin when used instead of remaining stable, making it sometimes difficult to use. Using his children's Lego pieces, Chris built an accessory that kept the card reader stable. With a successful design, Chris wanted to bring this new innovation to market. But taking this prototype to production would have been costly and inefficient using traditional product methods. So instead, Chris invested in a consumer-level 3D printer, which has literally become a factory on his desk, enabling him to take his invention into production from his home for the cost of a couple thousand dollars.

We take pride in stories like this. To us, they demonstrate that we are not just in the business of producing 3D machines, we are also helping empower entrepreneurs by bringing manufacturing into their homes and workplaces.

Here's another small-business story, this time about a company that used a high-end Stratasys 3D printer to help get a product to market quickly and inexpensively.

When South Dakota-based Peppermint Energy set out to make a portable, plug-and-play solar generator, they needed more than just a blueprint on paper to see their product take shape. Using a 3D printer, Peppermint produced a physical and functional prototype that helped them identify design flaws and make changes to the product quickly. By making these alterations with a 3D printer, Peppermint was able to save $250,000 on tooling costs.

Despite the existence of 3D printing technology for decades, only in recent years has the priced dropped enough to allow a new class of low-price systems to become accessible to everyday consumers and entrepreneurs. With that in mind, the best thing Washington can do right now is help the industry reach its full potential by encouraging further growth and investment.

Since 2002, nearly a quarter of Stratasys' business has been in education. By helping students learn design and manufacturing

through 3D technology, we're helping schools build a strong hiring pool for businesses in America.

The NAM, Stratasys, and all manufacturers are working to address the need for a skilled workforce and therefore are focused on a number of STEM initiatives. Stratasys, in particular, is a strong supporter of the STARBASE program, a STEM educational initiative that engages students—mostly 4th and 5th graders from inner city schools—in an intensive, five-day program in science, mathematics, and technology. STARBASE features a "Mission to Mars" theme that allows students to create a Mars colony. During the program, students get the greatest excitement and value from learning about a design concept in the classroom and turning that into reality by 3D printing several variants of their own tailfin design for a rocket that is launched on a field. Students also experience first-hand the results of each set of tailfins and how they affect the rocket flight stability, trajectory, and height. It is a powerful and moving experience for young students, and for many, it can be an epiphany that they too could pursue an engineering career. This program relies on federal grants and we believe Congress should continue supporting STEM initiatives that will help grow and develop the next generation to lead the 3D printing revolution.

As you can tell from our presence here today, the interest in 3D printing is strong and the future is infinite for this technology. Despite our industry's long history, we are experiencing rapid growth that is giving domestic manufacturing a new global competitive edge. As President Obama noted in this recent speech touting additive manufacturing (3D printing) hubs, "If we want to attract more good manufacturing jobs to America, we've got to make sure we're on the cutting edge."

Our company could not agree more.

This is an industry that was started in the United States and is dominated by domestic businesses. We must continue to grow, innovate, and lead in this area.

shapeways

TESTIMONY OF
MR. PETER WEIJMARSHAUSEN
CEO AND CO-FOUNDER, SHAPEWAYS, INC.

Before the U.S. House of Representatives Committee on Small Business
The Rise of 3D Printing: Opportunities for Entrepreneurs

March 12, 2014

Good afternoon Mr. Chairman and members of the Committee. My name is Peter Weijmarshausen and I am the CEO and Co-Founder of Shapeways. I'm honored to be here today to discuss how 3D printing is fueling small business growth, enabling anyone to create a business with physical products at low capital costs.

As a kid in the Netherlands, I loved coding and playing with computers, resulting in a passion for open source software. Driven by this and my entrepreneurial spirit, I spent much of my early career at various software startup companies. One of these was Blender, the first company to publish free 3D modeling software.

In 2006, I learned about a technology called 3D printing, which prints physical objects based on 3D computer designs.

I immediately thought about the Blender community, a large group of 3D modeling enthusiasts. They, like other designers, were using 3D software, but never imagined it would be possible to hold their own designs in their hands. So, I asked some of them for their designs to 3D print. When I showed the 3D printed "products" to them, they were blown away. They immediately agreed that it was a good idea to build an online service where people could 3D print their own designs. I knew that there could be a business opportunity, but how big was still to be seen.

I started working on Shapeways in March 2007, within the Lifestyle Incubator of Philips Electronics, who shared the vision that 3D printing could be very disruptive. At the time, 3D printing was used mostly for prototyping by large companies and was very expensive.

By 2008, we launched Shapeways.com to enable anyone to make and get the products they want. We started 3D printing products NOT prototypes!

In 2010, we spun Shapeways off as an independent company and moved the headquarters to New York City. New York is perfect for Shapeways, providing us with high-caliber, tech-savvy talent, who are hungry for innovative solutions. It's also the creative epicenter, so we have the ability to talk to so many of our customers and learn from them firsthand. At that point, we had fewer than 20 employees. Now, Shapeways has more than 140 employees who work at offices in New York and Seattle, and in our factories in Eindhoven and Long Island City. These factories are transforming old industrial hubs into factories of the future, with new and innovative processes and machinery.

Shapeways is now the world's leading marketplace and community to make, buy, and sell custom, 3D printed **products**, unlocking design opportunities for entrepreneurs and creative consumers. Shapeways itself is already a success story in terms of a small business growing out of the endless possibilities of 3D printing. But, the opportunities created by 3D printing for entrepreneurs are immeasurable.

When I think about what we can achieve, I relate it to how the Internet has enabled software engineers to become entrepreneurs. Before the Internet became mainstream, brining new software to the market was difficult. You had to know what users wanted,

build out the software on your own, typically with the support of a large company, and go through many, many rounds of testing. Once you had a product that you thought was viable, you had to manufacture large quantities of it on a CD or a floppy disk, get them into a retail environment, and determine how to market it so the software would sell.

Today, using the Internet, any software engineer can become an entrepreneur. The Internet has removed the barriers. Launching a website has become incredibly easy. This is the reason why companies like Goggle, Amazon and Facebook became so successful so quickly.

Similar to how the Internet removed barriers for software development, 3D printing is removing barriers for manufacturing products. Designers can: create their products and have them printed out with little cost; ideate and update their designs quickly so there's no need to do marketing research in advance; build products without costly upfront payments for manufacturing or molds; and distribute products directly online, with no retail investment. Plus, they can continuously evolve their products, since they don't have to keep any inventory.

And there is no question that entrepreneurs are taking notice. From 2012 to 2013, product uploads increased from 40,000 per month to 100,000 per month, and the number of new people creating products on Shapeways has doubled!

3D printing transforms how we think about launching products and enables the garage (product) entrepreneur in ways they could never conceive of in the past.

To understand it in more detail, I'll first tell you how Shapeways works:

- Anyone can upload a 3D design to Shapeways.com. There are many free and open source software programs available to use for 3D modeling so literally anyone can do it! And, they don't even need a lengthy or expensive class to learn how. In fact, Shapeways surveyed its shop owners in 2013 and found that 50 percent taught themselves how to 3D model!
- After the design is uploaded, the user selects the material in which to print or make available. Shapeways offers 40 materials and finishes, including precious metal, bronze, ceramic, plastic and full color sandstone.
- The designs are reviewed by our 3D print engineering team to ensure that they are viable for 3D printing. Once confirmed, the design is sent to a 3D printer.
- 3D printers build products one layer at a time, slowly forming the final product. This process can take anywhere from hours to days depending on the size and complexity of the design. However the industrial machines we use can build thousands of parts at the same time, enabling scale.
- Once complete, products are removed from the printer and cleaned by hand.
- Printed products may be polished or dyed depending on the material and order.

- Finally, the finished product is packaged by Shapeways and shipped directly to the creator or shopper!

On-demand 3D printing as described above is at the core of Shapeways. People have used it to create endless types of products for their hobby or business, including model trains, jewelry, funny internet memes, home décor such as lamps, dishware like cups and plates, cell phone covers, and so much more. But we allow, and encourage, designers to take it one step further by creating shops of their own. This is where the true ability to become a small business owner comes in.

GothamSmith is one example of this type of small business that came about because of 3D printing. Four friends who were working in creative industries in NYC wanted to create something more tangible and lasting than a website or app. Starting with designing cufflinks and eventually moving into other jewelry. GothamSmith uses 3D modeling applications to develop unique ideas. Shapeways gives them the ability to quickly turn these ideas into physical prototypes and then final products at scale—without relying on costly large-scale metal casting machinery. They sell their products on Shapeways.com and through other channels, and are emphatic that their business wouldn't exist without Shapeways or 3D printing.

The ability to easily create one-of-a-kind, customizable products is another phenomenon spurred by 3D printing. An otherwise extremely costly and labor intensive process, 3D printing and Shapeways make it seamless. One company that is leveraging the technology this way is Nervous System, a design studio that uses a novel process, creating computer simulations inspired on natural phenomena such as the growth of coral. Their process generates products such as jewelry and light fixtures. All of their products are one-of-a-kind and 3D printed by Shapeways, sold on our site and multiple retail channels, including the MoMA Store. They are another example of a successful business that is rapidly growing, and employing more people every day as demand grows!

These are just a couple examples among the more than 14,000 stores currently open on Shapeways, and we know our users are hungry for more. In a survey last year, we found that of our shop owners:

- 50 percent are first-time entrepreneurs (of anything!)
- 84 percent want selling on Shapeways to be their full-time job.
- 94 percent spent less than $1,000 to open their shops!

The technology has been around for decades and has impacted dozens of industries, including automotive, engineering, construction, entertainment, and even medicine. We're just now starting to really grasp what it can achieve.

Even the President of the United States has acknowledged this great opportunity. Shapeways is currently working with the White House to partner on the first ever White House Maker Faire, dedicated to showcasing and celebrating the Maker movement. The goal is to support a culture of making, and use it as a call to action

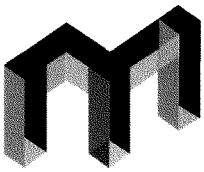
for stakeholders, and Shapeways has committed to help the White House use this moment-in-time to facilitate entrepreneurship.

And, in his State of the Union address last month, President Obama spoke about a facility in Ohio saying that: "A once-shuttered warehouse is now a state-of-the-art lab where new workers are mastering a 3-D printing that has the potential to revolutionize the way we make almost everything."

It's true, 3D printing does have the potential to revolutionize the way we make everything. I'm passionate about helping others see that, and I hope that I have effectively demonstrated to you the positive impact it can have on small businesses, creating many jobs in the process.

Moving forward, it will be critical that accessibility to 3D printing remains uninhibited.

Thank you for your time today, and allowing me the honor of speaking about 3D printing. A technology that will change the world.



3DMARYLAND

TESTIMONY OF

JAN BAUM

EXECUTIVE DIRECTOR, 3D MARYLAND

Before the

HOUSE COMMITTEE ON SMALL BUSINESS

Hearing on "The Impact of 3D Printing on Entrepreneurship/Small Businesses"

12 March 2014

Contact Information:
Jan Baum
3D Maryland
9250 Bendix Road
Columbia, Maryland 21045
410.313.5825





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 effi-

[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%2Oprintshow%20London%20UK%20-%20Building%20a%20small%20business%20around%203D%20printing.pdf

ciencies 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 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.

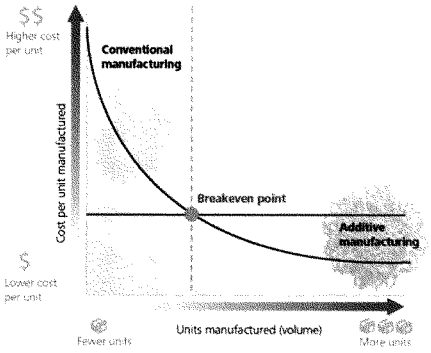
- Additive manufacturing's inherent flexibility further increases the technology's advantages from economies of scope. While each of the seven 3D printing technologies has specific applications, within those applications the tool can virtually produce an unlimited range of products without any tooling 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.

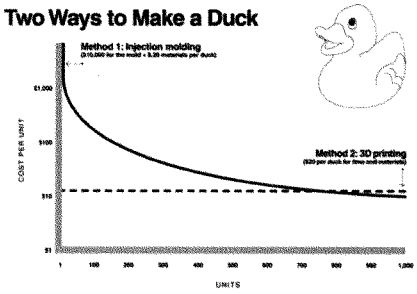
• The sweet spot for 3DP/AM today is in low volume/high value parts and products from end-of arm tooling to hearing aids. We are beginning to see manufacturing without traditional tooling and on-off tooling, and concepts such as mass customization are a reality. It costs no more per unit to run one unique 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 product 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 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

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

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 is 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 growth 3d 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 eliminated[5] 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.

3D Maryland

[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

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

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

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 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 move-

[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%20201%20-%203D%20printshow%20London%20UK%20-%20Building%20a%20small%20business%20around%203D%20printing.pdf

[9] Wohlers & Associates: Wohlers Report 2013: pg 261

ment towards leveling the playing field in modern manufacturing.

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

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