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THE DISRUPTER SERIES: 3D PRINTING

FRIDAY, FEBRUARY 26, 2016

House of Representatives,

Subcommittee on Commerce, Manufacturing, and Trade,

Committee on Energy and Commerce,

Washington, D.C.

The subcommittee met, pursuant to call, at 10:00 a.m., in Room 2123, Rayburn House Office Building, Hon. Michael C. Burgess, M.D., [chairman of the subcommittee] presiding.

Present: Representatives Burgess, Lance, Harper, Guthrie, Bilirakis, Brooks, Schakowsky, Clarke, Kennedy, Cardenas, Welch, and Pallone (ex officio).

Staff Present: Mike Bloomquist, Deputy Staff Director; Leighton

Brown, Deputy Press Secretary; Rebecca Card, Assistant Press Secretary; James Decker, Policy Coordinator, CMT; Andy Duberstein, Press Secretary; Graham Dufault, Counsel, CMT; Melissa Froelich, Counsel, CMT; Paul Nagle, Chief Counsel, CMT; Tim Pataki, Professional Staff Member; Olivia Trusty, Professional Staff, CMT; Dylan Vorbach, Legislative Clerk, CMT; Michelle Ash, Minority Chief Counsel, Commerce, Manufacturing, and Trade; Christine Brennan, Minority Press Secretary; Lisa Goldman, Minority Counsel, Commerce, Manufacturing, and Trade; Caroline Paris-Behr, Minority Policy Analyst; Tim Robinson, Minority Chief Counsel; and Diana Rudd, Minority Legal Fellow.

Mr. Burgess. The Subcommittee on Commerce, Manufacturing, and Trade will now come to order. I will recognize myself for 5 minutes for the purpose of an opening statement.

Today we are continuing our Disrupter Series and focusing today on additive manufacturing, also what is known as 3D printing. Additive manufacturing has disrupted the industries it has impacted, not just by challenging incumbents, but also by lowering cost and increasing efficiency.

Harnessed properly, this is another example of how innovation is creating jobs and opportunity and helping set the stage for a revival of manufacturing in the United States.

Additive manufacturing has been around since the 1980s with the patent for stereolithography issued to Charles Hull, the founder of one of the companies testifying today, 3D Systems. About 30 years later, surveys show that about two-thirds of industrial manufacturers say they are implementing additive manufacturing either by experimenting or using it to create prototypes of finished products, and the 3D printing industry is expected to grow from the $6 billion it is today to over $20 billion in a mere 5 years time.

3D printing has already woven its way into our manufactured products in subtle ways. For example, some of the commercial airliners we all fly will soon use 3D-printed parts in their engines, and GE will

testify about that today. Many of the cars on the road have had their development sped up dramatically thanks to 3D-printed prototypes.

Additive manufacturing has plugged itself into a growing proportion of the manufacturing supply chain because the designs are flexible and they are a naturally better solution for certain tasks.

But 3D printing is also making a splash in less subtle ways. People around the globe are benefitting from prosthetic limbs, which were otherwise unaffordable. Surgeons can create accurate surgical guides which reduce errors and as a result will save lives. Scientists have begun experimentally printing human cell structures using a person's DNA. That resulted as a logical use of life's own building blocks, but certainly potentially revolutionary for patients.

In my district, 3D printing is enabling businesses to get the job done more efficiently. I have a constituent back home, his name is Adrian Murray, he runs a hotrod modification shop called Painless Performance, and he provides customers with custom wiring harnesses for their classic cars. These parts are no longer manufactured on an assembly line, but using a 3D printing prototype offered by the Specialty Equipment Manufacturers Association, Painless Performance is able to speed up the development process. And I think we are going to show a video clip of that, if the technology doesn't fail us, and I will continue talking while that runs.

[Video shown.]

Mr. Burgess. As the subcommittee with jurisdiction over vehicle safety, we are especially interested in ways that vehicle suppliers and manufacturers are using polymers and plastics to enhance safety.

Can we just turn the sound down on that, because it is mostly the visual that we want.

Carbon fiber-reinforced plastics have 12 times the energy absorption capabilities, while adding half of the weight of some comparable metal parts. Additive manufacturing is helping automakers and part suppliers integrate these innovative materials into cars, which is making a safer and improving fuel efficiency. As 3D printers become more affordable, the universe of people able to print 3D-printed objects on their own expands.

One of the things in research for this hearing, my staff found an article for me, it is actually from Australia, that it talks about Ralph Mobbs, a neurosurgeon from Prince of Wales hospital in Sydney. And in resecting a tumor in a patient, he had to replace the top two vertebras, pretty difficult operation, and, obviously, without the proper type of prosthetic it would have been impossible.

So the surgeon worked with an Australian medical device manufacturer to craft replicas of the patient's top two vertebra out of titanium. I just want to read you a quote from the surgeon -- and

mind you, he is from Australia, so he talks funny, I am sure.

"To be able to get the printed implant that you know will fit perfectly because you have already done the operation on a model, it was a pure delight. It was as if someone had switched on a light and said, 'Crikey, if this isn't the future, well, I don't know what is.'"

So, Dr. Mobbs, I agree with you, if this isn't the future, I don't know what is.

I will now turn to Ms. Clarke from New York, ranking member of the subcommittee, for an opening statement.

[The prepared statement of Mr. Burgess follows:]

******** COMMITTEE INSERT ********

Ms. Clarke. Good morning, Chairman Burgess and members of this morning's panel. Mr. Chairman, thank you for holding this hearing on 3D printing.

For many of us, when we think of 3D printing, we think of plastic toys, key chains, and other trinkets, but 3D printing is about more than just the novelty of printing in plastic. This technology has many applications that we are only starting to explore.

3D printers enable small-scale personalized production that gives consumers more choice and convenience. Consumers can order affordable custom-printed items, from cell phone cases to shoes and prescription eyewear.

3D printers help product designers by allowing them to print prototypes more easily. Manufacturers can print replacement parts on demand. Prosthetics can make customized to make people who have lost a limb more comfortable. And recently, a 3D-printed vertebra, as our chairman has indicated, was implanted into a child with bone cancer.

While today we are mostly printing in plastic and metal, 3D bioprinting opens a whole new world of possibilities in the medical field. Doctors may one day be able to grow needed organs for transplants or skin for prosthetic limbs or skin grafts.

The future potential of this technology is one more reason why we need to increase our Federal investments in research and innovation.

But as we think about the tremendous potential of 3D printing, we also need to consider possible risks and challenges. Here are some of the questions on my mind. How should we protect consumers when the consumer doesn't buy the product but rather the blueprint to make a product? How does 3D printing work with our existing laws on intellectual property? And what should people be able to make with 3D printers?

I am especially concerned about 3D-printed weapons. Think about this: If someone has access to a 3D printer, all they need is the right blueprint. When the gun buyer is now the gun manufacturer, who does the background check? Who is responsible for keeping weapons out of the wrong hands? This isn't theoretical. The first 3D-printed gun was made 3 years ago.

An all-plastic gun would be a violation of the Undetectable Firearms Act, but a law banning the manufacture of nonmetal guns only goes far when a plastic firearm can be made at home. And we may not be far from seeing metal guns being printed at home.

Those who design blueprints for 3D printing and provide 3D printing capability must take responsibility to ensure that their business does not endanger other lives, and we in Congress need to make sure that our laws are up to date with today's technology.

I look forward to hearing from our witnesses on the potential for

3D printing as well as your perspectives on how we deal with some of these challenges.

Having said that, Mr. Chairman, I yield back.

[The prepared statement of Ms. Clarke follows:]

******** COMMITTEE INSERT ********

Mr. Burgess. The chair thanks the gentlelady. The gentlelady yields back.

The chair would inquire of Mr. Pallone if he seeks time for an opening statement.

Mr. Pallone. I do.

Mr. Burgess. Recognized for 5 minutes for an opening statement.

Mr. Pallone. Thank you, Mr. Chairman.

3D printers and the products they produce have the potential to transform and improve our lives. It is remarkable to think about what is already possible in this space, not to mention the possibilities for the future.

Today, 3D printers are driving innovation in American factories, schools, hospitals, and homes. All around the country, health researchers are using 3D printers to develop new approaches to tissue transplant and regeneration. The level of customization permitted by 3D printing can allow prosthetics, hearing aids, and dental aligners to be made more comfortable, effective, and affordable.

And now think about the potential for 3D printers to transform the way cutting-edge medical care is distributed. The latest and greatest discoveries would no longer be limited to those who have access to a select group of medical facilities. Instead, 3D printers could help to easily reproduce new treatments and therapies at any hospital

throughout the country and the world.

3D printing technology also has the potential to help build a more dynamic and inclusive workforce. At Rutgers University in my district, innovators created 3D-printed braille maps that make a local vocational training center easier to navigate for the visually impaired.

Additionally, 3D printers allow people to create prototypes of new designs or inventions at a lower cost than traditional production techniques, thus helping underrepresented communities gain access to entrepreneurship.

The development of 3D printing technology is a great example of how effective public-private partnerships can be. This administration and members such as Representative Kennedy have worked to strengthen Federal support for 21st century manufacturing technology such as 3D printing, and I look forward to hearing how the National Network for Manufacturing Innovation is working with companies, such as those represented by our witnesses today, to promote American innovation and safeguard the future of domestic manufacturing.

And as with all new technologies, the further adoption of 3D printing, especially its home use, raises safety and regulatory questions. Many of us have seen the media coverage about 3D-printed

guns. While the ability to make guns at home may not be new, the ability to make them easily and cheaply poses new safety risks, and increasing the number of guns made outside of the registration process could increase the number of guns in the hands of criminals.

In addition, questions have been raised about how to protect intellectual property as 3D printers proliferate. There have been concerns about some types of inks used in 3D printing containing BPA, a chemical that the FDA has banned from use in baby bottles and children's drinking cups.

3D printing offers enormous possibilities for innovation in manufacturing, increased opportunities for entrepreneurship, and convenience and customization that was not available before. So it is exciting to think about the possibilities, and I am confident these innovations can be coupled with consumer protections so that they really can improve people's lives.

Did you want some time?

[The prepared statement of Mr. Pallone follows:]

******** COMMITTEE INSERT ********

Mr. Kennedy. I will take 30 seconds.

Mr. Pallone. Yeah. I will yield you the rest of my time.

Mr. Kennedy. Thank you. Thank you very much, Mr. Pallone. And I want to thank the chairman for calling this hearing.

I was really excited just to get a chance to listen to all of you and understand a little bit about how the national institutes are going building out the progress. I have been bragging about you like crazy everywhere, so hopefully it is good. And very much look forward to understanding and getting some lessons learned from you about what is working well, where we can improve as other institutes are stood up around the country, how we can try to learn from your success.

Most importantly, trying to understand how government can be a positive source for innovation and trying to lower some of the barriers to entry and the risks that local innovators take and small businesses take and trying to make sure we can spur the next generation of manufacturing here in the United States, what that also means for the workforce, integration with our workforce, workforce training, all the way up the supply chain.

So I am grateful for the opportunity to be here, grateful that all of you are willing to come testify, and look forward to learning from you over the course of the rest of the morning.

Thank you. I yield back.

This is a preliminary, unedited transcript. The statements within may be inaccurate, incomplete, or misattributed to the speaker. A link to the final, official transcript will be posted on the Committee's website as soon as it is available.

[The prepared statement of Mr. Kennedy follows:]

******** COMMITTEE INSERT ********

Mr. Burgess. The chair thanks the gentleman. The gentleman yields back.

Seeing no other member seeking time, we will conclude with member opening statements. And the chair would remind members that, pursuant to committee rules, all members' opening statements will be made part of the record.

[The information follows:]

******** COMMITTEE INSERT ********

Mr. Burgess. We do want to thank our witnesses for being here today, taking time out of your day to testify before the subcommittee. Today's witnesses will have the opportunity to give opening statements, and then we will follow with questions from members.

Our witness panel for today's hearing includes Mr. Neal Orringer, vice president for alliances and partnerships, 3D Systems; Mr. Alan Amling, vice president for Global Logistics and Distribution Marketing with UPS; Mr. Ed Morris, director of national additive manufacturing innovation at the National Center for Defense Manufacturing and Machining; and Dr. Herderick, the additive technologies leader for corporate supply chain and operations within General Electric.

So we appreciate all of you being here today. We will begin the panel with Mr. Orringer.

And, Mr. Orringer, you are recognized for 5 minutes for an opening statement, please.

STATEMENTS OF ALAN AMLING, VICE PRESIDENT, GLOBAL LOGISTICS AND MARKETING, UNITED PARCEL SERVICE, INC.; DR. EDWARD HERDERICK, ADDITIVE TECHNOLOGIES LEADER, GE CORPORATE SUPPLY CHAIN AND OPERATIONS; NEAL ORRINGER, VICE PRESIDENT, ALLIANCES AND PARTNERSHIPS, 3D SYSTEMS CORP.; AND ED MORRIS, VICE PRESIDENT AND DIRECTOR, AMERICA MAKES, THE NATIONAL ADDITIVE MANUFACTURING INNOVATION INSTITUTE NATIONAL CENTER FOR DEFENSE MANUFACTURING AND MACHINING (NCDMM)

STATEMENT OF NEAL ORRINGER

Mr. Orringer. Thank you. Thank you, Mr. Chairman, Congresswoman Clarke, and members of the distinguished subcommittee. Thank you for the invitation to address you today.

I am honored to discuss a critically important topic, how additive manufacturing is revolutionizing the delivery of health care. In 1983 --

Mr. Burgess. Mr. Orringer, is the green light on in your microphone?

Mr. Orringer. It is.

Mr. Burgess. You may need to pull it a little closer.

Again, I would stress that even though this is the premier

technology committee in the United States Congress, we have pretty low-tech equipment. But please continue.

Mr. Orringer. How is this? Okay.

In 1983, my company's founder, Chuck Hull, invented 3D printing. He was applying a process called stereolithography to physically replicate an eyecup that was designed and digitally drawn on a computer. His patent was granted in 1986, and the business took off from there. More than 30 years later, the industry is in full throttle.

For its own part, 3D Systems is the world leader in additive manufacturing and the only major U.S.-based 3D printing company. From the offset, we have catalyzed continuous innovation in health care. So I guess I would amend Dr. Mobbs' comments and say the future is now.

In the early 1990s, we revolutionized the manufacturing of hearing aids, rapidly customizing the form and fit to an individual's ear with unparalleled precision, helping build wireless devices with comfortable biocompatible materials. And today, 99.5 percent of all hearing aids are 3D printed worldwide.

A decade later, we helped two graduate students from Stanford University discover a better way to straighten teeth. With our technology, they manufactured what became Invisalign, which are clear orthodontic aligners, as has been discussed. Today, Align is a world leader in mass customization, accuracy, and comfort, producing over

20 million individual aligners in the last 12 months alone.

So 3D printing continues to advance significant breakthroughs in the field of precision medicine. Now, that is a movement that has been championed by the FDA that tailors medical treatments intensively to individual characteristics of each patient. So as part of this movement, together with genomics, regenerative medicine, computational biology, and medical imaging, 3D printing is once again revolutionizing the practice of saving and improving lives.

Now, today I would like to concentrate on three areas: virtual surgical planning, fabrication of advanced implants and devices, and new modeling processes. Virtual surgical planning is what I would start with first.

VSP empowers surgeons with unparalleled precision in the most complex procedures. It significantly reduces the time in the surgical theater and saves lives. Our experts interact directly with doctors, receiving data from CT scans, and then design and build surgical guides that are placed on a patient to support a particular procedure.

[Video shown.]

Mr. Orringer. We are showing a video right now in the hearing room to highlight the case of Blessing Makwera. He sustained a land mine injury to his upper and lower jaws, tongue, lip, and teeth. Blessing's spirit and courage are truly inspirational, and today he

can smile.

Now, 3D Systems worked with Joel Berger, an oral and maxillofacial surgeon at Sharp Memorial Hospital in San Diego, California, to rebuild Blessing's face and give him new teeth. The fibula free flap operation involves taking bone, tissue, and vessels from the fibula and reconfiguring them to form an upper and lower jaw connected to blood vessels in the neck. We used CT scans to extract 3D anatomical information needed to visualize the surgery in 3D and map out the surgical plan.

Blessing required a number of 3D tools, including a mandible and maxilla cutting tools of the lower and upper jaw to guide the surgeon's saw blades in the operating room. It is an inspirational story among tens of thousands over the last several years.

Models and simulation. Aside from the surgical guides, Blessing's surgeons also used 3D printing models for reference during the operation. These models show surgeons what is hidden beneath layers of soft tissue, and it gave surgeons hands-on experience with Blessing's jaw and anatomy long before the surgery.

Finally, I want to talk not about customized tools but about how 3D printing is transforming wholesale production of medical devices and implants. I brought a titanium component of a hip transplant, which we 3D printed. Rather than go through the onerous process of

building a cast mold, shaping and cooling, and then coating a single part, metal 3D printing allows us to consolidate the supply chain, saving time and resources. It also allows us to add functions to the part with designs that maximize bone cohesion, structures that simply cannot be built via any other manufacturing process.

So doctors and device manufacturers can send us data to engineer 3D models, and then we use direct metal printing to build dozens of these titanium cups in a single build process. We have been working with U.S. and European regulators to ensure appropriate quality assurance in the process for an array of implants and devices.

In all these areas, we have a strong and constructive partner in the Federal Government. As we work to receive appropriate qualification for these products, it is essential we maintain an appropriate balance between promoting innovation and ensuring the safe delivery of care to patients.

As 3D printing improves the economics and the production of critical healthcare tools, I am hopeful we might someday see these efficiencies actually translate to lower costs for the patient. Integrating these novel processes and tools will require a greater understanding not only by the regulators, but the health insurance industry as well.

Now, in due time, perhaps it will be commonplace for these tools

to be integrated into conventional building processes. It is time for 3D printing to be appreciated as an important instrument for mainstream quality care, and I look forward to discussing this and other issues with the committee today. Thank you.

[The prepared statement of Mr. Orringer follows:]

******** INSERT 1-1 ********

Mr. Burgess. The chair thanks the gentleman.

The chair recognizes Mr. Amling for 5 minutes to summarize your opening statement, please.

STATEMENT OF ALAN AMLING

Mr. Amling. Good morning, Chairman Burgess, Ranking Member Schakowsky, members and staff of the committee, fellow witnesses, and attendees. My name is Alan Amling, and I am the vice president of marketing for UPS Global Logistics and Distribution. And during my 23-year tenure, I have helped our business develop and grow across all aspects of the e-economy and to launch innovative new solutions like carbon-neutral shipping.

While you are likely familiar with UPS' fleet of more than 100,000 brown trucks and our 425,000 employees globally, you may not know much about our supply chain business. More than 100 years ago, UPS started as a bike messenger in Seattle. In 2016, we operate one of the largest airlines in the world and offer global supply chain services, including ocean and air freight, ground freight, brokerage, and contract logistics, in addition to our more familiar brown package services.

Our global logistics network, made more intelligent and efficient, has the potential to radically reshape and reinvent

economies. That is why we are interested in 3D printing, which could disrupt traditional manufacturing the way that e-commerce has disrupted traditional retail. Certainly, as this new technology becomes more widely available, there will be bumps in the road and hurdles to overcome, but the power of 3D printing cannot be overstated. It is disruptive not just because it is new, but because it helps small businesses and entrepreneurs do what they already need to do today, only better and less expensively.

Therefore, as 3D printing revolutionizes manufacturing, it will also affect our business of supply chains and eventually product pricing and the end consumer experience. 3D printing effectively means that businesses no longer will face minimum quantities. They will be able to order what they need when they need it. Upfront tooling cost, which is a big expense for businesses both large and small, makes 3D printing ideal for small batch production runs. And there is no tax on complexity. And what I mean by that is there is no corresponding increase in cost for a more complex design like this.

The disruptive nature of 3D printing, therefore, will create opportunities, but it will also require adjustments. As it becomes possible to send product design instructions via the Internet and print products locally, small businesses and entrepreneurs will be able to move from the idea phase to the production phase more quickly and cost

effectively. Instead of delivering a product from a warehouse, products could be delivered from a 3D printing service offered at a retail outlet, such as a UPS store or right to your door.

Disruptive technology like 3D printing stands to help our customers do more with a lower environmental impact, all while benefitting consumers like you and me. It has the potential to increase profit margins within the supply chain by reducing cost, and that is good news for small businesses and entrepreneurs especially.

Additionally, it is important to understand that disruption will happen. There is almost no stopping the spread of technology and innovation. So we are either in the game or watching it, and I know what side of the equation UPS wants to be on.

And to that end, in anticipation of 3D printing's impact, UPS has already started putting 3D printers into UPS store locations. Our initial customer response was so positive that we have since expanded to more than 60 stores, with plans for continued growth.

Likewise, through our internal venture capital arm, we invested in a 3D printing manufacturer named CloudDDM and put their production facilities in the heart of our Louisville supply chain campus, just minutes from our global air hub. The operation has been up and running for a year and allows companies to order parts and prototypes to be printed late into the evening and have them delivered anywhere in the

U.S. by the next morning. In doing so, UPS has helped to create a model that actually increases package demand and differentiates the company from other carriers. Now that is groundbreaking stuff.

Today, UPS is learning and adapting to new technologies, something we have done many times over our more than 100 years of operation. As proven over and over throughout history, those who embrace innovation and change early and often are the most richly rewarded, and disruptive technology, like 3D printing, has that incredible potential.

I commend the committee for their interest in understanding more about 3D printing and welcome this opportunity to share what we have learned up to this time. Thank you for your time today, and I look forward to answering questions.

[The prepared statement of Mr. Amling follows:]

******** INSERT 1-2 ********

Mr. Burgess. The chair thanks the gentleman.

Mr. Morris, you are recognized for 5 minutes to summarize your opening statement, please.

STATEMENT OF ED MORRIS

Mr. Morris. Good morning, Chairman Burgess, Vice Chairman Lance, Ranking Member Schakowsky, and members and staff of the committee. My name is Ed Morris. I am the vice president and director for America Makes, the National Additive Manufacturing Innovation Institute, and we are consciously dual branded as America Makes, the National Manufacturing Innovation Institute.

The maker community wants to deal with America Makes. We are happy to deal with industry. In the maker community you get a little leery of institutes, too formal, too official, so that is the reason for the dual branding.

We are operated by the National Center for Defense Manufacturing and Machining, a not-for-profit 501(c)(3) company that has been in existence for over 14 years solving technical, manufacturing, and business problems for our clients.

Our mission at America Makes begins with, why do we exist? And as we all know, the U.S. manufacturing economy, the economic engine

of manufacturing, is nowhere near as robust as it has historically been or needs to be. So what are we going to do about that? We are taking this incredible technology of additive manufacturing and accelerating it in the United States by dealing with the technical issues, the technical barriers, doing technology transition to companies for real products, new companies, et cetera, and then training the next-generation workforce and reinvigorating the interest of the youth of America in manufacturing as a well-paid, excellent career.

Why additive manufacturing? As has been shared, it is a disruptive game changer. And game changer is often overused, but I am comfortable with declaring that additive manufacturing absolutely is a game changer, fundamentally because when you change the game, you change the rules, and this has a whole new set of rules.

We have a lot of people come to us and talk about the excitement and their interest in additive manufacturing and say: Ed, I want to get involved in additive manufacturing.

ASME has identified seven different types of additive manufacturing, and I realize when people approach us, they generally ask -- it is like asking me: Hey, Ed, I want to cook dinner. Help me cook dinner. And to be more specific, what heat source are you going to be using, lasers, et cetera? What materials are you going to be using? Are you going to be using polymers or plastics? Are you going

to be using metals? Are you going to be using ceramics? Are you going to be using organic tissue? Are you going to be using human tissue?

Then what are you going to do with it? What is for dinner? Are you going to be serving plastic parts, mechanical parts, electronic parts? Food? 3D Systems did a demonstration of printing Oreo cookies for a demonstration that we were involved with. And you can print body parts.

One of the things that excites me is the potential of integrated mechanical and electronic 3D printing devices, and one of our key members, the University of Texas at El Paso, with the W.M. Keck Center for 3D Innovation, we have recognized them as our first satellite center, broadening our footprint in a very substantial way across the United States.

Our public partners in this adventure are the Department of Defense, the Department of Energy, Department of Commerce, Department of Education, NASA, the National Science Foundation, FAA, and the FDA, and we are strong believers in the power and wisdom of a public-private partnership.

We currently have 163 members. In correcting an era in the printed testimony, we have 55 small businesses, not 85, 43 large businesses, 13 government partners, 10 nonprofit organizations, and 4 manufacturing extension partners, or MEPs, and they are a very

valuable partner in helping doing the technology transition for this.

As of January 2016, we had an $87 million portfolio of research and development. Sample projects, our use of additive manufacturing in the foundry business, led by Youngstown Business Incubator, revolutionizing the foundry casting business, making sure it stays on shore, taking out costs, cycle time, and improving product performance.

We also have a project on biomedical devices with the University of Pittsburgh working on optimizing magnesium alloy for bioabsorbable cranial implants.

Applying the partnership model to education, we are doing lots of activities, including a certification program with the Society of Manufacturing Engineers, a fellowship program with the American Society of Mechanical Engineers.

We are partnering with the U.S. Department of Veterans Affairs as part of a Google.org grant to train returning military veterans. We think that is a very important service to the Nation. What better source of expertise and competency to tap, and innovative people as well.

And then we are also revolutionizing STEM education for those that want hands-on learning, making math relevant in what you produce with the capabilities.

Regarding the public-private partnership, its ability to, with

cost share as the economic model, we think it is a very wise policy and business practice. With the taxpayers' investment on topics of mutual interest we are almost able to double the taxpayer's money. The industry side is able to maximize their research and development dollars. So it really is in line with the Better Buying Power vision of the Department of Defense to optimize contractor research and development and internal research and development.

And then finally, in closing, quoting a good friend, Steve Welby, the honorable secretary of defense for research and engineering, with this technology, let's disrupt ourselves before others disrupt us. Thank you.

[The prepared statement of Mr. Morris follows:]

******** INSERT 1-3 ********

Mr. Burgess. The chair thanks the gentleman.

Dr. Herderick, you are recognized for 5 minutes. Just summarize your opening statement, please.

STATEMENT OF EDWARD HERDERICK

Mr. Herderick. Thank you. Chairman Burgess, Vice Chairman Lance, Ranking Member Schakowsky, and members of the committee, it is a privilege to share GE's thoughts on 3D printing, which represents the larger digital industrial revolution happening in the U.S. and globally.

Today, a designer can create a computer-aided design model of a part and digitally transmit it to a 3D printer to be directly manufactured. Increasingly, new designs and processes like this are being connected and managed through a digital thread where the freedom of design and manufacturing seemingly has no limits. One of GE's engineering leaders appropriately captured it when she said: Complexity is free.

My name is Dr. Ed Herderick, and I am the additive technologies leader for GE helping to spread the application of additive technology across GE's industrial portfolio. This portfolio spans across industries that build, move, power, transport, and cure the world, from

jet engines and power-generation machines, to locomotives, medical imaging systems, and more.

The emergence of 3D printing and additive technologies in industry has been both sudden and disruptive. Recently, Boeing and Airbus conducted the first flight tests for their 737 MAX airplane and A320neo single-aisle jets with GE LEAP engines.

LEAP is the world's first jet engine to include 3D-printed fuel nozzles, one of which I have here on the table, which as the engine's fuel injector, mixing fuel and air in precise ways to achieve maximum fuel efficiency and lower emissions. Using metal printing, the fuel nozzles are more fuel efficient, lighter weight, and more durable compared to those made with conventional technologies.

The production of 3D-printed metal parts in jet engines would have been almost unheard of even a decade ago. Today, we are asking what else can be printed in the engine to drive performance even higher. As it is, GE Aviation will be producing 35,000 printed fuel nozzles per year at the world's first mass additive production facility in Auburn, Alabama. By 2020, we will have produced more than 100,000 metal-printed fuel nozzles.

This success of industrial implementation of additive technology in the aerospace industry is paving the way for broader applications in other industries. GE's use of additive technologies in aviation

is only the tipping point of an exciting transformation underway across our 400-plus factories. By 2025, we expect additive manufacturing methods will be used in the design and manufacture of more than 20 percent of GE's new product concepts.

Our efforts in additive are part of a much broader initiative to build a digital thread through manufacturing that transforms our factories into "Brilliant Factories." It is through this digital thread where additive technologies can truly emerge and realize their full potential for industries of all kinds.

In many ways, the excitement and emphasis on additive manufacturing of metals and industrial materials is the product of a more than 20-year research odyssey. As early as 1993, researchers at GE Global Research demonstrated the feasibility for binderless sintering of metal powders.

It is interesting to note the development and material advancement between then and now. In 1993, the laser used had only 7.5 watts of power, a scanning speed of 2 millimeters per second, and produced parts that were 30 percent dense. Today, we are using lasers with 200 to 1,000 watts of power, scanning speeds of 1,000 millimeters per second, and produce parts that are greater than 99.9 percent dense straight out of the box.

Further, when implemented with care, the performance of

additively produced metal parts today meets and even exceeds that of standard casting techniques, and this is a critical point. I cannot emphasize enough the importance of understanding the physical metallurgy in order to produce this high-quality repeatable performance as the materials' properties are determined during the printing process.

Manufacturers have had centuries to understand the physical properties of materials that have been traditionally milled or machined into the desired shape. With additive, and metals in particular, we have been working for 20 years. Fortunately, GE, through its Global Research Center, is home to some of the world's foremost experts in materials and additive techniques to help us make these evaluations.

I would like to highlight a particular example where GE printed a miniaturized version of a steam turbine rotor to test a new idea GE researchers have for reducing the cost of water desalination. The rotor, roughly 6 inches long, is being used to demonstrate cost-effective water and salt separation. In that case, metal printing empowered the team to design something that could not be made in any other way and has the potential to dramatically improve the energy efficiency for this critical water desalinization process.

In order to accelerate new applications like this one, GE has built a new facility in Pittsburgh, Pennsylvania, dedicated solely to

3D printing called the Center for Additive Technology Advancement. And that was an ARPA-E program and partnership.

So I would like to highlight some of our work and the critical importance of building a robust ecosystem in additive technologies across the U.S. We are proud to be a partner of and applaud the America Makes National Additive Manufacturing Innovation Institute in Youngstown, Ohio, which has been a leader in building this ecosystem of manufacturers, machine makers, and other key stakeholders in the additive supply chain. As we go forward, GE will continue to look for ways to strengthen the additive ecosystem here in the U.S.

In closing, additive manufacturing is a transformative technology that is opening up new frontiers and is an important tool in realizing GE's "Brilliant Factory" vision. It is and will have far-reaching impacts that accelerate the introduction of new high-performance products that will support global infrastructure for years to come.

Thank you, and I look forward to your questions.

[The prepared statement of Mr. Herderick follows:]

******** INSERT 1-4 ********

Mr. Burgess. The chair thanks the gentleman, thanks all of our witnesses for your compelling testimony this morning. Thanks for all you are doing for the revitalization for manufacturing in America, and we appreciate your efforts in that regard.

Dr. Herderick, you talked about the experience you have had with manufacturing things for years, and now you have moved into this new realm. So I suspect there were significant challenges for, like, the quality control folks who assured that the device in question was going to stand up under the heat and pressure of a jet engine or a pump or whatever you were building.

I mean, I suspect that has been an ongoing process and one that has developed sort of simultaneously with the technology. Is that a correct assumption?

Mr. Herderick. It is. Yes, so it has been a many year journey. And I think what GE brings to this is our knowledge of commercializing other advanced technologies, like advanced casting techniques, welding techniques, and the like. And so we use the same process methodology of really fundamentally understanding the science at our research center, as I mentioned, and then working closely with our partners to really understand how these products perform in the field.

Mr. Burgess. But you are literally building airplane parts out of pixie dust and putting them into planes that we are all going to

fly home later today.

Mr. Herderick. Well, it is advanced metal powder that looks like metal flour, so I suppose you could paraphrase to call it pixie dust, but it is very highly engineered pixie dust.

Mr. Burgess. That is reassuring.

Now, Mr. Orringer, let me just ask you, well, your technology, you talked about it in your testimony, invented your company in the United States. The patent system in the United States, despite challenges, is one that is the envy of the world. But then you intersect with the regulatory side of the world. So sometimes things that are invented here but then subsequent manufacturing tends to go other places in the world. So is that something that you all have encountered?

Mr. Orringer. So I am a little bit at a disadvantage because if I say anything wrong my lawyers are going to come down on me pretty hard.

Mr. Burgess. This subcommittee is so genteel. There is no oath given.

Mr. Orringer. I am not worried about you.

Mr. Burgess. There is no oath given, no lawyers backing up the panel.

Mr. Orringer. Let's just say you are absolutely right. So as

I said, this technology has been around for 30 years. We have invented many of the technologies that we have been discussing here today, and we have been acquiring a lot of these companies along the way as well.

In spite of it being 30 years old, it has become a little bit of the Wild West. And there are constantly new innovations, there are patents that seem to be very similar to patents that were filed previously, and we have to be vigilant. And, fortunately, we do have a very good, close relationship with the U.S. Patent and Trade Office. We do work very closely with regulators.

There are always going to be issues, particularly when you compare our system with a system overseas, and that is where we are really challenged, and we do appreciate the assistance that the government is providing us as we navigate these waters right now.

Mr. Burgess. Well, I want you to consider this subcommittee as your subcommittee, and the interaction that we have initiated today, I want it to be an ongoing dialogue. Because to the extent possible we want to remove barriers for you, we don't want the invention to happen here and then the manufacturing occur somewhere else. We want these jobs in the United States of America. We want to make America great again. Could I say it any more succinctly?

Mr. Orringer. I am not going to touch that.

I will say to that point, I very much appreciate that, and I will

say that what has actually been quite exciting coming here, I spent most of my career in the Federal Government and only have transitioned to the private sector 2 years ago. And I will tell you, coming to this company and seeing what we are doing in terms of U.S. jobs is phenomenal.

We just acquired two European companies, a French company and a Belgian company. These are companies that have been honing the craft of metal additive manufacturing. And we are now seeing an insourcing, thanks to my company, not only in terms of protection, but R&D. We are actually moving these jobs over here.

And it is actually thanks in part to projects that we are doing with America Makes. I am actually funding an aerospace and defense project. We have started to build up a laboratory in Penn State. And it is thanks to the good work of Ed and his colleagues, as well as other folks that we are teamed with, that is seeing this technology not sit still but continue to innovate, and we will certainly stay engaged with you as we navigate these waters.

Mr. Burgess. And I appreciate that. You are two of the most highly regulated industries, medicine/health care and the aerospace industry.

Mr. Morris, did you want to add something?

Mr. Morris. Yes. In regard to the global economic competition we find ourselves in, it is absolutely true that although the technology

of additive manufacturing was invented in the United States, we lost the lead, and generally the sense is the Europeans are ahead by about 5 years because they doubled down with national investments in their areas, and they are the major source of the materials and the 3D printing devices. Although in the United States companies such as 3D Systems are coming on very rapidly and regaining the lead for the United States, which we think is crucial.

I think this really comes into focus, the importance of a public-private partnership as a wise policy for a nation in this global economic competition we find ourselves, and it is a good business model for the taxpayer and for the companies and academia, for that matter.

Mr. Burgess. Very well. The chair thanks the gentleman.

My time has expired. I recognize the ranking member of the subcommittee, Ms. Schakowsky of Illinois, for 5 minutes for questions, please.

Ms. Schakowsky. Thank you, Mr. Chairman.

I encountered 3D printing in 2013. We had a manufacturing showcase, and Congressman John Sarbanes brought in a business from his district, Direct Dimensions, and they took a picture, three or four, and made this 3D print, a bust of me in plastic. It was very interesting and a little strange. But I did save it.

I want to say this is part of our series, as I am sure our chairman

said, of our Disrupter Series, and what we are hearing today are the wonders of this and the positive.

And I just want to say before I ask questions along those lines, that these technologies can be in the hands of all kinds of people as we go forward. And I hope, Mr. Chairman, that we will also have a hearing on what are the things that we ought to watch out for.

I know that Congresswoman Clarke raised the issue of the ability to produce perhaps small arms. But who knows? And so I think we ought to be looking ahead to and thinking about if there are threats to our country because of these kinds of new technologies and in the wrong hands, not only through our concerns about competition around the world and making sure that we can advance making an America, but actual threats.

But I wanted to focus on the positive too. At Northwestern University, which is in my district in Evanston, Illinois, researchers are pioneering biocompatible inks made of graphene that are used to 3D print scaffolding for tissue transplants and regeneration. Very exciting. These graphene structures can stimulate cell regeneration and also are cost effective.

So, Mr. Orringer, could these kinds of cutting-edge treatments become more widely accessible through the use of 3D printers?

Mr. Orringer. Yes. Actually, I just returned from your

district. I was just there last week.

Ms. Schakowsky. Okay.

Mr. Orringer. I talked to a couple of folks about Northwestern's interest in metal. And I will tell you, the Chicago area is booming in this area, very competitive area for this technology, and it is very important that we continue to innovate there and incubate that technology.

On the bio side, I will tell you, there is a lot of fact and fiction and aspiration. To answer your question, I think you summed it up quite well. There is sort of the short term, there is a lot that can be done in scaffolding, and it is being done currently, and I would say we are about 1 to 2 years away from seeing this matured sufficiently where it is going to become as commonplace as some of the other methodologies I discussed.

On the other side, our folks in our medical modeling department indicated that we are still a few years away from actually seeing a viable process for some of the other bioprintable inks. But the research is being done. Actually we do a feasible path forward. We are watching a lot happen in this marketplace. There are a lot of exciting new companies that are coming online in this space, and we would encourage that technology continue to flourish.

The government itself has a role to play. We have been talking

to NIH about this particular issue to see if there are ways we can work with them in terms of spurring innovation in this area.

Ms. Schakowsky. So you indicated some fairly early benefits here too. So at what point do you think we will be able to see real savings for patients, and are we doing what we need to do now to make that occur?

Mr. Orringer. Well, as I highlighted in my opening statement, 3D printing has long been providing strong value to patients, not only in the hearing aid, where we are making 99.5 percent of hearing aids through 3D printing, or Invisalign, but in the medical modeling and in the implant process as well.

It is literally saving lives. We were talking about this early before the hearing. We have seen estimates that it takes about -- we charge patients about $100 a minute in the operating theater.

So if you can reduce that time by rehearsal, by using CT scans, 3D printing, the model, and then practicing that surgery over and over again -- and then also 3D printing surgical guides, which are essentially stencils that you place on a patient, reducing the amount of improvisation to zero -- then you are literally going to be saving lives, enhancing precision, and saving money.

And so I can tell you that we have done tens of thousands of these procedures, and we are seeing a lot of breakthroughs.

In terms of the scaffolding, there is a lot of investment in this

arena right now. There is a lot of promise. And the government is well involved as well, not only from the NIH, but in the Department of Defense, the United States Navy, Walter Reed National Medical Center. There is a lot of work being done here, and I think we are not too far away from some active clinical trials.

Ms. Schakowsky. Great. Maybe in another round I could ask Mr. Morris how America Makes works in this health space.

Thank you.

Mr. Burgess. The gentlelady yields back. The chair thanks the gentlelady, recognizes the gentleman from Kentucky, Mr. Guthrie, 5 minutes for questions, please.

Mr. Guthrie. Thank you very much.

It is great to have everybody here. What an interesting series we have had. And as I really grasp technology when I was in grad school in the mid-1990s, not even that long ago, and it just really disrupted the typewriter and the calculator industry because we did the same thing that they were already doing, just did it more efficient. I think also it disrupted the wite-out industry, when I got to go on a word processor, didn't have to use it anymore. But it really just already took what we were doing and just made it better.

And what is happening now is you are actually taking this technology and just doing things we could never do before. It is

amazing in the body parts and the replacement, you couldn't do those vertebra probably in any other type of manufacture.

I have a manufacturing background, and we take blocks of steel and make dyes out of it. We whittle it down, for lack of a better term. That is actually what we do, just computer-controlled machines. We are now creating stuff by printing it. By being additive it just -- I hope it doesn't replace what we do, but it certainly enhances the precision of what you can do in specific things. So it is fascinating to be here.

I am going focus with UPS. Their Worldport is just outside of my district. But a lot of your employees and a lot of your customers are in my district, Zappos shoes, Bestbuy.com, and Geek Squad, which is a pretty interesting place to go. They don't have a plant manager. They have a mayor. And they don't have community leaders. They have ambassadors. So it is just an interesting business concept, but great, great people to be around.

But a lot of it is based on supply chain. I know a lot of us think of UPS as -- and you said it in kind of your opening statement -- the brown trucks and the airplanes that are flying in and out of Louisville. But I am more interested in what UPS really does. You talked about it a little bit. I would just give you some time to elaborate on how UPS actually helps small businesses with supply chain management to

build their businesses and how 3D printing is a big part of that mission.

Mr. Amling. Yeah. Thank you very much.

So UPS is more than a package delivery company. We are a network company. We are not a manufacturer. But we are a network company. We are a problem solver. And so we see 3D printing as another tool in the bag to make businesses more efficient and to help them expand. So that is what the small businesses, it is what the UPS store is all about, in helping small businesses grow.

So when we put 3D printers in the UPS stores, one of the things small businesses have to do, if they have a new product idea, is to design a prototype. Prior to 3D printing, that is an arduous task, right. You have got to create a model. Sometimes that model is produced outside of the U.S. and shipped back. Now we are giving them the opportunity to produce that model and do rapid prototyping right in their home city.

I have an example of a gentleman that we highlighted during our 3D Printing Week named Caleb Kraft. And what he did was he is creating supplements to gaming controls so people with disabilities can play the game. And because people have different disabilities, everyone is different. Can you imagine how difficult that would be before 3D printing?

That is one of the things. We are unleashing innovation. And

so that is the small customers. We are seeing a lot of hobbyists, small businesses, and designers using the UPS stores.

We have now more of an industrial-grade 3D printing operation in our Louisville supply chain headquarters, and that is being used by designers, but it is also being used by big manufacturers that have these service part networks, and they need to have on-demand parts. And so we are allowing them to order parts from us and be delivered anywhere in the country.

Mr. Guthrie. I have just about a minute. I just want to ask you a couple of more questions.

Mr. Amling. Yes.

Mr. Guthrie. I will ask them both and then let you answer.

So where do you see the most demand for 3D printing today and where do you see it in 3 to 5 years? And what policies should we consider, what are important for us to consider as you see the demand for 3D printing and where it is going? And what can Congress do to help or not help -- or get out of way, I guess?

Mr. Amling. So great. So right now this is what we are seeing. We are seeing a lot of rapid prototyping. That is kind of the application we are seeing the most. We are also seeing a lot of small batch production runs. So even large manufacturers, if they are only printing or need to produce 500 or 1,000 of a certain item, it is

actually less expensive right now to do it via 3D printing. And we are all about efficiency, and that is what they are doing.

Now, 5 years out, I wish I had a crystal ball, but what we see is we see more customized products, right, that are tailored to the specific needs of the individual, and 3D printing can allow that to happen. We think that is a little further out, but right now we see definitely on-demand parts in prototypes.

In terms of legislation, again, UPS is a network, UPS is a global network. Right now we are only doing 3D printing in the United States. Eventually, just like we have helped businesses by connecting a global network with our transportation, the plan is to do that with 3D printing. And so as that happens, there are going to be legislative issues that arise that will need to be addressed to keep that going because we know that the more we can promote global commerce and trade, it is good for everybody.

Mr. Guthrie. Thank you. Yield back.

Mr. Burgess. The chair thanks the gentleman. The gentleman yields back.

The chair recognizes Ms. Clarke from New York, 5 minutes for your questions, please.

Ms. Clarke. I thank you, Mr. Chairman.

I thank our panelists today. Very stimulating conversation. It

is great to hear all of the innovation that is taking place, and the sky is the limit as far as I see it.

I would like to focus on access for underrepresented communities. This has been one of the focus issues that are especially important to me, using the emerging 3D printing industry as a unique means of empowering and including entrepreneurs from underserved and minority communities, because startups costs are lower, flexible, customization is easier, 3D printers offer advantages and opportunities to small businesses and new entrepreneurs entering the market.

Still, huge diversity gaps remain in the technology manufacturing space. So to harness the true potential of 3D printing, I think it is important to commit to eliminating obstacles to sort of equitable and to promoting initiatives that I believe could close this gap.

You, Mr. Orringer, spoke about a relationship that was established with Penn State. I want to drill down a little bit and talk about perhaps colleges and universities in the HBCU system and the HSI system and community colleges.

And then, Mr. Amling, you spoke to the small business advantage as well.

So, Mr. Morris, my first question goes to you. What kind of outreach does America Makes do to communities that are underrepresented in the tech world, including minority, low-income, and disabled

workers?

Mr. Morris. Thank you. Excellent question. That is one of the key reasons why the University of Texas, El Paso, was so attracted to us. Not only are they a leader in developing the technology of additive manufacturing, but also in deploying it in their community with a heavy U.S. Mexican population, economically handicapped. And we want to partner deeper with them to be able to help them continue and then expand their technology transitions, again more education in that area, and spawn new products, et cetera.

Tied to that also is the vision that we have of getting printers in every school in the United States. I was certainly taken aback last year when China announced an intent to put 400,000 printers in every one of their elementary schools. We should be doing the same thing and proceeding up the chain for more than just the elementary schools. That is the time to catch the youth in America, get them excited in careers in making things.

And in our context, when we talk about additive manufacturing, it is a system of systems of design, manufacturing, inspection, production, et cetera. So it is all of these different well-paid, good careers, long-term careers. Catching the youth in America no matter where they are, no matter who they are, I think is pivotal for the United States and is an important step forward.

Ms. Clarke. Can you speak to some of the common challenges that entrepreneurs from underrepresented communities may face when beginning to incorporate 3D printing into their own small businesses?

RPTR HUMISTON

EDTR CRYSTAL

[10:58 a.m.]

Mr. Morris. What we are finding as small companies come into America Makes as members, and we operate as a community of practice openly sharing, and we operate in this middle ground of precompetitive activities, when the small companies are able to rub shoulders with companies like 3D Systems, Rockwell Collins, Lockheed Martin, Northrop Grumman, et cetera, they develop relationships. So one of our small companies, rp+m in Cleveland, has benefited from that relationship and is now doing contracted work for them.

So building this community -- and we are very focused on the additive manufacturing supply chain ecosystem, how do we define that, how do we focus it in regional areas. We are doing some pretty incredible things in our region in northeast Ohio and in southwest Pennsylvania trying to flesh out, define that ecosystem, and energize it for all of the communities, and with a focus on those that are most urgently needing that economic boost.

Ms. Clarke. Very well.

Mr. Orringer, I saw you nodding a bit there and smiling. Do you want to share your thoughts?

Mr. Orringer. Well, sure. As we were talking about education, I was just reminded, when I started working for this company, I came home with a little 3D printer and a 3D scanner. And I have a 5-year-old at home who is more advanced technologically than I am. My wife is a surgeon, so she came home from a long day performing surgery, fell asleep watching TV. My daughter scanned her head, produced a model not too different from that, and she is 5 years old. And I was blown away, because I still hadn't figured out how to turn the darn thing on.

And if you can see what happens when we bring these things into schools, it is not about 3D printing. 3D printing is a means to an end, and that is what we need to understand.

What I think about, I think about this in terms of digital literacy, and this is really critically important, particularly in underserved areas. We need to make sure people have a full sense of what it means to be part of the digital economy.

So rather than focusing on getting expensive 3D printers into small businesses, what we really should be doing is making sure they have access to the digital tools, different kinds of CAD, computer-aided design technologies, training in this kind of technology.

We can find ways to give them access to machines, whether it is

through great companies like UPS. We have similar programs. We have a company called Quickparts that does on-demand printing. You send us the CAD, we will print out the parts.

It is not about getting the 3D printer necessarily to those entrepreneurs. We actually are able to reduce the logistical footprint for folks. And now we are digitizing things. You don't even need to have that.

So I think the task is important. I don't think it is as difficult as it could be, and there are institutions like America Makes and others that are doing some, but we need to do more. We have talked a little bit about our outreach to the veterans community. We have done a lot with Walter Reed and the Veterans Affairs Administration. But again, there needs to be more in this space, and we would love to talk to the committee and figure out ways to catalyze more of this.

Mr. Herderick. Actually, if I may add to that.

Mr. Burgess. Yes, please.

Mr. Herderick. Just briefly.

Mr. Burgess. Sure.

Mr. Herderick. I think you made some great points. And I think what is really exciting about 3D printing is it is just such a transformational educational technology for getting people into manufacturing, and it has really just gotten into the public

consciousness.

And I was actually with a GE Volunteers group in the Bronx. We did an outreach, young entrepreneurs workshop with some students, middle school and junior high school students. And what was amazing was half the students, they were coming up with ideas to 3D print different consumer parts for iPods and things. And when we go out and do these GE Volunteers outreach activities, I am doing things like taking fuel nozzles, taking manufactured components, we take 3D printers into schools in different workshops and things.

It is this tool to get people hands-on with manufacturing in a way that we couldn't do with casting or welding. So it is really a gateway to get them into these great entrepreneurial fields and these great careers. It just gets me really, really excited.

Mr. Morris. Very quickly. We do some summer camps, and one particular summer camp was 7- through 10-year-olds. And one of the exercises was to take the students into a little kiva round hut, white board, and they drew cookie-cutters. And one minority student drew a nice little figure cookie-cutter. He then took it is over to the desktop 3D printer and made the cookie-cutter. And we have got a picture of him, you know, look, mom, this is what I thought, this is what I designed, this is what I manufactured, here is a cookie-cutter for you.

Mr. Burgess. The chair thanks the gentlelady. The gentlelady yields back.

The chair recognizes the gentleman from New Jersey, Mr. Lance, 5 minutes for your questions, please.

Mr. Lance. Thank you, Mr. Chairman. A very interesting hearing.

Mr. Orringer, balancing health and safety is obviously an important mission for medical device manufacturers and Federal regulators alike. What steps are the Federal regulators taking in order to educate themselves and the public about 3D-printed surgical implants? Has this approach been proactive? And what else, in your judgment, could be done?

Mr. Orringer. Yes, sir. Thank you so much for this question.

I have to say, and it is not just because I am a former Federal bureaucrat, we have been actually pretty pleased with the engagement that the Food and Drug Administration and others have shown. They actually held a workshop in October 2014 on their Silver Spring campus. They invited companies not only from the United States, but from all over the world, to have this dialogue, and it was an all-day affair.

The FDA said they were in receiving mode. They wanted to hear what the concerns were from us about regulation, what the concerns were for us in terms of barriers for innovation, are we any different from

any other technology when it comes to regulation. And I think in the end, the conclusion was no, we are one tool in a toolbox. You have digital tools, you have means for designing things, which is the CAD package, and you have different ways for actually executing.

So I think one of the challenges we need to stay on top of is folks' attempts to redefine this technology as something that is extraordinarily different. We are not making Star Trek replicators here. These are very important tools, they have their uses. They also have their limits.

One of the things I sort of alluded to in my statement, though, was concern about the inability for the pay codes to keep pace with innovation. So right now we are innovating doing unique surgical processes, we are saving a lot of money for the health system overall. But the truth is there are no insurance pay codes that can tell the patient this is how much it really costs.

So what is actually happening is we are saving money, but the insurance companies, whether it is Medicaid, Medicare, or private insurance, don't have a means to code what that procedure is. And so there is actually a bit of a margin here. And we would love to engage the folks at CMS, Medicare, Medicaid, or others to ensure that we are actually able to make a fair process and bring that up to standard.

Because right now, as you know, sometimes government regulation

is a little slow, sometimes standards can be a letter slow to implement. We really need to get this right, because we are not really realizing all the potential for this.

Mr. Lance. I trust those at Medicare and Medicaid and CMS will be monitoring this hearing, because obviously we need those codes for the reasons you have suggested.

Mr. Morris, you wish to comment?

Mr. Morris. I personally attended that workshop by FDA in 2014, and I found it intriguing. My background is aerospace and defense, and as I was sitting through the different presentations on medical applications, I found myself about two-thirds away through the first of a 2-day event, I was getting bored.

Why would I be getting bored? The problems and issues that they were all addressing are ubiquitous in additive manufacturing: need better materials properties, need better inspection capabilities, need better design tools, et cetera.

At the end of the 2 days, my personal synthesis was there are basically two differences in medical applications from all the different things, like what they are doing in GE: sterilization and body biocompatibility. Because of the problems, it makes the importance of an institute focused on additive manufacturing and being able to share across business sectors really relevant.

So we were very pleased when the FDA actually became a signed member about a month ago so they can sweep up the things we are already learning, hear their specific needs, and advance all the technology across the United States.

Mr. Lance. To the distinguished members of the panel, are we in the advance in this country or do other countries, perhaps in Europe or Asia, have a system that recognizes this to a greater extent than we do in this country?

Mr. Morris. It has been interesting in that one of the things that I heard from a good friend, Terry Wohl, who is one of our members, of Wohl Associates, he did some visits at the invitation of the Chinese Government a couple years ago, and they shared that they are doubling down on their national investments in additive manufacturing because they saw what the United States was doing, so they are now surpassing us.

A representative from Singapore visited me personally in Youngstown, Ohio, in our facility in downtown Youngstown, and they have now stood up a center for 3D printing and innovation in Singapore with initial funding of $150 million, more than twice the funding I have.

Mr. Lance. Thank you. My time has expired, but I hope to be able to purchase this further in the future. Thank you, Mr. Chairman.

Mr. Burgess. The chair thanks the gentleman. The gentleman

yields back.

The chair recognizes the gentleman from California, Mr. Cardenas, for 5 minutes for your questions, please.

Mr. Cardenas. Thank you very much for imparting your knowledge with us on what is going on in this dynamic, fast-changing industry.

The first question is from my wife. When do you think that they will be able to make a husband's brain? I didn't say a human brain, I said a husband's brain to help someone pick up after oneself, remember anniversaries, et cetera. Just kidding, just kidding. That is the impossible, I know.

Now, on a more serious note, we have noticed that in America's libraries we have had an increase of donations and opportunities where libraries are investing in 3D printers now to the tune of over 400 libraries have access to little or no cost to individuals going to the library.

To me, this is a very important issue for making sure that we have access to as many minds and as many inquisitive folks so that they can get turned on to how wonderful it is and the potential of getting a job in the industry.

How committed is the industry to advancing that kind of effort?

Mr. Orringer. Well, I can take a shot at this just because we had a little bit of an excess inventory of desktop 3D printers about

a year and a half ago. And we didn't rehearse this, by the way. And I had this great idea: Why don't we donate these printers to libraries across the country? With one hitch. I didn't want to donate a couple hundred printers to libraries and have them just sit on a shelf and collect dust. That is a really big problem I see.

So we actually held a competition, we partnered with America Makes, because they know how to do competitions, and had an overwhelming response from all across the country.

We need to do more like this. It is going to pay back dividends. We are struggling certainly still in terms of workforce development, in terms of making sure people have access to this technology. And I strongly believe that if we can start bringing these kinds of tools to young people as soon as possible, that is going to pay dividends in the long run.

So we are strongly committed. I know other folks on this panel are as well. And we will be happy to keep you informed on our progress.

Mr. Cardenas. Yes. That is an investment in human capital and connecting your industry to the minds of the workers of the future.

Yes, Mr. Morris?

Mr. Morris. I pay a lot of attention to unintended consequences in what we do. You can do something really admirable, and at the end of the day you are not doing something so admirable. So even with the

vision of a printer in every school, we are urgently needing encouragement at all levels of the government, beginning at the local communities and perhaps in some of the local rotaries, et cetera, foundations and groups that are able to provide some funding.

For example, if we put a 3D printer in Ms. Brown's class and it breaks, who is going to fix it? Who is going to buy the materials? Ms. Brown? That is not very kind.

And for the libraries, same vignette. How do we keep it operating, how do we get the training materials in all the libraries and all the schools, how do we have the resources made available so it is not burdensome when this thing shows up. You can do great things with innovation, but we have to do it wisely.

Mr. Cardenas. Yes. Thank you for pointing that out.

One of the things that I am so proud to be an American is the fact that we have this reputation that when we embark on something and we dedicate ourselves to doing it well, it takes a long-term vision and a long-term commitment. And there are infrastructure costs, there are ongoing costs, et cetera, instead of just the flash of, for example, the ribbon cutting, giving away printers, and then coming back a year later and embarrassingly realize that none of them are in use because, you just explained, that without the follow-through, they are not doing anybody any good.

Mr. Morris. Right.

Mr. Cardenas. And it is a falsehood whenever any of us, whether it is government or private industry or philanthropically, we do something without looking at the long sight of the issue. So thank you for pointing that out.

But the follow-up on that is I hope that you read into my question, and not just libraries, public schools, et cetera, that the industry actually maps out and shows us how we can either partner or they can take the lead, et cetera, and how we can make sure that we have that available as much as possible to every community in America. Again, it is an investment in human capital, I think.

I want to point out with my limited time here that when it comes to bioprinting, apparently when you look at the 3D printer is used to place bio ink in precise locations, allowing cell types to align themselves in a manner that resembles the origination of native human tissues. These 3D human tissues can then be employed in drug discovery and development, biological research, and therapeutic implants for the treatment of damaged and degenerating tissues and organs, et cetera. You get the picture. This is amazing.

What do you see the top-line issues facing those efforts when it comes to regulatory and technology and world competition?

Mr. Morris. I am not competent to address the regulatory issues,

but what I will say is I think where our National Additive Manufacturing Innovation Institute can come to play in a very important way in advancing bioprinting, as we do with all the other areas of application of additive manufacturing, is getting from the research to the true product application there is historically what is called the valley of death.

And we have got a structure to cross that valley of death. It begins with pooling a community of the researchers, academics, labs, et cetera, across the Nation, with the end users, and start that discourse of what do you need, where are you going, what are you building, how can we apply it, how can we accelerate it.

And so we do a lot of workshops to do roadmapping, and we would eagerly like to do roadmapping with bioprinting. We have several of our members who are doing some landmark research and development in bioprinting, such as the University of Pittsburgh, Case Western University, et cetera. Team those up with the medical end users, working with our new member FDA, et cetera, to lay out what is the right path, how do we accelerate, what is the funding model.

And then continue to go back to this model of the opportunity to do the key thing in a public-private partnership, and that is share the cost. Where it is high risk, government money comes into play. Industry needs to invest because they are doing the product

application. We think that is a very shrewd model going forward, a public-private partnership with cost share, which is the unique capability of an Additive Manufacturing Innovation Institute.

Mr. Cardenas. Thank you, Mr. Chairman. I yield back.

Mr. Burgess. The chair thanks the gentleman. The gentleman yields back.

The chair recognizes the gentlelady from Indiana, Mrs. Brooks, 5 minutes for your questions, please.

Mrs. Brooks. Thank you, Mr. Chairman.

And thank you all to your panelists for your actually exciting testimony. I wasn't sure when I was reading this initially.

But I think why this is so exciting is because I think this is the way to draw young people back into manufacturing. We have in central Indiana, in my district, about 50 middle and high schools that have 3D printers that are being utilized in the classroom. Indiana is one of the country's most manufacturing-intensive States.

And then before coming to Congress, I was senior vice president at our State's community college, and where I learned about 3D printing during that time period, but I think we still need to make sure that the adults and the educators who are working with our young people have an understanding about this 3D printing.

I had an event, and we welcomed 3D Parts Manufacturing to educate

school counselors at a school counselor event, to try to educate them about 3D printing, because they are the ones who influence our children and get them excited about these things.

So I am curious, in expanding on the public-private partnerships, which I completely believe in, how do we do a better job bringing industry, collaborating with our educators and with either our nonprofits, and try and get the young people more engaged in 3D printing and skills that they need? What are some best practices you have seen? How do we expand this? Because I think it is one of the manufacturing tools of the future. What do we need to be doing better?

And believe it or not, I actually think calling the place where they work maker spaces actually helps because young people are not as interested in manufacturing, I think, as they are in making.

Mr. Morris, you want to start?

Mr. Morris. I am wrestling with jeopardizing and putting at risk a very important relationship we have with Elizabeth Forward School District outside of Pittsburgh, Pennsylvania, and Elizabeth Forward. They are a premier benchmark of redefining education in the United States and leveraging the power of additive manufacturing 3D printing to teach.

The risk in the friendship is they are already being inundated with people that want to know what they are doing, because this is the

right place to go. So we need to find some way to assist them. And the key thing at this point is communication, communication. We could use more resources to communicate better across the Nation this is what is happening, this is how you do it, this is where we can work together in the public-private partnership model to in very interesting terms infect the United States with manufacturing is back and it is the right place for careers.

Mrs. Brooks. But if you think about -- so, Dr. Herderick, GE is located in so many locations across the country, UPS obviously is, I don't know that your company is yet, but, I mean, what do you view as industry's role in partnering with the education community? And I welcome the fact that you put them into libraries and so forth, but what should we be doing that we are not doing?

Mr. Orringer. So I guess I want to, at the risk of contradicting myself, I want to make sure we distinguish a little bit. Ed did this a little bit already. But there is a distinction between what we see in maker spaces and what we see on a factory floor, and particularly when we get into some of the very hardline manufacturing industries such as aerospace and defense and others. And I really think it is important that we embrace both cultures and drive innovation in both areas.

So there is a great company that I work with in Indiana called

3rd Dimension. They have a beautiful shop of many metal 3D printers. They have a whole host of aerospace and defense customers.

They are tied to Purdue. They are not too far away from Purdue, actually. And they are a small business, but they are embracing a whole host of fellowships and internships, getting folks excited, not just about the usual maker kind of space where you maybe play around with tchotchkes and toys, but these massive million-dollar hunks of hardware, to actually see what actually happens on a shop floor and how we are revolutionizing manufacturing, which is a totally different concept.

It is really important that you see both sides of the spectrum. Maybe you could see the maker spaces as a gateway. But if you don't bring in the other part of the equation, then you are missing it.

Because additive manufacturing is a serious business. We are a global company, we are the largest, we are in 50 locations all over the world. People haven't really heard of us. And there is probably a reason for that. The reason is until recently GE wouldn't want to brag that they used additive manufacturing, because they didn't want their competition to know how they made the secret sauce.

And that still takes place. Our first additive manufacturing machine, the serial number is SLA-3. I saw it a couple years ago in General Motors. It was installed there in 1989. This is not a new

industry, it is just new to people who are suddenly -- so I think the maker space concept is great, because it suddenly captured people's imaginations. Bus is also important when you think about public-private partnerships, encouraging manufacturing, that you also bring people into the fold and understand this is also revolutionizing manufacturing now.

Mrs. Brooks. Thank you.

Thank you. My time has expired.

Mr. Burgess. The gentlelady yields back. The chair thanks the gentlelady and recognizes the gentleman from Mississippi, Mr. Harper, 5 minutes for your questions, please.

Mr. Harper. Thank you, Mr. Chairman.

And thanks to each of you. It is an amazing technology, and we really are just only beginning to see what all we are going to be able to do in the future.

And, Mr. Amling, I don't have a question, but certainly welcome. UPS was my very first job in my life as a 15-year-old. I loaded an 18-wheeler every night with boxes. And I am the one who packs the trunk on the family trips.

Mr. Amling. So you learned to work hard.

Mr. Harper. We know how to build the wall.

Mr. Amling. Bend at the knees, right?

Mr. Harper. That is it. And it might have been a 3D component to that as well, I am thinking.

But thank you each for being here.

Dr. Herderick, when GE obtained certification from the FAA for its LEAP jet engines, it was clearly a major accomplishment for additive manufacturing. I am just curious, how many pages of testing data does a company need to rely on in order to obtain that FAA certification for a new item like that?

Mr. Herderick. I mean, so our materials testing database that we build up before we take it to the FAA, I mean, it is many hundreds, even thousands of pages. I mean, it represents over a 10-year journey from initial concept. I mean, it was a single engineer, she had an idea in our combustors group for the fuel nozzle looking at machines, and then, of course, it became a cast of many hundreds. And so it was a pretty serious book of knowledge that we took to the FAA, as you might imagine.

Mr. Harper. It is amazing. I am just curious, what extra effort was needed to show that the nozzles, which was entirely 3D printed, that they were strong enough and did not create a safety risk? How do you go about that?

Mr. Herderick. So it all starts with understanding the fundamentals of the process and demonstrating what we would call a

stable process. So demonstrating over many, many thousands of cycles. It is not just building one and going out and testing it. It is many years of effort and building many thousands of fuel nozzles and demonstrating that every one is the same coming out of the machine process.

We do post-treatments to heal any defects that come out of the machining process. And then we actually x ray the parts before they go out into service. So each part, we have a 3D image of the part before it goes onto any engine.

Mr. Harper. And, of course, going through this process, did this help GE learn how to navigate the certification process so that future parts maybe experience a quicker process?

Mr. Herderick. It did.

Mr. Harper. Okay. That is great.

How does additive manufacturing fit with and add value to the traditional supply chain? Explain that to me a little better.

Mr. Herderick. Yeah, it is a great question. So I will talk about the metals technology. So I think a lot of people look at these metal printing technologies and think maybe this could replace casting or replace forging. In reality what we are using it for is to create more valuable, higher performance products during the design phase that then transition to castings and forgings. So really what it is doing

is opening up some highly value-added applications, which really truly fit with American manufacturing, high value, complex shapes and parts that we wouldn't be able to design without having the metal prototyping processes during our testing phase.

Mr. Harper. Right. That is great.

Let's talk about cost for a minute. What kind of cost savings do you think could be achieved if a manufacturer is able to take full advantage of 3D printing and integrate it as fully as possible into supply chain?

Mr. Herderick. Well, I think the biggest cost is time to market, so being able to get to market much, much more quickly, and reducing the cost of different iterations of product lines. That is really where we are seeing the biggest benefit: getting to market faster with higher performance products.

Mr. Harper. Got it.

Mr. Orringer, what method of printing was used to produce the titanium hip implant, and why was this the method best for the implant?

Mr. Orringer. Yes. So this is the part we were talking about here, and you can see it is pretty porous. We use a process called -- well, we call it direct metal printing. It is powder bed laser fusion, which is kind of a mouthful.

The reason why it is so important -- and I actually had to check

with my wife who is a surgeon to actually understand fully what we are talking about here. So typically when you make a part like this, it is going to be casted, and you can ultimately cast a pretty solid and dense part. That is going to cause, when you are talking about titanium, stress on a bone.

What we are able to do with 3D printing is we are able to actually design a part that is optimized to both reduce stress on the bone and also be porous enough to get bone to actually grow and actually regenerate, and this can only be done through this process. Typically, what they have done in the past is they will cast this component and they will have a coating on top that is porous. It is relatively superficial. If you can get a densely made part that is also porous, as contradictory as that sounds, you can actually help regenerate bone and help with the growth and not lead to bone stress and --

Mr. Harper. So this is not only going to be better for that area, but also speed up the healing process.

Mr. Orringer. Exactly. Exactly. And we are actually seeing this area explode. This is part of the factory of the future.

Mr. Harper. Great.

Well, look, I want to say thanks to each of you being here.

I am over my time, I yield back, even though I don't have any time, Mr. Chairman.

Mr. Burgess. The gentleman yields back. The chair thanks the gentleman and recognizes the ranking member of the subcommittee, Ms. Schakowsky, for redirection.

Ms. Schakowsky. Mr. Morris, I had just wanted to ask you a question on how America Makes' work in the health space has the ability to translate into increased access for patients across the country to the advancements that 3D technology has helped to do

Mr. Morris. So I am not sure I heard everything there. Excuse me.

Ms. Schakowsky. Well, I am just interested in your work in the health space and how that is going to advance patients' access to better health care.

Mr. Morris. Right. We have got a couple of projects underway and several of our members are deeply involved in medical applications, 3D printing.

Again, the challenge is to get the word out across the Nation in effective ways, so we try to do that communication as best we can. And there are some interesting things that we have been learning in the process, both in terms of the technology of how you do the inspections and the similarity of problems for making parts for a jet engine versus parts that would be embedded in a body, and then some of the more subtle things, and this is really cross-cutting more the medical.

What you heard in some of the testimony from Neal was the models that were made. So a major use of the technique of that manufacturing is for tooling, to be able to do tooling to adopt the surgery and to very carefully and precisely guide the surgery tools, et cetera.

And then there is something interesting to all of these. One of the key pieces of technology that has come along with 3D printing was 3D scanning. And as I was engaged with a conversation with a research scientist in the medical community. Obviously when you have got a piece of bone missing maybe from a car accident, maybe it is a wounded soldier, and you want to do a 3D scan so that that implant perfectly fits, and this is where that bioreabsorbable piece comes into play. As the bone grows back, the body absorbs the implant, then you don't have to remove the metal implant, which is really clever.

And they pointed out something, which was sort of an "ah-ha, boy, I should have seen this one coming." You want it to match, but you also want it to match this side of the head, because if you make this one a different shape than this shape, you have cursed that person for life.

So there are all these different subtleties that we are communicating with the medical community. The explosive use of the technology is incredible. About one-third of the patents as of 2 years ago were in the medical applications of 3D printing.

Ms. Schakowsky. Thank you so much. Thanks all of you.

Mr. Burgess. The gentlelady yields back and the chair thanks the gentlelady.

I will recognize myself for redirection.

I mean, you all brought it up, so it is going to come up when we go back home. Our schools are going to ask us: Hey, how do we get that for our students? So any of you want to provide some direction and advice to the members of the subcommittee?

Mr. Morris. We have initiated 2 years ago a process with DonorsChoose, where donors can go to the Web site and contribute funds and allocate it for 3D printers in their schools or wherever, maybe a Boy Scout troop, Girl Scout troop, et cetera. So that is one mechanism for the public to partner in and put their skin in the game, if you will, to get the printers in the hands of the youth of the United States.

I wanted to also quickly point out another really outstanding benchmarking of using additive manufacturing 3D printing for education is U.S. FIRST in the FIRST Robotics Competitions. Industry has been stepping up in great fashion to tutor and mentor the teams in the FIRST Robotics Competitions. I personally got involved in this attending two of their annual nationwide and global competitions. And we actually set up, we took some 3D printers, and we were doing hospital

repair of broken parts in the competition, which was kind of cool.

But that is another excellent model of STEM education, training in all of the aspects of design, including business with this technology, and partnering with industry to put up the deep engineering talent working and mentor the students outside school.

Mr. Burgess. Very well.

Mr. Orringer, I just wanted to ask you -- well, you hear the bells go off. So we had a vote series called. Fortunately, it looks like we have made it through our hearing, and the good news for you is we have got a long series of votes, so it would keep us away for a while. So I think we will be able to adjourn before we go and vote.

We do not, this subcommittee does not deal with the FDA, but our full committee does. And it just strikes me as we are talking about things like the templates of the lattice to build new body parts, this really is cutting-edge stuff. And we have a regulatory agency. Yes, They are equipped to tell someone how to go about getting a drug approved, they are equipped to tell someone how to go about getting a device approved, but something that sort of blurs the lines between those two areas may be more difficult.

So have you had any experience, positive or negative, in dealing with the regulatory side of this on your medical side?

Mr. Orringer. We are actually certified to build Class I, II,

and III devices in our facility in Colorado, which is where our medical modeling facility is placed. And our folks there tell me it is a difficult process, it is difficult to be certified to be able to manufacture these kinds of components. You probably want that, though, to ensure that we maintain the appropriate levels of quality, safety, et cetera.

Mr. Burgess. Yeah. I want to interrupt you just for a second. Yeah, you want it, but you also want the regulatory agency to be able to provide you -- or I want the regulatory agency to be able to provide you direction. What are the steps that I have got to go through? What is the pathway to getting this completed?

And then the complaint that I will hear frequently is somehow the rules all change along the way and then I have got to go back and recertify or reapply.

Yes, I want the devices to be safe. I don't want to hear about things having to be recalled or removed. It is one thing with an automobile, it is a dreadful thing if it is in a child. But we also want to lay out the regulatory pathway for you so that you know and it is predictable, and you know the steps and the sequence, and you know that when you complete the tasks, that is the end of the process, that it is not an endless back and forth, oh, we are going to need more stuff, we didn't ask you this, we are going to need for you to go back

and do this for a couple of years and come back and see us.

So when I am saying that this is your subcommittee too, I mean, that is the sort of feedback that I need to hear, the committee needs to hear, our staff needs to hear. We are anxious to have this be a continuing dialogue, because it is -- I mean, this is the sort of stuff that is over the horizon, but it is really pretty bright. When I talk to medical students, it is the doctors of -- the kids in medical school today are going to have tools that no generation of doctors has ever known.

Mr. Orringer. That is right.

Mr. Burgess. That is pretty powerful.

Mr. Orringer. Yeah. I appreciate that. We will certainly keep you posted. I think it has already been discussed.

A really huge barrier to entry is just that certification process. Five to 10 years just to introduce a new material, new process into the system. If we can figure out a way to accelerate that process, not only on the aerospace and defense side, but in all of our industries. And I think the FDA, as well as the Department of Defense, have a lot to contribute to this area, and we would definitely appreciate your help in making that dialogue happen.

Mr. Burgess. Well, thank you.

And, again, thanks to all of you on the panel. It has been a very

informative morning.

Seeing that there are no further members wishing to ask questions, I will thank our witnesses for being here today.

Before we conclude, I would like to submit the following documents for the record, by unanimous consent. A statement for the record from the American Chemistry Council. Without objection, so ordered.

[The information follows:]

******** COMMITTEE INSERT ********

Mr. Burgess. I would also like to submit a letter from the Specialty Equipment Market Association. Without objection, so ordered.

[The information follows:]

******** COMMITTEE INSERT ********

Mr. Burgess. Pursuant to committee rules, I remind members that they have 10 business days to submit additional questions for the record. I ask the witnesses to submit their responses to those questions within 10 business days upon the receipt of those questions.

[The information follows:]

******** COMMITTEE INSERT ********

Mr. Burgess. And without objection, the subcommittee stands adjourned.

[Whereupon, at 11:38 a.m., the subcommittee was adjourned.]