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DISRUPTER SERIES: ADVANCED MATERIALS AND PRODUCTION

WEDNESDAY, MARCH 15, 2017

House of Representatives,

Subcommittee on Digital Commerce and Consumer Protection,

Committee on Energy and Commerce,

Washington, D.C.

The subcommittee met, pursuant to call, at 1:03 p.m., in Room 2322, Rayburn House Office Building, Hon. Robert Latta, [chairman of the subcommittee] presiding.

Present: Representatives Latta, Harper, Burgess, Lance, Guthrie, McKinley, Kinzinger, Mullin, Walters, Costello, Walden (ex officio), Schakowsky, Matsui, Kennedy, and Pallone (ex officio).

Staff Present: Blair Ellis, Digital Coordinator Press Secretary; Melissa Froelich, Counsel, Digital Commerce and Consumer Protection; Giulia Giannangeli Legislative Clerk, Digital Commerce and

Consumer Protection/Environment; Alex Miller, Video Production Aide and Press Assistant; Paul Nagle, Chief Counsel, Digital Commerce and Consumer Protection, Olivia Trusty, Professional Staff Member, Digital Commerce and Consumer Protection; Madeline Vey, Policy Coordinator, Digital Commerce and Consumer Protection; Hamlin Wade, Special Advisor, External Affairs, Everett Winnick, Director of Information Technology; Michelle Ash, Minority Chief Counsel, Digital Commerce and Consumer Protection; Jeff Carroll, Minority Staff Director; Lisa Goldman, Minority Counsel; Caroline Paris-Behr, Minority Policy Analyst; Andrew Souvall, Minority Director of Communications, Outreach and Member Services; and C.J. Young, Minority Press Secretary.

Mr. Latta. The Subcommittee on Digital Commerce and Consumer Protection will now come to order; and the chair recognizes himself for 5 minutes for an opening statement.

And pardon me, I get down here after about 12 hours, and my allergies already start kicking in, even with the snow.

And I also need to just let the witnesses know that we also have the Energy and Commerce's Subcommittee on Energy is meeting right now or in the next 15 minutes. You are going to have members coming in and out, because both subcommittees are meeting at the same time.

But, again, good afternoon and welcome to the first hearing of the Disrupter Series in the 115th Congress. I would like to thank all of our witnesses for their flexibility with the time change, given the weather challenges of the past 2 days. The continuation of the Disrupter Series ensures that the Digital Commerce and Consumer Protection Subcommittee continues to learn about the cutting-edge developments across industry.

I am excited to continue this series. As chairman, I look forward to more hearings, including tomorrow's hearing on smart communities. Today, we are focused on advanced materials and production methods. The panel of witnesses are experts in a number of different fields, from graphene and other nanoparticles to bio-ink and techniques to 3-D print human tissue. We also have experts in new materials and fabrication methods, developing plastics, metals, and composite materials.

The potential for each of these materials, and even those that

may not be represented on the panel today, are subject to the health of the U.S. economy and the willingness of public and private investors to take some of the amount of the risk.

The applications of these materials is seemingly endless: infrastructure, energy, telecommunication, automobiles, health care, aerospace, transportation, and more.

The path to future applications and investment in early-stage development can be uncertain, given immediate capital investment requirements. However, on the other end of the equation is the potential for the improved safety and long-term cost savings. There should be a full vetting of the costs and benefits as we examine potential use cases for the advanced materials.

Moreover, if we are serious about improving safety, bringing consumers more and better options, and ensuring manufacturing jobs with that Made in America label, then we must be leaders in the development and application of these materials.

Basic research and development of new materials often is a result of an accidental discovery or an unexpected result. There is a tumultuous path for many materials from discovery to commercialization. U.S. job growth and material science and engineering is dependent on the health of individual industries over the next 5 to 10 years.

I look forward to hearing from our witnesses about their experiences along this development chain and how the government, at any level, is either helping or hindering further development of the

U.S. innovation in material science and advanced production methods.

And I think I have a little bit of time left, and any members on our side that would like to make an opening statement? Mr. McKinley.

Mr. McKinley. Thank you, Mr. Chairman, and good afternoon.

I would like to welcome everyone to today's important hearing on advanced materials and production. We are excited about this panel on this topic to learn more about some of the latest developments in material sciences and how they have the potential to revolutionize our industries and electronics and health care.

But I am particularly interested in learning more about the development and commercial applications of graphene. To the rest of the committee, that is a fascinating material that is one atom thick. It is the thinnest material made by man, lightweight, transparent, and 200 times the strength of steel, and holds great promise. Not only that, but also is a semiconductor and in composite construction.

So additionally, I would like to extend a special welcome to one of our witnesses, Dr. Hota GangaRao, with whom, actually professionally, we have worked together on some projects. He is from the West Virginia University in Morgantown. And Dr. GangaRao is a Maurice and Jo Ann Wadsworth Distinguished Professor of Civil and Environmental Engineering at WVU, and has done extensive research on the use of composite materials in infrastructure projects.

Dr. GangaRao, I thank you for traveling here today. I ran through that storm yesterday for 5 hours in the snow, and I saw four or five cars over in the ditch. So hopefully, you didn't have the same

experience that I had coming over yesterday.

So, for the rest of you, we look forward to thoughtful discussion with each of you. And I apologize, because I am going to be one, I am in that other committee. I am going to be back and forth here on this, but I want to get back and learn more about this.

So I yield back the balance of my time.

Mr. Latta. Thank you very much. The gentleman yields back.

And at this time, the chair would now recognize the gentlelady from California for opening remarks.

Ms. Matsui. Thank you very much, Chairman Latta, and I am here instead of the Ranking Member Schakowsky, who is trying to get out of Chicago. So I think you will understand that.

I am glad that some of us are here today, and thank you all for the witnesses for your flexibility on our scheduling. We can't control the weather, as you know.

This hearing continues the subcommittee's Disrupter Series, where we look at innovative products and technologies. Today, we are looking at advanced materials. Our research institutions have been driving this innovation forward. For instance, the University of California's 10 campuses are doing some of the most cutting-edge research in the world. They regularly lead all universities in the number of patents filed each year. The university's materials research has been pivotal in many fields, but the work being done at UC Davis is particularly impressive. UC Davis engineers have been using 3-D printing technology to create personalized, medically

accurate models of organs. These models help surgeons determine the best approach for operating on a patient, or whether an operation would be helpful at all.

Researchers at UC Davis have also developed technology that integrates renewable organic materials into water bottles. Currently, a plant in my district makes bottles that are 80 percent renewable, and they have a 100 percent renewable goal in sight. These advanced materials and many more being developed and already in use could make it much easier for us to reach environmental and sustainability goals.

Manufacturers can already use an aluminum-steel alloy that is lighter and stronger than conventional steel. That could mean lighter cars that require less energy. Permeable concrete could reduce flooding and help remove contaminants in groundwater. Our witnesses have many other examples of the ways that composite materials can benefit our communities. The possibilities are exciting; the question is how we get there. Many of these materials were developed through Federal research dollars.

Professor Rabiei lists in a written testimony the many funding sources her team used to develop composite metal foam, which include the National Science Foundation, NASA, the Department of Energy, and the Department of Transportation. Those agencies' funds largely come from nonDefense discretionary appropriations, and today, those funds are at risk. The President has suggested cutting nonDefense discretionary spending by $54 billion in fiscal year 2018. That is

not just cutting excess spending; these cuts could jeopardize our national competitiveness.

This would impair our ability to invest in the country's economic future. It would leave our researchers underfunded, and allow other countries to claim global leadership, instead of encouraging homegrown innovation. If we want continued innovation, we need to invest in the research that makes it happen. That starts with protecting nonDefense discretionary spending in this year's budget.

I look forward to hearing more from our witnesses about how federally funded research has supported development of advanced materials. I am also interested in the challenges of moving from research to market.

Thank you all for being here, and I look forward to your testimony.

And I yield back.

Mr. Latta. Thank you very much. The gentlelady yields back.

The chair now recognizes the chairman of the full committee, the gentleman from Oregon, for 5 minutes.

Mr. Walden. Thank you very much, Mr. Chairman.

I want to welcome our witnesses and I really appreciate your testimony, which I have enjoyed reading through.

I think your mic is still on. There we go. It is an old radio thing in me. You know, I am a radio guy. It is no problem.

Thank you. Again, thank you for what you are doing. This subcommittee is really, really important in the work of the Energy and Commerce Committee. It gets labeled as a Disrupter Subcommittee in

the sense that with all these new technologies and innovations in the private sector, and the partnerships with the public education institutions and all, there are some amazing things we are standing on the cusp of. And so we have held several hearings over the last few years on emerging technologies and as part of the Disrupter Series, from the internet of things and health apps to drones and robotics, revolutionary capabilities with 3-D printing. Many of these technologies are literally transforming commerce and creating new opportunities for economic prosperity for Americans and for generations to come.

Today, our Disrupter Series continues with a look at innovative materials and production methods that are the building blocks for some of the emerging technologies that could change how we see the world.

The work that is taking place at our universities around the country, truly groundbreaking. Today is an opportunity to learn firsthand from you, the top minds in academia. We want to learn about your full spectrum of work, and how basic research and how you shepherd this through your projects to commercialization. As my friend from West Virginia talked about with graphene, hailed as this discovery that will do for the internet of things what silicon did for the chip industry. We have not reached the point of mass commercialization, I understand, but there have been advances in patenting and licensing, and these are really important discoveries for some applications.

Additionally, composite materials incorporating graphene have increased strength and conductivity properties that are not found in

more traditional materials. These composites could have interesting applications in the automotive and infrastructure space. So I look forward to hearing from Dr. Tour about his work on graphene and the U.S.' position relative to other nations.

There is also the opportunity to work with traditional materials to create new composites that could solve some of the competing cost and safety questions. For example, new bridges and car bumpers could both benefit from taking into consideration new technologies.

So I am interested in hearing from our panelists in industry and academia about their experience approaching investors and clients about their products and services. So, as we look at the relationship between job creation and our Nation's infrastructure, it is crucial we understand the marketplace and what is currently under development.

Remember, simply because a material is new does not mean that it is a realistic replacement for some traditional material. However, there may be improved safety benefits and long-term repair and replacement cost savings in some cases. These are all worthwhile considerations for stakeholders to consider and important factors that we look forward to hearing from you all today on.

I will admit up front, I have to go down to the Energy Subcommittee and give an opening statement there and hope to bounce back and forth, but I do have your testimony here. And you are in able hands with our terrific chairman of the Subcommittee on Digital Commerce and Consumer Protection, DCCP, which is not a Russian acronym. It may look like that, but it is not.

And with that, I yield back, Mr. Chairman.

Mr. Latta. Thank you very much, Mr. Chairman. And, as I mentioned, we do have members that will be coming in and out.

But at this time, the chair recognizes the gentleman from New Jersey, the ranking member, for his opening statement of 5 minutes.

Mr. Pallone. Thank you, Mr. Chairman.

Today's hearing gives us the opportunity to explore some ways in which science and scientific research is allowing us to improve materials already in use or create new materials that are more adaptable to the needs of consumers and industry.

Advanced materials can be found in almost every industry sector. In the aerospace field, a new material composed of a multilayer lamination of glass and plastic is being used in helicopters and planes to make stronger and more durable windshields. Advanced materials research is also happening with regard to a wide range of consumer products.

As one example, researchers are working on creating batteries that are more stable and safer than the common Lithium ion batteries used in so many consumer electronics. Just this week in a tragic accident in Harrisburg, Pennsylvania, a toddler died as a result of an exploding hoverboard. Safer batteries would prevent these kinds of tragedies from occurring.

And today, we are fortunate to have Professor Rabiei -- I hope I pronounced it properly -- who is here to describe how advanced materials are used to create protective armor, armor that has been

described as metal bubble wrap. This metal wrap can be used to protect individuals as well as to protect multiple personnel in vehicles and other forms of transportation.

Now, some of these successes in advanced materials resulted, in part, from the Federal Government's investment in basic scientific research. As with all new scientific breakthroughs, funding for research and development is paramount, and the Federal Government is the largest financial supporter of basic research. The return on publicly funded scientific research and development, R&D, is well-established, and Federal support of this kind of innovation is a key to the success of America's economy.

In 2011, President Obama established the Materials Genome Initiative, that has invested more than $500 million in Federal funding to discover and deploy advanced materials. President Obama also established the National Network for Manufacturing Innovation, a network of nine federally supported advanced manufacturing research institutes throughout the country.

These institutes have provided research centers to academia, industry, and government for testing as well as opportunities to collaborate with others in their fields, or complementary fields of expertise. These institutes work on lightweighting vehicles so that they are more energy-efficient, but still just as strong and safe. They are also promoting 3-D printing and manufacturing, develop the fabrics of tomorrow that will act as connected devices, and help commercialize advanced resin and fiber composites that have a longer

room temperature shelf life.

So America's leadership in advanced materials and other important R&D may be at risk, based on the preliminary budget summaries we have seen from the Trump administration. We should not walk away from the significant efforts made or the public funds that have made these advances possible. The U.S. should be the most attractive place to research, develop, commercialize, and produce advanced materials. These are some of the jobs of the future, and we should do everything we can to continue to support this important R&D work so that these jobs stay here in the United States rather than go abroad.

So I am pleased that the subcommittee will have the opportunity today to learn more about advanced materials from those who know it best, the panel. Science, engineering, and technology are together creating jobs, good jobs for Americans, and I hope to see that continue.

But, again, I have to apologize, because I am going to run to the other committee and then come back as well. So I may miss some or all of your testimony. But thank you all for being here.

And I yield back, Mr. Chairman.

Mr. Latta. Well, thank you very much. The gentleman yields back.

And, again, I want to thank the witnesses for being with us today. And, again, I apologize. We have members that will be back and forth throughout the hearing upstairs and downstairs here.

But, again, I want to, again, thank today's witnesses, and we are going to have the opportunity -- witnesses will have the opportunity

to give opening statements, followed by a round of questions from the members.

On our witness panel for today's hearing will include, and I would like to just go through. I know the gentleman from West Virginia has already given one, but I will give it again.

Dr. James M. Tour, T.T. and W.F. Chao professor of chemistry, computer science, material science, and nanoengineering, at the Smalley Institute of Nanoscale Science and Technology at Rice University; Mr. Keith Murphy, chairman and chief executive officer at Organovo Holdings, Inc.; Dr. Afsaneh Rabiei, professor of mechanical and aerospace engineering at North Carolina State University; Dr. Hota GangaRao, Maurice A. and Jo Ann Wadsworth Distinguished Professor of Civil and Environmental Engineering, Director of Constructed Facilities Center, and Director of Center for Integration of Composites into Infrastructure at West Virginia University; and Mr. Shane Weyant, who is the chief executive officer and president at Creative Pultrusions, Inc.

We appreciate you all being here today, and we are going to begin the panel with Dr. Tour. And you are now recognized for 5 minutes for your opening statements. And, again, thank you very much for being with us.

STATEMENTS OF DR. JAMES M. TOUR, W. F. CHAO PROFESSOR OF CHEMISTRY, PROFESSOR OF COMPUTER SCIENCE, AND PROFESSOR OF MATERIALS SCIENCE AND NANOENGINEERING, SMALLEY INSTITUTE FOR NANOSCALE SCIENCE & TECHNOLOGY, RICE UNIVERSITY; HOTA GANGARAO, MAURICE A. AND JO ANN WADSWORTH DISTINGUISHED PROFESSOR OF CEE, CEMR, DIRECTOR, CONSTRUCTED FACILITIES CENTER, WEST VIRGINIA UNIVERSITY; KEITH MURPHY, CHAIRMAN AND CHIEF EXECUTIVE OFFICER, ORGANOVO HOLDINGS INC.; DR. AFSANEH RABIEI, PROFESSOR, DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING, NORTH CAROLINA STATE UNIVERSITY; AND SHANE WEYANT, CHIEF EXECUTIVE OFFICER AND PRESIDENT, CREATIVE PULTRUSIONS, INC.

STATEMENT OF DR. JAMES M. TOUR

Mr. Tour. Thank you. I am here to discuss graphene and establishing U.S. preeminence in the field of this disruptive advanced material. What is graphene? It is a sheet of graphite, one atom thick. At the atomic scale, it looks like chicken wire. I am a professor of chemistry, material science, and nanoengineering at Rice University. I have 625 research publications, 155 of those being on the topic of graphene. I also have 112 patents on graphene, ranking me as the third most prolific graphene inventor in the world and number one in the U.S. Our research on graphene has led to the formation of five nanomaterials and nanomedicine companies, plus suites of licenses to existing large multinational companies.

The U.S. is no longer leading in graphene research and has already lost in graphene production capabilities. Without investment to leverage the private sector, we will cede this advanced material to foreign competitors. At its size scale, graphene is tops for toughness, heat conduction, electrical mobility, and lightweight. From a safety standpoint, we have shown graphene to be nontoxic and environmentally friendly in many respects. A nanomaterial cannot merely be sprinkled like pixie dust into a composite or device to show beneficial behavior, but with persistence and investment, the advances can be realized.

The number of graphene patents rose rapidly during the last 5 years. In 2015, it surpassed the cumulative patent pool of 10 related main groups of technologies. That means that the country that dominates in graphene will dominate in high-technology advances for decades to come. It is now like a space race. China has 25 percent more graphene patents than does the U.S. Of the top 20 entities in the world that hold graphene patents, eight are foreign-owned companies versus three U.S. companies. Eight are foreign universities, all in Asia, while only one U.S. university is on that list, namely, Rice University.

The worldwide market for graphene is a few tens of millions of dollars per year, but now rapidly rising. Bulk-scale production of graphene is an initial part of those revenues, but that is not where the most value resides. The greatest value is from ownership of the innovative techniques to apply graphene in advanced applications that

were formerly unforeseen, like in ultrahigh-frequency supercapacitors, or medical device formulations that regenerate damaged spinal cords within a few weeks to near perfect function. These are two technologies that we have witnessed in our own laboratory.

The country with the best researchers and the easiest route to entrepreneurial success will be preeminent. But the U.S. universities are trailing way behind Asian universities in high-tech equipment for nano-analysis and basic research. This is the result of diminished Federal support for academic science.

Grimmer, however, has been the dramatic loss of our top young investigators from pursuing academic positions, due to the diminished research funds to universities on a per-researcher basis. Our top international students, who formerly always remained in the U.S. to become professors, are returning to their home countries upon graduation, taking our advanced technology expertise with them. Even more frightening, some of our top U.S. established senior professors are moving abroad in order to keep their programs funded. Foreign universities are trolling in the U.S. academies for our top professors. Previously, the U.S. was the recipient of the world's most talented, profiting from the brain drain of other nations. Now, the U.S. is being drained. Sadly, it will take decades to recover from what we have already lost.

I have three recommendations to correct these problems and ensure that the United States is preeminent in graphene advanced materials:

First, Congress should consider the rapid initiation of a $200

million-per-year program administered over 4 years through the standard Federal science funding agencies, and $7 million-per-year multi-investigator programs, requiring strong in-kind university and corporate partner matching, and dedicated facilities, equipment, and personnel. That way, the Federal money will be leveraged to produce 50 percent more from university development campaigns, and industrial partners. Programs like the NSF's Innovation Corps could assist in the translation of technology to industry. This is shovel-ready science, and should be thought of in the same way that Congress is addressing infrastructure investment.

Second, we must keep our start-up companies in the U.S. My last three companies were started abroad, but if the U.S. corporate tax rate were reduced to 15 percent, we would gladly remain in the U.S.

Finally, streamline the Green Card process for scientists and engineers that received their Ph.D.s in the U.S. We need them.

In closing, Asia is leading in graphene research and commerce, but I think the U.S. could pull ahead with a little help from the Federal Government. If our congressional leaders would do that, we would beat the pants off our foreign counterparts.

[The prepared statement of Mr. Tour follows:]

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

Mr. Latta. Thank you very much, I appreciate your testimony. Mr. Murphy, you are recognized for 5 minutes.

STATEMENT OF KEITH MURPHY

Mr. Murphy. Thank you. Good morning, Chairman Latta, Congresswoman Matsui, and members of the subcommittee. Thank you for inviting me today to discuss Organovo and the capabilities of our 3-D bioprinted human tissue models. Bioprinted 3-D human tissue models are disrupting the drug discovery process, because they give researchers and regulators new testing tools and capabilities to make drug discovery safer, speedier, more likely to find breakthrough drugs in new areas, and less costly, and because they enable future implantable tissue therapies to restore or cure failing organ function and address the long waiting list for organ transplant.

What is 3-D bioprinting? An office printer uses ink to print on paper; and industrial 3-D printers use liquid, plastic, or metals to print machine parts or prototypes. We at Organovo use human cells to make bioink that is deposited by a bioprinter which layers the bioink onto a surface to form organic, living 3-D human tissue. Bioprinted model tissues have been shown to replicate the key elements, architecture, and function of living, native human tissues. Bioprinted tissues for transplant have been demonstrated to have powerful potential to treat serious illness by direct transplant into patients.

I have submitted slides along with the written testimony that will help you visualize the manufacturing process, where we fit into the current drug discovery process, the current progress in transplantable tissues, and examples of the peer-reviewed data we have used to validate the capabilities of our bioprinted tissues.

Founded in 2007, Organovo is based in San Diego, California, and has grown from the back room of my house -- we couldn't afford a garage -- to be 120 employees and 45,000 square feet in 10 years. We perform research, build 3-D bioprinters, print tissue models, and run our testing services out of our headquarters building, which Congresswoman Walters has visited.

Our customers and partners include almost half of the world's top pharmaceutical companies and leading academic research centers. There is diversity of organ tissues to replicate -- liver, kidney, and others -- and potential commercial applications beyond drug discovery, such as cosmetics and chemical testing. There are wide-ranging applications for the Department of Defense, including everything from delivering testing tissues for developing protections against biological attack to creation of tissues to replace function lost by wounded warriors.

From 1990 to 2010, 73 percent of phase 3 clinical trials failed due to toxicity or lack of efficacy. In 2012 alone, 10 late-stage clinical trial failures cost innovators $7 to $10 billion in losses.

Organovo's 3-D human tissue models are currently being used by drug manufacturers to give researchers the ability to look to see if

the drug is working, how it is being metabolized over time, and whether it is producing toxic side effects. These models are also being used to help improve the safety and efficacy of potential drugs currently progressing through human trial phases.

3-D human tissue models also can be used to help improve the post market safety understanding of approved products. For example, a recent study using 3-D bioprinted liver tissues modeled drug-induced liver injury to investigate the effects of Trovafloxin, a drug withdrawn from the market due to acute liver failure in patients. The study found that 3-D bioprinted liver tissues identified significant Trovafloxin liver toxicity after just 7 days of exposure. In contrast, Trovafloxin did not show strong toxicity signals in common traditional 2-D in vitro systems, or in animal models.

A December paper coauthored by the head of FDA's Center for Toxicological Research concluded that both researchers and regulators should prioritize and quickly adopt the use of 3-D bioprinted human tissue models.

We are pleased that both the 21st Century Cures legislation and the draft Prescription Drug User Fee Act (PDUFA) VI agreement take steps to encourage the use and adoption of new drug discovery tools. However, it should be fine-tuned to accelerate the adoption of currently available technologies with existing validating proof versus longer-term technologies not yet available.

We are grateful that committee members introduced legislation, the Patient Safety and Toxicology Modernization Act, requiring FDA to

issue guidance by the end of 2018. We hope that the committee includes this legislation in PDUFA VI, to ensure FDA prioritizes adoption of commercially available and proven discovery tools that can speed and lower the cost of drug discovery.

Organovo's 3-D bioprinting technology also is being used to develop first-in-class implantable tissues that cure or meaningfully restore a patient's organ function. There remains a tremendous gap between patients waiting for organ transplants and those who receive them. In 2015, roughly 120,000 Americans were waiting for an organ transplant and only 30,000 patients received them.

Organovo's data shows survival and sustained functionality of our 3-D bioprinted human liver tissue when implanted into animal models. Our implantable tissue showed encouraging evidence of the potential to restore organ function and to treat inborn errors of metabolism.

The FDA will soon have cell-based bioprinted tissue therapy applications under review. We are grateful that the 21st Century Cures legislation not only created a new regenerative medicine pathway at FDA without lowering safety standards, but also provided greater clarity on how FDA will review so-called combination products. Global regulatory agencies in Europe and Japan already have implemented regenerative medicine pathways. FDA's clear, timely, and collaborative implementation of relevant 21st Century Cures provisions will help ensure that regenerative medicine innovation, research, and clinical trials remain in the U.S.

Thank you again for inviting me to participate in today's hearing.

I am happy to answer questions related to my submitted testimony or slides.

[The prepared statement of Mr. Murphy follows:]

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

Mr. Latta. Well, thank you very much. We appreciate your testimony.

And at this time, we will recognize Dr. Rabiei for 5 minutes for your statement. Thank you very much.

STATEMENT OF AFSANEH RABIEI

Ms. Rabiei. Good afternoon. Thank you very much for the invitation. It is an honor to be here and to introduce our material. I decided to use my slides because I believe that seeing is believing. So it is a new material. I am very excited to see that -- I am very excited to see that there is an attention to advanced materials.

My name is Afsaneh Rabiei, and I am a professor at North Carolina State University, and there is a link to my website for more information about what we are doing.

We are learning from nature, and the art of engineering is to watch what happens in nature and learn from it. So if you look at the slides, we have our brain encapsulated in skull, which is a porous material, bird's wing, leaves, bone, trees. Everything is benefiting from a porous structure filled with air. And speaking of air, earth is surrounded by that to protect us against meteoroids and radiation and heat and so forth.

So how do we learn from it by using Styrofoam or bubble wrap to carry fragile materials, or just carrying a hot beverage using Styrofoam. So how did I learn from it? We used the generous support,

like Congresswoman Matsui mentioned, to have almost $2 million funding to start building a new material, something that is more or less like a metallic bubble wrap.

And it can show -- when you put them side by side, you can see the similarities. It is much lighter than steel. This scale shows two pieces of steel. One is regular steel and the other one is our composite metal foam steel. And it is a third of weight. It is the same size, but the density is a third. And the material has shown a huge energy absorption capability and performing like sponge. It can be used for high-speed impact protection. It can be used for ballistic or blast and frag protection. It can be used for radiation shielding or heat or sound and vibration shielding.

So the possibilities are endless. So the $2 million is just a drop in an ocean. If we want to get this material in the hands of our soldiers to benefit from its protection, we really need more support.

Here, you probably have seen the picture in a lot of media news coverage, Fox News, Huffington Post, and so forth. In this video, we see the composite metal foam being squeezed down. Of course, the force is huge. What you see is like a kitchen sponge; it is squeezing down, and that is what provides us the energy absorption. This video also shows a composite structure partly made by our composite metal foam. The bullet is hitting the material. It is totally disintegrating.

The panel that you see here in this picture is just 1 foot by 1 foot. It shows a multishock capability that other armors are not providing. This picture is beautiful. If you see, we have the hard

core of a bullet entrapped inside those squeezed bubbles. So it basically works as a bubble wrap, but a heavy-duty one.

So the back of the armor also is showing just a small indentation. And if you remember, the National Institute of Justice have up to 44-millimeter indentations, which basically, you stop the bullet but you hurt the soldier by those huge indentations in the back of the armor. This one does have a very small indentation, as you can see, less than an eighth of an inch.

Here, we put this in front of a large HEI 23-millimeter blast and frag, the panel, less-than-an-inch panel. I put a piece of aluminum with the same weight and our material. The red one that you can see totally stressed is aluminum; and the one that is green and happy is our material. So you can put it under the vehicle, in a vehicle, armor. You can put it, you know, anywhere to protect our soldiers, and I bet they are going to be much happier.

The cross-section also is shown, and the aluminum has been damaged a lot and composite metal bomb stopped all the fragments, stopped the blast wave energy. These particles have been flying up to 5,000 foot per second and they hit the panel, and the panel stopped them.

The rest of it is confidential with Army.

We also learned from our atmosphere, and we put it in front of 800 degrees C flame. And, as you can see, our material takes 8 minutes to reach the saturation of 800 degrees C with just less than an inch thickness. Steel takes 4 minutes, and aluminum takes 20 seconds. So that shows how the material can insulate against heat and protect

against high temperatures.

So you can imagine all of the cases, a lot of, you know, cargos that carry explosives, things that can be helpful in all directions to protect against heat. And also, we also learned from atmosphere and put it against x-ray. We are not reaching lead yet, but we have shown almost 275 percent improvement in blocking x-ray compared to aluminum.

So in our recent studies funded by Nuclear Energy University Program, we have collected those data and we learned that if we add a little bit of other elements into our material, we can further improve it, but we need more support. This has been done in the last decade or so, and I have done all of these single-handed. We need much more funding. If this technology needs to go out and protect our soldiers, our people, we definitely need more support.

I did not notice the time. I am so sorry I took longer.

[The prepared statement of Ms. Rabiei follows:]

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

Mr. Latta. Well, thank you very much for your testimony. I really appreciate that.

And at this time, we will recognize Dr. GangaRao for 5 minutes. Thanks again for being here.

STATEMENT OF DR. HOTA GANGARAO

Mr. GangaRao. Thank you very much, Mr. Chairman. My theme today is going to be on the renovation of American infrastructure with advanced composite materials.

Herein, I do not want to propose rip and replace of existing conventional materials. We want to reinforce them, make them safe. According to last week's American Society of Civil Engineers' report, our infrastructure received a grade of D-plus. This low grade is attributed to $4.5 trillion over 10-year funding gap between revenue and infrastructure needs. On top of it, motorists are spending $500 a year per vehicle to maintain, due to the poor quality of our bridges and highways.

Where could we get the funding from? Public-private partnership. We have been doing that, to a small extent, and as you have seen, I-267 outside D.C. More debt to our $20 trillion debt package. Not sure that the Congress wants this up. Increasing Federal and State gas taxes. That I am afraid doesn't have the appetite of the Congress.

I have a fourth idea: Do not rip and replace, but renovate with

advanced composite materials. Here are some of the composite materials that we at the Constructed Facilities Center of West Virginia University have been developing since 1987. Thanks to Congressman McKinley, we built a bridge in his backyard back in 1996. It is standing, functioning extremely well, with a reinforcing bar in lieu of the steel bar. This is four times lighter, two times stronger, noncorrosive, nonconductive. I have several materials to that effect.

These developments have taken place in cooperation with government agencies, a wide range of industries, and academia. To illustrate West Virginia University activities with government and industry help, we have built over 100 new bridges, including laminated composite timber, polymer, and glass or carbon composites. And also, we did some of the hybrid development, implying the wrapping of concrete and timber with composite. And these approaches do not call for any rip of the existing commodity product, but reinforce these products with glass or carbon as a shell with conventional materials as a substrate or a core.

Today, I want to focus on discussions on saving huge sums of money for taxpayers without compromising safety or user inconvenience. Allow me to use three great examples to illustrate my savings plan. Say, for example, we will focus on transportation infrastructure. One is the bridge deck systems. These are the first lines of defense when it comes to structural material deterioration of bridge superstructures. This is a $120- to $150 billion problem. We can remove this falling concrete and do a few other things, and put a glass

or a carbon fabric carpet on top of the existing concrete deck and fuse it with proper resin. Where is the savings? This can be done with about $50 to $60 a square foot of a deck while, in fact, a rip and a replace will cost you about $150 to $180 a square foot. You can imagine the savings.

The second example, we discard 20 million railroad ties that are creosote-treated, and this has a humongous environmental problem. What we propose is put a Band-Aid, known as a glass composite wrap, or a carbon composite wrap, to enhance the service life to about 50 to 60 years, if not 80 years. Imagine the amount of money one can save from -- we have done the field testing and also the Pueblo, Colorado, testing, and we have shown that the life expectancy can be tremendously improved.

The third item I would like to talk about is the shale gas movement. West Virginia is the epicenter of gas deposits. With these new composite materials, with nanocoatings made of graphene or whatever that are noncorrosive and nonconductive, we can design pipelines with internal pressures of 3,000 to 5,000 psi, and be able to push more gas at a most economical price.

I have several other examples. I need to skip a few of them for the sake of time factor. Then the question is, one wonders if these all so good, why the free market is not accepting them? There are several impediments. I will not go into them. In conclusion, those impediments are clearly stated in my write-up.

However, in conclusion, this is what I would like to say: We are

most grateful that the U.S. Government support has been integral in the initial development and implementation of composites in civil infrastructure. With continued support, manufacturers will continue to expand, create high-paying jobs, and improve U.S. infrastructure so that advanced composite materials will be an integral part of our infrastructure landscape.

Thank you very much for the opportunity.

[The prepared statement of Mr. GangaRao follows:]

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

Mr. Latta. Again, thank you very much for your testimony.

And, Mr. Weyant, we will give you 5 minutes now for your opening statement. Thank you for being with us.

STATEMENT OF SHANE E. WEYANT

Mr. Weyant. Good afternoon, Chairman Latta, Congresswoman Matsui, and the members of the subcommittee. Thank you, and I appreciate the opportunity to testify before you today.

I am testifying on behalf of Creative Pultrusions and my fellow members of the American Composite Manufacturers Association.

Creative Pultrusions is one of over 3,000 manufacturers of composites who are represented by the ACMA. Since World War II, this industry has made products using combinations of glass or carbon fiber reinforcements, and tough engineered polymers. The resulting material is stronger than the constituent materials individually.

Composites provide characteristics specifically tailored for maximum performance in a host of different applications. Composites are stronger than other materials, such as steel, concrete, and wood. They are also lighter, more energy-efficient, and easier to transport, assemble, and install. They offer design flexibility and durability and, most importantly, are resistant to corrosion and structural degradation.

We have been in business for over 44 years and have seen many changes to the industry. Some applications for composites have been

disrupters, but are now common practice, like fiberglass boats and windmill blades. The industry has great potential to upend traditional infrastructure and construction markets and address an immediate national challenge.

Nearly every key development in our industry since its inception began in the United States. However, the committee should be aware that other countries have accelerated research and commercialization in an effort to gain market dominance. Policymakers should ensure that disruptive domestic technologies likes ours have a framework and an environment to encourage their continued advancement and adoption, including supporting institutions, such as the advanced manufacturing institutes.

Our energy and communications infrastructure is more critical than ever, yet, it is reliant upon 19th century technology, wood poles. Tens of thousands were wiped out by Superstorm Sandy, and hundreds of thousands of wood poles and crossarms are nearing or past their functional service life. We have a choice to continue with this outmoded technology, or use 21st century material. My company is one of many manufacturers of composite utility poles and crossarms that are easier to install, and more durable against extreme weather, fire, and require less maintenance and last significantly longer.

Composite poles are the best choice in environmentally sensitive areas, because they will not leach toxic chemicals and are resistant to rot and pests. The structural capabilities of composites give these materials the ability to disrupt the 150-plus-year span for building

bridges in this country as well, a disruption welcomed by Canadians and other nations.

Composites bring the advantage of extended service life and superior performance through the inherent resistance to rust and degradation. When traditional materials such as steel-reinforced concrete rust, crumble, and spall, composites remain unchanged.

An additional benefit of composites is the speed of production and installation. Traditionally, bridges can take months to build on site. We have installed bridges, with the help of Dr. GangaRao, like the Market Street Bridge in Wheeling, West Virginia, with less than 14 hours of labor to install the bridge deck.

The recent events in Flint and Oroville show our water infrastructure is also in need of modernization. Composite technologies have the capacity to revolutionize the water systems around this country. Composites can provide pipe and structures that are easier to install, stronger, and more durable than the other materials, and are inert, and don't leach chemicals into drinking water.

Composites also have a game-changing potential in marine infrastructure. Our SuperLoc sheet piling system, for example, rehabilitates deteriorated waterfront structures subject to harsh marine environments. A similar product, our fender pile system, was used to rehabilitate the service dock at the Statue of Liberty in wake of Superstorm Sandy, replacing outdated wooden structures.

Standards are a crucial issue. The Federal Government has been

instrumental in the development of standards for other industries. Now is the time for Federal agencies to work with us and our academic partners, like my fellow witness, Dr. GangaRao, to develop these standards that would allow us to meet the challenge of our future with innovative solutions.

Thank you for the opportunity to testify today on behalf of the domestic composite industry, and I am happy to answer any questions.

[The prepared statement of Mr. Weyant follows:]

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

Mr. Latta. Well, thank you very much.

And we will now move into our question-answer portion of the hearing, and I will recognize myself for 5 minutes for opening questions.

First, let me just thank you all for being here again, because it is fascinating, especially where you are all taking us is amazing. But I just wrote down a few other questions, if I could just get maybe brief answers to.

Dr. Tour, you had mentioned that you had started three companies recently, and they all started abroad. What countries did you go to, because of the tax question?

Mr. Tour. They were all started in Israel.

Mr. Latta. In Israel. Thank you.

Mr. Murphy, if I could ask you a question, you were talking about -- because we always have discussions around here about FDA and where we are going and who is faster, European, U.S. And you said that the European and Japanese have been implementing, I believe theirs, it sounds like it is faster than we are doing it here. Would that be correct? Did I understand that?

Mr. Murphy. They have given clarity to the pathway. It is not specifically about how fast in Japan. It has the promise to be faster.

Mr. Latta. Could you maybe define more clarity to that pathway?

Mr. Murphy. Yes, absolutely. In Europe, they have a dedicated pathway for advanced medicinal therapies that they established a while ago, and it has just been getting use and has more clarity about how

it operates.

21st Century Cures Act in the U.S. actually requires the establishment of an accelerated pathway for tissue and cell-based therapies which we think will be attractive, but it doesn't change the safety mandate. It simply requires speedier review, or it is yet to be seen.

And so what we are asking for today, one thing we would like to see is proper and speedy implementation of what that pathway will be. We need clarity in our industry to keep companies here in the U.S. and keep the clinical trials here in the U.S., because even U.S.-based companies will often go overseas to run their clinical trials first, because they see more clarity in the process.

Mr. Latta. Thank you.

Dr. Rabiei, I am just kind of curious. Maybe I missed it. How thick is that material? And what is the weight factor, especially in that protective armor that you are working on?

Ms. Rabiei. We have made armor that all of them were less than an inch. And we have been putting them in front of very large threats, like armor-piercing kind of threats. They call it 7.62, .50 cal. And it performed always surprising. One of my colleagues that I have been working with from Advanced Aviation Research Center, he always tells me when I take samples there, he says, Afsaneh, your samples always surprise me, and I am not surprised anymore, because you have surprised me enough.

So it always performed well. Of course, it is not the -- we don't

claim that it is perfect in all different directions. Definitely, we do need support to further develop the material for specific applications. Like, for example, when we put it in front of the blast wave, it is still less than an inch, and it still performed. But how would that work against IED, we still do not know. We put it in front of, you know, HEI. So every one of those need more in-depth analysis so that we can take it faster to our soldiers' hands.

Mr. Latta. Thank you.

Dr. GangaRao, we had hearings and with legislation in the last Congress, especially on pipeline safety. And how would this material work? I know you were explaining about the pressure and all, but would that prolong the life of the pipe by having this technology in that pipe?

Mr. GangaRao. My colleagues from Creative Pultrusions have been manufacturing these kinds of pipes for a few years. And there are several advantages of this type of a pipe, number one. It is of higher strength and lower weight.

Number two, it is noncorrosive, and it is nonconductive. And it can take much higher pressures on a sustained basis and be able to enhance the safety, because there will be no burst-type failures for one reason or the other.

Mr. Latta. Well, thank you.

And, Mr. Weyant, if I could ask you, you mentioned something that caught my ear, that you had a bridge deck that went in in 14 hours?

Mr. Weyant. Yes.

Mr. Latta. How big was that deck, just out of curiosity?

Mr. Weyant. The actual bridge in Wheeling was 200 feet long, and approximately 68 feet wide, with a sidewalk.

Mr. Latta. In 14 hours?

Mr. Weyant. That deck was installed in 14 hours. So knowing concrete would be probably a 30- to 40-day just on the deck itself to disrupt, you know, the traffic and delays.

Mr. Latta. Well, I know that they were doing some replacement on I-75 not too far from me, and they slid the bridge in, but it was an all-day affair. And getting everything lined up at 14 hours is quite an accomplishment.

And I have overrun my time, but I really appreciate your testimony today. And at this time, I am going to recognize the gentlelady from California for 5 minutes.

Ms. Matsui. Thank you very much, Mr. Chairman. And I agree, this has been absolutely fascinating testimony that we have heard here today. I keep thinking about all the things that we can be doing with some of the products that you are talking about.

But let me just first, I want to ask all of you just quickly, did you receive Federal funding during the process of developing your material and, if so, can you describe for me the role that Federal funding played? And this is just quickly.

Mr. Tour. Yes. I received a lot of Federal funding for our work on graphene from the Air Force Office of Scientific Research and the Office of Naval Research, and it was critical for the development.

Without that, we never could have done this.

Ms. Matsui. Okay. Thank you.

Mr. Murphy. The founding technology which came out of the University of Missouri was funded heavily by the National Science Foundation. After the formation of the company, we have gotten multiple NIH SBIR grants. And we also benefited from an ARRA grant that was established for biotech companies. We also just got a great score on our latest NIH SBIR grant. So if you guys can pull any strings, that would be great.

Ms. Matsui. I think I heard, but is there more that you would like to tell us about your funding?

Ms. Rabiei. Sure. We also have received funding, as I mentioned in my presentation, again, started from National Science Foundation, where discovery began. I absolutely support that statement.

All of the funding that I have received so far were through my university. We have multiple patents and we have started a company to commercialize the technology, and the company has not received any funding.

Ms. Matsui. Okay. Dr. GangaRao?

Mr. GangaRao. The Constructed Facilities Center at West Virginia University has been receiving funding from the National Science Foundation since mid 1980s. We have also been getting good bit of funding from the Department of Defense, Army Corps of Engineers, Department of Transportation. And we are very fortunate to have been consistently receiving their support.

We want to emphasize that these composite materials might look a little bit more expensive to begin with in terms of the initial cost. However, there are certain products that we have developed with industry folks like Creative Pultrusions, able to install them at about half the price of conventional material.

Ms. Matsui. All right. Thank you.

Mr. Weyant. Yes, Congresswoman Matsui. We have received Federal funding on the bridges. In early 2000, there was some funding put in place to help offset the cost difference, the original cost difference of the materials. That also was allowed to let us develop other technologies that we could use in other infrastructure areas to develop a lot of our marine structures. So we appreciate that support.

Ms. Matsui. Thank you.

Dr. Rabiei, you know, in the past few years, this committee has done a lot of work on the issue of head injuries and brain trauma in sports. We often use an analogy to a yolk in an eggshell. Helmets may be able to protect the skull from fractures, but not protect the brain from injuries.

I am curious. Do you see any potential application for your invention in that area? And how would it be different from the traditional helmets?

Ms. Rabiei. Yes. Actually, I was here in D.C. last Wednesday, with a group of people who were advocating for Society for Brain Mapping and Therapeutics. So there were, like, six brain surgeons, and I was the only rocket scientist in there.

So one of the potential applications of the material can be for helmets, and for any kind of protective layers. So what I always say is that when you want to transfer an egg, you put it in Styrofoam. When you are transferring glass, you put it in bubble wrap.

When you transfer humans to outer space, or from here to another place in an airplane, in a train, or send them to hockey or in a war field, you don't protect them. We care more for the glass than for the human. We just put it in a solid material, and what solid material does is just to transfer the load from one side to the other, and it is not my problem. But when you put it in a porous metal, the porous metal squeeze and the human behind it is protected. So whether it is helmet, whether it is armor, whether it is in front of the car, it works.

Ms. Matsui. Well, that is wonderful.

You know, we also have jurisdiction over automobile safety. How about metal foams, can they be used to reduce the damage of vehicle crashes?

Ms. Rabiei. For, I am sorry?

Ms. Matsui. Metal foams. Is that possible to reduce the damage?

Ms. Rabiei. Yes. Yes, absolutely. I had some funding from the DOT, and a program called IDEA that was for crashworthiness and impact protection. So in our preliminary studies, it shows that if you put two pieces of our material in front of the car and have an accident, like 35 miles per hour, it will feel like 5 miles per hour for the passenger sitting in the car, because the energy is absorbed and damped, but --

Ms. Matsui. Thank you very much. Could I have just one more question?

Mr. Latta. Uh-huh.

Ms. Matsui. I was curious. I live in Sacramento. We have two big rivers and we are always talking about water infrastructure. So I was curious, because some of what you are talking about might be very helpful for us, if we are thinking about materials that would be stronger and be able to withstand more pressures and things like that.

Are there available -- when you build bridges, are you also thinking about dams and things like that also?

RPTR ZAMORA

EDTR SECKMAN

[1:03 p.m.]

Mr. GangaRao. Yes, we have a great bit of funding from the Army Corps of Engineers. And we have recently, about 4 years, 3 years ago, we rehabilitated a dam underwater, without draining it out, using the composite materials.

Ms. Matsui. Oh, that sounds pretty good. Okay. Well, thank you.

I know I have run out of time. Thank you.

Mr. Latta. Well, thank you very much.

The chair now recognizes the gentleman from Mississippi, the vice chairman of the subcommittee, for 5 minutes.

Mr. Harper. Thank you, Mr. Chairman.

And thanks to each of you for being here. It is fascinating every time we learn more and more about this. So thank you for your work and your concern.

And, Dr. Tour, your testimony earlier and your remarks and your written testimony, if we were to increase the funding for research at universities and the corporate tax rate were reduced, what impact do you see that having -- the concern that you have about the brain drain of research scientists?

Mr. Tour. Right. Well, as far as the corporate tax rate, it was on the advice of our accountants to start our companies overseas, and

so that would cease. We very much would rather start it here. It is much easier here because of the knowledge that you don't have to transfer it as far. So that would immediately keep companies here that are going overseas, and then two of them are already on the public markets overseas.

As far as the increase in research funding, we have seen very little increase in research funding over the last 8 years. It has been devastating in the universities and so much so that our -- I collaborate with the Chinese, and I put their names on our papers. Why? Because I need access to their equipment. They have better equipment than we have in the United States because we haven't been able to maintain our equipment budgets.

I come from a university that is only 4,000 undergraduates, 4,000 graduates, and we have $5.5 billion endowment. So we are well endowed. We are hurting on equipment. And so I collaborate with people overseas just to get access to their equipment. So this is going to be a long-term problem for our country that I really care about if we keep on seeing this.

Our best students are now going home. They would gladly take jobs in the U.S. as professors and do this, but they get huge startup packages in China. They have the 1,000 scholars program, which is more than 1,000 people, but they will start it with multimillion dollar packages as young people. So we are losing them.

Mr. Harper. All right. Well, thanks for your input, and I think we get the message and appreciate that.

Mr. Weyant, if I may ask, you mentioned a number of industries leveraging fiber-reinforced polymer composites in the U.S. from aerospace, automotive, defense, health care. How has your company had to adjust to new materials entering those industries over the years?

Mr. Weyant. Well, the big adjustment is trying to develop standardizations that don't exist for advanced composites. A lot of traditional materials, there are handbooks that exist. Dr. GangaRao can pull out a steel handbook.

So the big challenge I would challenge and ask for is to help develop those standards. A lot of these companies are very small with restricted budgets, but if the government and universities and industry could develop standards to penetrate so any engineer out of school could pull out a standard and develop around these products, that would be a great return.

Mr. Harper. Great. Great. Thank you.

Dr. GangaRao, how large is the market for composite infrastructure applications? What do you envision?

Mr. GangaRao. As I indicated, we are dealing with a $4.5 trillion market in the infrastructure arena for the next 10 years. If I had to make a guess at it, we can easily capture a trillion-dollar type market in the next 10 years provided we do certain things right, as Shane pointed out, and a few others, and I also put it in my testimony.

Mr. Harper. Okay. Great. Thank you.

And, also, Dr. GangaRao, in your testimony, you discussed, you know, the societal impact of developing advanced composites for

infrastructure applications. Can you please explain this in a little more detail, that impact? And is there also a monetary benefit to using advanced composites, and if so, in what ways?

Mr. GangaRao. Let me start with the monitoring aspect of it. For example, the longevity of a given system can be enhanced using the composite, not necessarily displacing existing conventional materials but hybridizing the conventional materials with the composite. I gave you one such example: Take the case of a bridge deck. I believe we can save the next 10 years several billion dollars, perhaps up to $50 billion just on one aspect of that.

Then let me move on to something like the railroad ties where the operational costs are tremendously high today. Herein, if I can increase the life expectancy from 10 years, which is what it is today in the southeast United States, to 40 to 50 years, then I can have a huge savings there. For example, New York City today pays $2,100 a tie for replacement, even though the tie cost is only $100 to $150. $2,100.

Now, if I can break this cycle of once in 20 years to once in 50 years, imagine the amount of moneys we are going to --

Mr. Harper. Well, thank you. And thanks to each of you.

And my time has expired. I yield back.

Mr. GangaRao. Yes, sir.

Mr. Latta. Thank you.

The gentleman's time has expired and has yield backed.

The chair now recognizes the gentleman from Massachusetts for

5 minutes.

Mr. Kennedy. Thank you, Mr. Chairman.

Thank you to our witnesses and for the committee for calling this hearing.

To our witnesses, thank you for the work that you do, extraordinarily exciting stuff. The pathway from the basic research to the commercialization to bringing these products to market to helping people is, I think, a critical one for policymakers to understand. How academia plays into that is critical as well. And I want to thank you for making the time to testify today and make sure that your thoughts help guide the committee forward as we try to navigate the policy implications before us.

Dr. Rabiei, just to start with you if I may, your inventions have had an exciting range of possibilities. And I wanted to get a sense as we -- I mentioned a little bit about that commercialization process. I wanted to get a sense from you as to what comes next so that more people can have access to the potential benefits of your discoveries.

So how are you -- assuming you are -- planning to commercialize your composite metal foam? And if you are, could you tell us more about what that process is like and how you are going about it?

Ms. Rabiei. Well, in a nutshell, we have it now -- we have established a startup; it is an LLC company outside of the university. I do have the opportunity to continue research at the university. So, if I get funding from the university, we can continue promoting the technology and figuring out more properties that can be beneficial.

And from the company side, we are hoping to get through the fundraising process and establish a small production line where we can make prototype samples for different companies. Right now, everywhere I have companies from -- large companies are making tanks and Army vehicles to body armors to, you know, any kind of industry you can imagine. They have seen what new material is -- how the material is performing, and they want to get their hands on the material.

But I do not have production line. I do have a small laboratory-scale production, and that is where we are right now. If we get funding to have our production line established, even a small production line where we can make little larger, like, samples and smaller-scale samples, that would take us to the next step faster.

Mr. Kennedy. And where do you plan to -- if you had your choice, where would you plan to manufacture it?

Ms. Rabiei. Right now, I am in North Carolina. So I do not have any plan to take the production outside the country. I do believe that --

Mr. Kennedy. How about Massachusetts?

Ms. Rabiei. Oh, my daughter would love that.

Mr. Kennedy. There we go.

Ms. Rabiei. She was born in Boston, actually.

Mr. Kennedy. That is what we are looking for.

Ms. Rabiei. And she always wants to come back to Harvard.

Mr. Kennedy. There is -- we have got a couple institutions of higher learning in Massachusetts, not just -- well, and a couple in

Cambridge, too. MIT, that other school in Cambridge, happens to be one of the recipients of one of the national institutes of manufacturing awards from the U.S. Government created by -- under the Obama administration but stood up also with a bipartisan piece of legislation passed 3 years ago now creating the national network of manufacturing institutes all over the country. And the one at MIT is based on advanced fabrics.

So, at the kickoff, about a year or so ago at the announcement, Secretary Ash Carter was in Cambridge and talked about how they were trying to develop fabrics that could tell you if -- a T-shirt that could tell you if you were sick, a parachute that could repair itself in the middle of a jump.

The ideas and the applications, obviously, of such products are extraordinary and I think exactly the type of innovation that government and working with academia and industry and business community and entrepreneurs teaming up can lower those barriers of entry, increase the ability of innovators to actually take risk without having such a huge downside if those risks fall short but also making sure we keep that pipeline of funding that goes through that basic research, keeping that pump prime so that we can continue to make the groundbreaking discoveries that years later will lead to that commercialization and those end products.

And so curious then, based -- if my understanding is right -- well, I guess I should say, is that understanding of that process correct? And what advice would you give us as we try to refine

it going forward?

Ms. Rabiei. Well, I guess, you said it right to point of everything is -- ends up at the funding. If the funding is available, everybody will move wherever the funding goes, right. So that actually is a smart way to do it in a university when you know where the interest is and you can adjust your research to that, and you are going to be a successful faculty.

So, as far as my research goes, we definitely would love to look for opportunities. And wherever opportunities take us, then we will be happy to --

Mr. Kennedy. I am over my time. If the chairman would indulge me for 10 more seconds. That national network has actually been successful enough that our Republican Governor is mimicking it at a State-wide level creating State-wide manufacturing partnerships for the next generation of innovation if any of you should be choosing to. It has been a rough weather week, but we have got really good sports teams if any of you are interested in locating north.

Ms. Rabiei. Thank you.

Mr. Latta. Ohio didn't have too bad of one, or two.

At this time -- thank you very much. The gentleman's time has expired.

The chair will now recognize the gentleman from West Virginia for 5 minutes.

Mr. Guthrie. Thank you, Mr. Chairman.

Dr. GangaRao, when I read your testimony, if I could be

paraphrasing a little bit, you are saying that one of the things, the obstacles we have, the barriers that have been put up about our composite construction, is being able to evaluate the durability and the cost savings over time. How would you suggest we do that? Which agency should be funded to do that, or how would we go to rectify that problem?

Mr. GangaRao. We have been doing some work already in the area of durability, and there is a lot that needs to be done. And some of the agencies that have been funding are the National Science Foundation, the Army Corps of Engineers, the Department of Transportation. So these are some of the agencies.

Mr. Guthrie. Are you suggesting that we put some language in to make sure, as projects go ahead, that they check for that long term?

Mr. GangaRao. That is correct.

Mr. Guthrie. Okay. Thank you.

Let me do -- now, Dr. Tour, this subject of graphene is fascinating to me. I have been studying it now for about 3-1/2 years. But I have found here in Washington that almost nobody knows anything about it, is aware of the product.

So I am curious: How would you suggest we make people aware to understand the importance of the development of graphene, and what are some of the commercial applications that we could possibly use in discussions for funding? And, thirdly, what would be the best agency that we could plus-up their account possibly so that we would have money to be able to do more work in graphene?

Mr. Tour. So, as far as getting the word out, I mean, there has been a huge amount of press on graphene. I think the people in Washington have been consumed with other things of late. So that is a distraction area that I am not sure I can speak to.

But as far as the areas, this extends -- and even from my own work, it goes from the medical area. We have two drugs: one on traumatic brain injury and stroke -- traumatic brain injury being the number one disabler of young adults; stroke being the number one disabler of older adults -- that are based on graphene nanoparticles that have transitioned to industries.

We have aircraft coatings based on graphene. We have used oil -- graphene in the oil and gas industry, and we have used graphene, as I said, for healing of spinal cord. So it is very broad. I don't think it would be wise to give it to just, say, the DOD agencies.

I think that taking the money and spreading it across as you did, quite wisely, as the Congress did, with the National Nanotechnology Initiative, they pushed nanotechnology across all the different agencies and said: Each one of you is responsible for pushing nanotechnology through your different agencies. And so we got the NSF, the NIH, and the Air Force, and the Navy, and the Army all pushing, and so it came out of all of these different sectors because it can influence all of those.

Mr. Guthrie. Where do you see applications that we could more demonstratively convince people that this is a product that we should be advancing?

Mr. Tour. So we have --

Mr. Guthrie. Other than, I heard you say about -- some of that, but give me some other things that perhaps we can load our gun up a little bit to be able to promote.

Mr. Tour. Right. So, on a day like today, for de-icing leading edges of aircraft or de-icing entire aircrafts by putting a coating of graphene, you use a Joule-heated resistive coating. And what it does is it makes it so that you can easily de-ice aircraft without having to use chemicals -- this is just a thermal process -- or de-icing power lines. No more ice on power lines. There is no more energy. You can just coat these properly, and the magnetic field from the power line heats this just even a few degrees higher than ambient, and you will get no more ice on the power lines.

So it is very good for de-icing applications, which is something you can talk about with somebody today, and then it can extend into the medical applications. When we are talking about the number one disabler of both older and younger adults, what these particles can do is really quite amazing.

So, again, there are lots of applications. I can give you tens of pages of press releases on different application areas, even from our own university.

Mr. Guthrie. Okay. I would like to see that.

Mr. Tour. Okay.

Mr. Guthrie. I know that it has the potential, I guess, of being a replacement for silicon wafers in our computers, but there is a band

gap problem with that.

Mr. Tour. Right, there is a band gap problem. So probably what we won't do is replace. Where silicon is good, we will use it in other things. So, for example, for heat release or for touch-screen displays, the problem with graphene is, as you said, the band gap is too small. It is too metallic in nature. But its mobility is so high. Its mobility is 100 to 300 times faster than silicon; that means the rate at which you could do computation.

So we have to think about using it in different ways. And there is actually a team actually at MIT that is thinking about using graphene, not as silicon is used but differently in computing. So, if you would change the computing hardware then you could change -- then you could revert to graphene. What people had tried to do is force graphene into the silicon box, and that has not worked.

Mr. Guthrie. Very good. Thank you.

I yield back.

Mr. Latta. Thank you very much.

The gentleman yields back.

The chair now recognizes the gentleman from Pennsylvania for 5 minutes.

Mr. Costello. Thank you, Mr. Chairman.

And thank you all for your testimony.

Mr. Murphy, you mentioned over 100,000 Americans are on organ transplant waiting lists -- or were in 2015, I think. Only 30,000 of those patients received transplants. Is there a potential for your

technology and 3-D printed tissue to address the needs of these patients, and if so, how? And when do you think treatments like these could be ready for use in patients?

Mr. Murphy. Thank you for the question, Congressman.

Yes, so we are developing a 3-D bioprinted liver tissue for transplant into humans. It is now at the stage of animal trials. We have been testing it in rodents quite successfully. It has already established that we can get it to engraft well, persist for months, that it has metabolic function, that you can measure human proteins that are produced by that liver circulating in the animal.

And we are moving this along a normal development pathway anticipating starting clinical trials as soon as 3 to 4 years from now. We are targeting 2020 to have the clinical trials started for this. We think it can be tremendously impactful for patients because there are so many patients, as you mentioned, on the waiting list, in this case for liver. Many people can't even get on the waiting list. If you are elderly or you have other diseases, you are not even going to be put on that waiting list, and there are no solutions. And basically these folks are down to 10 or 15 percent organ function.

So we are sort of on a staircase, I would say, of how we can help people. With the technology we have available today, we hope to give these folks up to 10 or 20 percent function with a patch rather than a full organ that can bridge them to a full transplant that they can get 1 or 2 years later. We can give them 1 or 2 years additional without one. And then longer term, if the technology is applied

broadly and we work with others and bring in more tools and technologies to this, we believe we can make fuller organs over time and do full transplants.

Mr. Costello. You referred to a paper from December in which the authors referred to the value of 3-D bioprinted human tissue as reducing the need for animals and animal testing -- animals in chemicals and cosmetic testing. Are you aware of existing or ongoing studies that have shown more accurate outcomes regarding drug and product testing using bioprinted tissues versus animal trial methods?

Mr. Murphy. Yes, thank you.

The best way to think about what we do is that we have been, as a society, for 50 years or more, dependent on a single paradigm, which is testing cells in a dish and using animals as surrogates for humans. But there is a gap between animals and humans. And essentially, that means we don't know a lot about drugs when we put them into humans.

Those are truly experiments done in humans, those clinical trials, and that is why we go so carefully and so slowly, and that is why you end up with major surprises for drugs, things that are unforeseen.

And liver is a classic example because liver cells on a dish don't perform like the liver fully ever, and they stop performing at all like a liver within 3 to 5 days. So the opportunity we have, the reason bioprinted tissues work is because we put the liver cells -- we use three different cell types. We put them with specific architecture into the tissue. So it performs more like a native function.

And to your exact question, we have been able to show over time that first with trovafloxacin, which was a known drug failure, that drug, which was tested for many years before it was put into humans -- toxicity was not seen in rats and in liver cells in the dish -- we could pick it up in 7 days in our system very clearly because there is basic biological function in our tissue that just doesn't exist in those other models. Humans and animals are different.

And so we have got now a growing set of data that was referred to in the paper you mentioned. And people are relying on the fact that, for example, one of the authors of that paper was also from Merck. We have worked with top 10 Pharma companies like Merck, taken drugs from them in a blinded fashion. They have given us a set of 12 drugs that can sometimes include their own clinical trial failure drugs. And we hit those drugs at a very high rate, meaning we found about 70 percent of the drugs that have gone into clinical trials and failed, we can detect the toxicity of those in our system under a month.

So it is a very powerful advance in the predictive tools, and we expect this to extend into diseases, into study of liver fibrosis and other diseases over time, and many other tissues as well.

Mr. Costello. Dr. GangaRao -- did I pronounce that correctly? -- my question, and it could apply to any of the applications, but in particular, as it relates to infrastructure, and you hear a lot of talk about an infrastructure bill or public spending in the infrastructure space, and the issue of useful life, return on investment, cost-benefit analysis. And some of these applications

obviously or may cost more than the traditional means of doing an infrastructure project. The commercial viability, I think, then becomes a question of when is it worth it based on how much more additional wear and tear and years can we get out of it.

Big picture, and it doesn't just have to relate to infrastructure, but I use that to illustrate the point to ask the question, are there shortcomings, or are there not shortcomings in the analysis on how much it will cost, what the return on investment is, so that as policymakers we are in a position to say, "Well, we can do that project for $10, or we can do that project for $15; but if we do it for $15, it is going to be twice as value-added to the public benefit because of the materials that we are using and the way that we are designing and building a project"?

And I don't ask that question just of you, I welcome everyone to answer it. But I think that there is something to that. I just don't know if, in addition to the technology and the advancements all of you are making, whether we as policymakers and the public have an appreciation for that analysis so that when we make decisions, we are able to justify spending more.

Mr. GangaRao. As scientists, we have been struggling to answer that question with a degree of accuracy. One of the best ways to do it is we have been building these infrastructures for the last 25 years, and we need to field monitor them today and see how well they are doing. We have certain mechanisms of establishing the remaining life; thus, we should be in a position to establish a decent number in terms of

the durability of that product. Once we have that done, then we can translate into a reasonable life expectancy of that product. That is issue number one.

And issue number two, you keep talking about the cost. We need to be talking about, how best can we scale up in terms of low-volume productions to high-volume productions? Once we have these two sorted out, recognizing the fact that certain costs will come down with experience with certain kinds of insights into what we have been doing -- so these are the three different factors that need to be looked at to get you a decent projection of how much it is going to cost.

Mr. Latta. And I thank the gentleman for his questioning. Again, I am sorry that our clocks aren't working here in the hearing room, but if you notice when the lights go on for the witnesses, that is on the 5-minute. But --

Mr. Costello. I am sorry if I went over.

Mr. Latta. No problem at all. We have had that problem from the start of the committee hearing. So we appreciate your questions.

The chair now recognizes the gentleman from Oklahoma for 5 minutes.

Mr. Mullin. Thank you so much, Mr. Chairman.

And thank you guys for being here.

I have been reading lately on the use and the application, which seems almost endless on graphene -- am I saying that right? Graphene? And what I can't wrap my head around is, why aren't we hearing more about this? I mean, it seems like there are so many possibilities.

I read that China is outpacing us in this.

And I am just not sure, from a practical standpoint, from even a military perspective to a construction background, I just can't understand, why are we not pushing this? Is it the barriers that we have created? Is it the lack of investment interest from the public? And I really don't know who wants to take this on. Mr. Tour, if you want to take this on or --

Mr. Tour. So I think certainly those in the field, those working in the field know well about this, of how important this is and the advances that are occurring across many different areas, from biomedicine to structural materials to space and aircraft materials. So it is actually quite broad. There is a huge amount of press on graphene. The nice thing about it is that it is so light and you can make single sheets of it and deal with it in this amazing way.

One of the things that is hurting enormously is the cuts that have come or the lack of any increases in Federal support for research to do these types of things, and that is why I have proposed having these efforts go forward to increase that.

But it is true that China has 25 percent more patents in the area of graphene than does the U.S. But if you look at the Chinese equipment, it is way ahead of us now. And so what I was telling the committee --

Mr. Mullin. Equipment in which way? Are you talking about the equipment, the ability to produce it?

Mr. Tour. No, I am talking about the analysis equipment just at

the university level.

Mr. Mullin. Okay.

Mr. Tour. So I partner with Chinese teams just to get access to their equipment. It is really quite odd that the United States needs to go China to get their analyses done. But if you look at the equipment budgets that have come to universities, they have been cut back enormously in the last 10 years. And so, in order to do the nano analyses, we have to partner with the Chinese in order to do the analyses, and they get their names on our papers.

And they are far more aggressive in starting out young people. We don't have the infrastructure to be starting out the young people in professorships to do this. We train many Chinese, and they are tremendous in our laboratories. And they would all stay and become professors and work here. But it is very difficult for them to stay, number one, because there is no money to have them -- there is very little money to start up the $1 million-plus startup packages in the U.S. for young faculty whereas they will get that in an instant in China.

It is the problem of making it tough for them to get their green cards here to work. If they have gotten their Ph.D.s here, I am all for them. You know, they have been extremely vetted by me. They have been extremely vetted by us for the last 5 years. And they would come and participate, they never go to our prisons, and they pay taxes. And they add tremendously to what we are doing. So there are very simple barriers that we could begin to deal with these sort of things.

Mr. Mullin. What do you see as the most practical application

for graphene?

Mr. Tour. Okay. So it is like asking me, which one of my four children do I love the most? It is very hard to do that. It is very hard to say a specific application.

Mr. Mullin. Right now, since Jim is with me, it is him, but it will change when the next one is with me.

Mr. Tour. I understand. I am the same way. I love them all the most, whoever is with me.

In biological applications, it is extreme. So we have seen solutions for great improvements in traumatic brain injury and stroke using graphene. We have seen the melding of spinal cords --

Mr. Mullin. How is that? What are the advances you have seen? How is this application being practical there?

Mr. Tour. So this was initially funded by the Department of Defense, the medical command and -- because so many of our soldiers were coming back from the Middle East theater and Afghanistan with head injuries. And so what it does is these are rapid antioxidants that sequester the superoxide that usually brings damage to the brain based upon reinfusion of the blood after severing of an artery with a head blow.

And it is the same sort of thing that happens with stroke. There is deficient oxygen to the brain. You bring the patient to the hospital. Corkscrew is used to open up or chemicals are used to open up that clot. Re-profusion of blood, the oxidation problems causes the damage to the brain.

So I can show you pictures of rats that have had their entire spinal cord completely severed all the way through. We put one drop of a graphene solution and bring that spinal cord together. Within 3 weeks, that rat is running and scores a 19 out of 21 on a mobility scale.

Mr. Mullin. Oh, my goodness.

Mr. Tour. And we can do de-icing. We have important materials applications. We have applications for fluorescent materials, graphene quantum dots. And a lot of this technology has left the U.S. These companies have gone overseas.

Mr. Mullin. Have there been any -- on the spine, have there been any studies on a human on this?

Mr. Tour. No, no studies on humans. The studies on humans are going to take place certainly overseas because of the lower barriers for that overseas. And those studies may, in fact, take place this year on humans overseas.

Mr. Mullin. Well, I think you can see that -- one, my time, I guess, is out because I saw the red light up there, but you can see this panel and this committee is very intrigued. Moving forward, I would love to be as helpful as I can. Of course, the building composites of it is intriguing, but the human composites of it is extremely intriguing. And I want to be as helpful. You will find my office being helpful, but I think you will find this committee being helpful too. So thank you so much for you all's time.

Mr. Latta. Well, thank you very much.

The gentleman's time has expired.

The chair will now recognize the gentleman from Texas for 5 minutes.

Mr. Burgess. Thank you, Mr. Chairman.

And, Mr. Chairman, being the previous chairman of this subcommittee, I just want to acknowledge that I feel your pain that one of the preeminent technological committees in the United States House of Representatives, the greatest deliberative body in the free world, does not have a clock. It pains me. So I will put my full force behind getting you a new clock.

And I apologize for missing part of the hearing. Obviously, there is a lot of stuff going on with the snow day and just the fact that there is a lot going on right now.

But, Dr. Tour and Mr. Murphy, perhaps let me direct my questions to you.

Dr. Tour, I believe you referenced the nanotechnology bill that we did here in 2003 and 2004. I was on the Science Committee at the time but deeply involved with that.

And then, Mr. Murphy, in your written testimony at least, you reference Cures for the 21st Century Act from the last Congress.

So I realize it is a little bit risky, given the answer you gave to Markwayne Mullin from Oklahoma about funding, but can you kind of look over the horizon and perhaps give us some insight? Here we have two major pieces of legislation: nanotechnology, Cures for the 21st Century. What are some other things that you see as worthy of your

time and attention?

Mr. Tour. I think, broadly, looking at the funding that was available when I started as a faculty member 30 years ago, the funding available to faculty members on a per-faculty-member basis around the country, and get back to numbers like that. It used to be we would write three proposals in order to get one funded. Now you have to write 10 to get 1 funded, and people are just giving up. They are going overseas. They are leaving the country.

Mr. Burgess. May I interrupt you for a moment?

Mr. Tour. Yes, please.

Mr. Burgess. Is that at the NIH or Department of Defense or all of the above --

Mr. Tour. This is across the whole thing.

Mr. Burgess. Okay. Please proceed.

Mr. Tour. So I think if we looked at what is being put into science and engineering training in the United States and look at the funding rates per professor and begin to move that back up, because we haven't been increasing, and so we have just been killed by the cost of research, and the funding has been flat. So, overall, we are down more than 40 percent.

Mr. Murphy. So, Congressman, you ask about 21st Century Cures and what to focus on next. Well, there is a lot left open in 21st Century Cures. One of the things it does talk about is a pathway for new drug discovery tools to be validated. One of the things we are focused on is asking you to make that -- accelerate the adoption of

available tools that are already proven versus focus on longer term investment for things that won't yet be available.

The opportunity with our technology is to --

Mr. Burgess. May I ask you to give us a couple of examples of the current tools that are available?

Mr. Murphy. I would mention one that Organovo has produced, but there are a number of technologies. But, for example, our liver tissue to test safety for drugs for toxicology has a growing set of proof on it and has been published on by the director of the National Center for Toxicology Research and an associate VP of toxicology at Merck as something that is part of the future.

So there is a growing body of evidence around that driving adoption of that. And getting clarity at FDA through this validation of the drug discovery tools that is laid out in 21st Century Cures -- there is an opportunity to include that in PDUFA VI as well -- would give clarity to people who want to use that but don't know how the FDA will rely upon it. Giving the FDA the ability and the clear guidance to actually be studying these and issuing guidance around them will be very helpful to achieve the potential of these technologies, which is to lower the cost of drugs.

If you are avoiding these billion-dollar failures for drug toxicity safety issues that are late stage in clinical trials, if people can instead fine tune the drugs with tools that are now available and pick the right ones, you get the avoidance of those costs, the reduction of drug costs overall, and you enable patients to get safer drugs

faster.

Mr. Burgess. I know Dr. DePinho at MD Anderson Hospital has talked about getting to failures quickly so you avoid the time and trouble and expense of a long pathway to something that is ultimately not going to be successful.

Now, Mr. Murphy, you also mentioned -- and I guess it is in relation to your liver work -- treating some of the inborn areas of metabolism and, of course, the rare diseases that we heard so much about during the Cures hearings, and obviously, those are very sympathetic populations when they come in and talk with us. Is that something that we can actually look to for clinical results in the near future?

Mr. Murphy. That is another indication we are pursuing. So I described the bridge to transplant and liver transplant capabilities of this tissue patch. The liver tissue patch would also be used for inborn areas of metabolisms. So an example of that would be something like hemophilia, where people lack the factor for blood clotting. The genetic deficiency expresses itself in the liver where those factors aren't produced.

But there is alpha-1 antitrypsin deficiency and a number of others, and by giving a patch, we think we can supplement the production of that or create the production of that key factor inside a patient who suffers from inborn areas of metabolism, yes.

And that will be on the same timeframe: 3 years to clinical trials. And it would help us if you could, in the implementation of 21st Century Cures, assure the accelerated pathway for tissues is clear

for folks like us when we bring those to the clinical trial stage.

Mr. Burgess. Very good.

And, Dr. Tour, I would just be remiss if I did not echo what Markwayne Mullin from Oklahoma said: if you have got a way take your hexamethyl chicken wire and help people walk again with spinal injuries, we want to help you.

So thank you, and thank you all for your testimony today.

I yield back.

Mr. Latta. Well, thank you.

The gentlelady from Illinois formally passes at this time.

The chair will recognize the gentleman from Florida for 5 minutes.

Mr. Bilirakis. Thank you so very much. I appreciate it, Mr. Chairman, and I apologize for being late.

Mr. Murphy, I understand your technology holds a promise to lower the cost of drug development. Can you explain to the committee how the use of bioprinted tissues will improve the drug development process and ultimately lower cost for patients?

Mr. Murphy. Yes. Thank you for the question, Congressman.

So what we do is create a tissue that can be used in a number of ways. I have mentioned liver toxicity safety as an example, but patients are suffering right now because we don't have solutions for liver fibrosis. There are animal models for fibrosis that have basically been rejected by Pharma because they are not predictive.

So we have done and Pharma companies have taken forward a number

of drugs into clinical trials to try and treat fibrosis only to find out that what was predicted as potentially useful in the animal models doesn't pan out. That is a cost that they build into their overall infrastructure, and we are paying for that cost through drugs that do get approved.

And if you think about it, it is about avoiding these costly failures and getting to the drugs that will work faster. That is the overall promise. So we make -- that same liver tissue we use when exposed to known agents that cause fibrosis, like methotrexate -- and this is published with the University of North Carolina researchers -- induces fibrosis in a way that is clinically relevant and shows a good comparison to what you see in a biopsy of those patients.

So, taking that drug into nonalcoholic steatohepatitis and these fatty liver disease fibrosis things, diseases where Pharma is very focused now gives the opportunity to actually find drugs for those and avoid taking drugs forward that are based only on animal models and end up having failures.

Mr. Bilirakis. Very good. We are here to help as well. I appreciate the panel's testimony.

And I yield back, Mr. Chairman.

Mr. Latta. Well, thank you very much.

The gentleman yields back.

And the chair recognizes the ranking member of the subcommittee, the gentlelady from Illinois, for 5 minutes.

Ms. Schakowsky. I can't tell you how disappointed I am. My plane was 3 hours late, and it was really -- I am really, really interested in this panel. I am glad that at least you are here for a few more minutes, and I will look over the testimony in the transcript.

I wanted to -- I am concerned about the money that is available for research and want to be sure that we have that. So I wanted to -- Federal funding contributed directly to American business by ensuring that they can compete successfully around the world is so important. Further cuts in funding for education, government support for small business and research I think would definitely harm our economy and hamper our ability to innovate.

And even worse, these proposed cuts are coming at a critical time as other countries are aggressively ramping up their spending on R&D and education. The U.S. is still the world leader when it comes to government research funding, but at our current levels, China is projected to overtake us in just a few years.

I think we stand at a moment where the United States of America can be the exporter of such exciting technologies if we actually put the research in. I have the Northwestern University, University of Illinois, University of Chicago that are looking, doing incredible research for improved and nanotechnology at the university, at Northwestern University, batteries at the University of Illinois, just amazing work.

So I want to ask you -- and maybe you answered this already; I would like to put it on the record again if you have anyway -- how would

a further decline in research funding to American universities affect your work? Anybody.

Mr. Tour. It is already affecting us so that we have not seen an increase in several years. It is already affecting us. If we are going to go down even more, it is going to be devastating to the research science community within the United States.

Our best and brightest are already leaving the country, going back to their home countries because there are no startup packages for their positions here. And China is paying them extremely well. Singapore is paying them extremely well to start up their companies.

And it is not just that; it is our established senior U.S. professors that are now leaving and packing up their programs and going overseas because it is so hard to get funding here in this environment that they can go overseas and get their programs funded.

Ms. Schakowsky. Let me ask you one other thing. I understand too for research, start and stop is very devastating, that there has to be a sense of continuum here. Is that a problem as well?

Mr. Tour. That is a problem because once it stops, it is very hard to restart, because your students go onto other things; they graduate. That is it; the infrastructure is lost. And so it is very hard to start and re-stop. There is only stop.

Ms. Schakowsky. Thank you.

Anyone else?

Mr. GangaRao. Dr. Tour is talking about how it affects the students' funding for the faculty, what have you. I would like to take

that one step further in the sense that we have exported out our manufacturing industry, and we are hurting very badly now. Likewise, if we begin to export out our research capabilities 10, 20 years from now, you can be assured we will be looking to be a Third World country.

Ms. Schakowsky. Wow.

Yes, Dr. Rabiei.

Ms. Rabiei. I also wanted to elaborate that right now the research environment is becoming harder and harder for us to keep up. I had some colleagues from Europe coming to visit us, and we had a meeting starting from 8 o'clock to 7 p.m., and he was saying, why do you have this kind of long hours? And I said, because, like what Dr. Tour was mentioning, we have to write 10 proposals if you want to get 1.

So if you want to have 5 proposals funded, then you have to write 50 proposals, and each one of them take a lot of time if you want to write something competitive. On top of that, you have teaching and you have other service and writing and supporting Ph.D. students and all that.

So it is really competitive, and the more you cut the budget for research, the more it becomes competitive because we still have to compete for that, and our chances go down. Like, if you look at NSF reports, they say it is 1 out of 13 that is funded. Sometimes it is 1 out of 10 is funded. So, obviously, in all of this, people write 100 proposals; 90 of them are down into trash, and 10 of them are funded.

Ms. Schakowsky. Does the funding also shape the research you do?

Because if you know that funding is available, you may go in a different direction? I mean, I think that could be a not-great thing.

Mr. Tour. It is not a great thing. You are always chasing money.

Ms. Rabiei. Yep.

Mr. Murphy. Mr. Chairman, can I add a comment to the question?

Mr. Latta. Go right ahead.

Mr. Murphy. Out-of-the-box thinking, we are supposed to be disruptive. After my success in founding the company, I started with my own money a nonprofit that gives philanthropic dollars in terms of research grants. So Jason Wertheim, who is a surgeon at Northwestern, transplant surgeon that does research on de novo organs, received a grant from Human Organ Project that is nonprofit.

If there were ways that Congress could -- there is not a lot of that kind of funding that -- private, philanthropic funding that goes directly into research grants. There is a lot of work that is done for patient education, patient help, and things like that.

If there were ways over the long haul -- I don't have proposals in mind; this is just coming to me -- if there were ways that Congress could work toward stimulating more philanthropic investment direct in the research grants, some of which, honestly -- you know, a lot of stuff goes overseas in terms of world health and things like that, very noble enterprises. But if there were ways to get more direct private investment into research in the U.S., that would be helpful too, I think.

Ms. Schakowsky. Let me just say: I agree with you, but on the

other hand, I don't think private dollars are going to be able to make up the difference between an investment by the Federal Government. But it is still a good thing.

Mr. Latta. Well, thank you very much for our panel today. You can tell from the questions you received from the subcommittee that we are all very, very interested in this, and we really appreciate your testimony and your expertise and being with us today.

And in pursuant to committee rules, I remind members that they have 10 business days to submit additional questions for the record. And I ask the witnesses to submit any responses within 10 days upon request or other questions.

And, without objection, the subcommittee will stand adjourned. Thank you very much for coming.

[Whereupon, at 1:53 p.m., the subcommittee was adjourned.]