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DISRUPTER SERIES: QUANTUM COMPUTING

WEDNESDAY, MAY 18, 2018

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 9:16 a.m., in Room 2322, Rayburn House Office Building, Hon. Robert Latta, [chairman of the subcommittee] presiding.

Present: Representatives Latta, Lance, Guthrie, McKinley, Kinzinger, Bilirakis, Bucshon, Walters, Costello, Schakowsky, Welch, Kennedy, and Green.

Staff Present: Mike Bloomquist Staff Director; Margaret Tucker Fogarty, Staff Assistant; Melissa Froelich, Chief Counsel, Digital Commerce and Consumer Protection; Adam Fromm, Director of Outreach and Coalitions; Ali Fulling, Legislative Clerk, O&I, Digital Commerce and Consumer Protection; Elena Hernandez, Press Secretary; Paul Jackson, Professional Staff, Digital Commerce and Consumer Protection; Bijan

Koohmaraie, Counsel, Digital Commerce and Consumer Protection; Peter Spencer, Senior Professional Staff Member, Energy; Andy Zach, Senior Professional Staff Member, Environment; Greg Zerzan, Counsel, Digital Commerce and Consumer Protection; Michelle Ash, Minority Chief Counsel, Digital Commerce and Consumer Protection; Jeff Carroll, Minority Staff Director; Caroline Paris-Behr, Minority Policy Analyst; and Michelle Rusk, Minority FTC Detailee.

Mr. Latta. Good morning. And again, I would like to welcome you all to the Subcommittee on Digital Commerce and Consumer Protection here on Energy and Commerce. As I mentioned, we have another subcommittee that is running right now, so we will have members coming back from first floor, upstairs, during the committee from one to the other. But again, I do thank you all for being here today.

And I will recognize myself for my 5-minute opening statement. And again, welcome to the subcommittee in today's disruptor series hearing examining quantum computing. We continue our disrupter series as we examine emerging technology supporting U.S. innovation and jobs. This morning, we are discussing the revolutionary technology known as quantum computing. This involves harnessing the power of physics at its most basis level. Unlike the computers we are familiar with we use today, a quantum computer holds the potential to be faster and more powerful. This innovation is expected to change every industry and make problems that are impossible to solve today, something that can be solved in a matter of days or weeks.

Efforts to develop a commercially available and practical quantum computer are being pursued around the world. Because of the tremendous costs involved in developing a suitable environment for a quantum computer to operate, many of these efforts involve government support, both the European Union and China have pledged, or already have spent billions to develop a quantum computer.

In the United States, development of quantum computer is proceeding at the academic, governmental, and private sectors. In addition to the larger and familiar technology companies, smaller startups are also leading efforts in this area. We are fortunate to have one of these startups, IonQ, to testify today.

Although a quantum computer holds a tremendous potential to solve previously noncomputable problems, there are skeptics who question whether it will be possible to ever develop such technology. We look forward to our witnesses giving us their thoughts on this question.

On the other hand, some fear that the threats such a computer would pose to traditional computing model, especially when it comes to encryption and data security. Some fear that a quantum computer would make it nearly impossible to keep future computers secure. Data security and consumer privacy are key concerns of this committee.

We also look forward to our witnesses addressing this issue as well. Quantum computers hold tremendous potential to help solve problems involving the discovery of new drugs, developing more efficient supply chains and logistics operations, searching massive volumes of data, and developing artificial intelligence.

Whichever nation first develops a practical quantum computer will have a tremendous advantage over its foreign peers. We hope our witnesses will help us examine the state of the race to develop a quantum computer, and how the United States is doing in that race. This is obviously a very dense subject. We also understand there are several other areas under development leveraging the principle of quantum mechanics. Our goal today is simple: to develop a better understanding of the potential of quantum computers, the obstacles to developing this technology, and what policymakers should be doing to remove barriers and to help spur innovation, competition, and ensure a strong and prepared workforce for future jobs.

As we explore this topic today, I would, again, like to thank our witnesses for coming to share their expertise on this very complicated and revolutionary technology. I again appreciate you all being here today.

And at this time, I will yield back my time and recognize the gentlelady from Illinois, the ranking member of the subcommittee, for 5 minutes.

Ms. Schakowsky. Well, I want to thank you, Mr. Chairman. We continue our disrupter series with exploration of quantum computing. I want to congratulate all of you for being so smart. Dr. Franklin, I was just told I think it was your mother and I graduated from the University of Illinois about the same time. This was a time before we knew anything about computers really, it was just beginning. And here you are today, the next generation leading us into the future. So I appreciate all of you being here today.

This technology, I understand, is still in the research phase, but the potential applications are tremendous, from healthcare to energy efficiency and everything in between. Given this potential, global competitors from the European Union to China are rushing to invest in quantum computing. The U.S. must make strategic investments if it wants to stay ahead. And those investments really start with STEM education. We must encourage students, including young women and students of color to pursue interests in computer science and physics. Fostering curiosity today prepares young minds to become great innovator of tomorrow.

As a former teacher myself, I strongly believe that our future economic success depends on investing in our children's education. Our research universities are leading the way on quantum computing. Public investment is crucial to develop technology until it can be profitable, possibly deployed in the private sector. However, the Federal Government has so far failed to provide robust reliable investments in quantum computing. The lack of investment in STEM education and research speaks to the misguided priorities of this Republican Congress. While wealthy shareholders get most of the gains from a $2 trillion Republican tax bill, Congress is underinvesting in students and research institutions. We fund tax cuts for the rich at the expense of our future prosperity.

Now that Congress has passed a budget agreement, we have the chance to make some of the investments that our country so desperately needs. But instead of embracing the opportunity to advance bipartisan appropriations bills, the Republican majority plans to bring up a rescission bill to pull back funding for children's health insurance programs and other programs. And today, we will be voting on a bill to literally take food out of the mouths of families.

We need to get our priorities straight. The U.S. can be a global leader in quantum computing and other groundbreaking technologies, but only if we prioritize investment for our future over tax cuts for the wealthy.

I look forward to hearing from our panel about the promise of quantum computing. I will try my best to follow what you are telling me and the challenges that we face in developing this technology. I am especially proud to welcome Professor Diana Franklin from the University of Chicago. The University of Chicago is one of the leaders in quantum computing research, and I am eager to hear more about this work.

So thank you, chairman Latta, and I yield back.

Mr. Latta. Well, thank you very much. The gentlelady yields back. The chairman of the full committee has not made it in yet. Is there any one on the Republican side wishing to claim his time? If not, at this time that will conclude the member's opening statements. And to get to the real meat of the issue today that we want to hear about. And I won't tell you how long ago, Madam Ranker, how long -- when I took computer science in college, I probably shouldn't say this, we used punch cards and teletype machines. It was a bad Saturday morning, we went back to the computer science department, and you were expecting about that much and came back with that much, and you knew you had made a mistake. But I want to thank our witnesses for being here with us today and we are really looking forward this -- your testimony today.

And our witnesses will have an opportunity to make 5-minute opening statements. And our witnesses today are Dr. Matthew Putman, Founder and CEO of Nanotronics; Dr. Christopher Monroe, Chief Scientist and Founder of IonQ, and Professor of Physics at the University Maryland; Dr. Diana Franklin, Professor and Director of Computer Science at the University of Chicago; and Mr. Michael Brett, CEO of QxBranch. And so again, we appreciate you being here today. And Dr. Putman, you are recognized for 5 minutes for your opening statement. If you would just press that microphone and pull it close to you and we will get started.

STATEMENTS OF MATTHEW PUTMAN, FOUNDER AND CEO, NANOTRONICS; CHRISTOPHER MONROE, CHIEF SCIENTIST AND FOUNDER, IONQ, PROFESSOR OF PHYSICS, UNIVERSITY OF MARYLAND; DIANA FRANKLIN, PROFESSOR, UNIVERSITY OF CHICAGO; AND MICHAEL BRETT, CEO, QXBRANCH

STATEMENT OF MATTHEW PUTMAN

Mr. Putman. Thank you so much, Chairman Latta, Congresswomen and Congressmen.

Nanotronics does not make quantum computers. We are the enablers of technologists and companies that with us strive to revolutionize the way information can be transformed. We have provided some of the world's largest companies and smaller entrepreneurial innovators with the tools of modern computation and imaging. We work with those that build the most advanced materials in microelectronics. Nanotronics achieved this in the only way we see feasible for the continued exponential progression of technology, which is through artificially intelligent factories.

Quantum computing not only promises to break the barriers of encryption, it also breaks some fundamental barriers to human progress. Many of our greatest achievements have been characterized in terms of competition and races. Often, a technological race appears to be a war of ideologies or of business dominance. With quantum computing, there is an even greater battle, the fight against physical scarcity.

There are three areas that we must work together on to win, not only for our Nation, but for humanity, agriculture, new fertilizers can feed the increasing population of the world while maintaining diversity of crops, drug discovery by being able to simulate and produce molecules faster and with greater precision than are possible by traditional means. This will not only lead to cures for diseases, but reduce the often financially restrictive experimentation and trials that are required to make even incremental improvements and treatments.

Materials for power devices from batteries to solar cells. These have been studied for decades, but in many respects, the United States is still early on in this journey. Companies are moving with speed, and with national support, it is possible that quantum computing can soon reach an inflection point.

The race to achieve a workable quantum computer that can reduce scarcity to this level requires greater national attention than has currently been realized by either the vast majority of companies, or of the country as a whole. The steps to enabling quantum computing will need to involve, one, an effort that funds the creation of factories for new quantum chips.

A semiconductor fab for classical computers can cost as much as $20 billion. To a large extent, these fabs are not being built in the United States. We have an opportunity to acknowledge and to change this trend by leading the way in the construction of factories for this next generation of powerful computing.

Two, artificial intelligence. While quantum computing itself will increase the capabilities of artificial intelligence, the ability to design materials and software for quantum computers themselves will come through the interaction of human and computer agents.

Understanding such key elements as component design, fabrication conditions, and the number of qubits needed requires collaboration of humans and machines. The number of qubits in a quantum computer is directly related to the number of calculations. A 10 qubit quantum computer can produce 1,000 calculations, and a 30 qubit quantum computer can produce 1 billion. Millions of qubits are required to achieve the full potential of quantum computing. This exponential growth in qubit to calculations is beyond the reach of factories as they are. Without the advanced tools of AI for controlling factories, a truly useful quantum computer may not be possible.

Three, education. We need to develop the expertise required for the multidisciplinary nature of quantum computer science. It is physics, chemistry, mathematics, computer science, and application curiosity and expertise are all necessary. We cannot work in isolation. We need to embrace immigration and welcome strong talent from around the world with expertise in these areas.

When we look towards the future, we can see it as a battle of ideologies, of resources, or of technologies. Quantum computers encompass all of these to some extent. Quantum mechanics is the basis of universal behavior at the smallest scales, but affects the largest of matter. It is, therefore, not surprising that harnessing this physical property has such far-reaching implications. It is because of this, that it is important that we view it with the powerful association that it warrants, with the weight of risk in a fractured world, or of great rewards in a unified one.

As we move forward, we see how quantum computing lets us scale in ways that meet not only the needs of industry, but of our country and the world.

Thank you very much.

[The prepared statement of Mr. Putman follows:]

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Mr. Latta. Well, thank you for your testimony, this morning. And Dr. Monroe, you are recognized for 5 minutes. Thank you.

STATEMENT OF CHRISTOPHER MONROE

Mr. Monroe. Thank you for the opportunity to testify, Mr. Chairman. I am honored to be here for this committee's disrupter series on quantum computing.

I am a quantum physicist at the University of Maryland, and also, co-founder and chief scientist at IonQ, which is a startup company that aims to build and manufacture small quantum computers. I have also worked with the National Photonics Initiative, which is a collaborative alliance among industry, academic -- and academics with the interest in developing quantum technology. And I, with the National Photonics Initiative, we have promoted the idea of a National Quantum Initiative, and there is pending legislation that is coming up in the House Science Committee.

So I have about 1 minute to define what quantum computers are, and I think I can get to some of the basics. We know that information is stored in bits, zeros or ones. The fundamental difference in quantum information it is stored in quantum bits, or qubits, these can be both zero and one at the same time, as long as you don't look. And at the end of day, you look, and it randomly assumes one of the values. But as long as you don't look, there is a potential for massive parallelism as you add qubits, you get exponential storage capacity. And because quantum computers only work while you are not looking, it involves quite revolutionary, and even exotic hardware to realize this. Individual atoms, that is the technology we use at IonQ, superconducting circuits that are kept at very low temperatures, other competing platforms involved that type of technology. It is very exotic stuff. And I think within the next several years, we are going to see small quantum computers with up to about 100 quantum bits. It sounds pretty small, but even with 100 quantum bits, it can, in a sense, deal with information that eclipses that of all the hard drives in the world. And on our way to a million qubits, where we can do new problems that conventional qubit computers could never tackle, we need to build the small ones first.

So in terms of quantum applications, I would say it falls roughly into three categories, there is strong overlaps. In the short term, quantum sensors can enhance sensitivity to certain measurements that could impact navigation, and it may be in a GPS-blind environment and also remote sensing.

In the medium turn, quantum communication networks may allow the transmission of information that can be provably secure, because remember, quantum information only exists when nobody looks at it. If somebody looks at it, it changes. And that can make communication inherently secure.

In the long term, probably the most disruptive technology are quantum computers. And quantum computers are not just more powerful computers, they are radically different, and they may allow us to solve problems that could never, ever be solved using classical computers. These involve optimization routines that could impact logistics, economic and financial modeling, and also, the design of new materials and molecular function that could impact the health sciences and drug delivery, for instance. An even longer term, quantum computers could be used to do decryption, breaking of popular codes. So there is a security aspect to everything that quantum information touches.

Now, the challenges are pronounced in this field. There are a few issues. One involving the workforce and one involving the marketplace. The workforce issue is that universities are chock full of students and faculty that are comfortable with quantum physics, and we do research in the area, but we don't build things that can be used by somebody that doesn't want to or need to know all the details. Whereas industry makes those things, but they don't have a quantum engineering workforce.

The marketplace is also a challenge because we don't know exactly what the killer app for quantum computers, in particular, will be. So we have promoted the idea of a National Quantum Initiative that would establish several large and focused hub labs throughout the country, and other components as well, including the user access program for existing quantum computers. It is imperative that the U.S. retain its leadership in this technological frontier. As we heard from the chairman, there is concerted efforts in Europe and, in particular, China, that is spending lots of very focused investments in this field.

So, in conclusion, quantum technology is coming and the U.S. should lead in this next generation of sensors, computers and communication networks. The National Quantum Initiative provides a framework for implementing a comprehensive quantum initiative across the Federal Government.

Thank you, Mr. Chairman, members of the committee, for the opportunity to speak on quantum technology and the need for a nationally focused effort to advanced quantum information science and technology in the U.S.

[The prepared statement of Mr. Monroe follows:]

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Mr. Latta. Well, thank you very much.

And Dr. Franklin, you are recognized for 5 minutes.

STATEMENT OF DIANA FRANKLIN

Ms. Franklin. Thank you for the opportunity to testify, Mr. Chairman, and Ranking Member Schakowsky. I am honored to be here before you in the committee to offer testimony on the promise of quantum technology. The important role universities must play to realize commercialization, and the biggest challenges we are facing in doing so. In my dual roles as director of computer science education at UChicago STEM Ed, and a research associate professor in the Department of Computer Science at the University of Chicago. I research emerging technologies and computer science education.

As lead investigator for quantum education for the EPIC quantum computing project in the NSF expeditions in computing program, it is my mission to design and implement educational initiatives at K-12, university and professional venues to develop a quantum computing workforce.

Quantum computing can be a game changer in promising areas, including drug design and food production. By accelerating research time to develop drugs, critical Federal research in Medicaid dollars could be saved, along with improved quality of life.

Unlocking the secrets of nitrogen fixation through quantum simulation could vastly reduce the energy costs of fertilizer production, and thus food production throughout the world. While the university has historically been on the forefront of computer science and emerging technologies, lapses in academic funding for quantum computer science have allowed global competitors to make great strides. Putting the

U.S. back 10 years from where it could have been in research output and workforce development.

In the past 17 years, since the inception of quantum computer science, distinguished from quantum physics and algorithm development, academic funding has only been available for 8 of these years, leading to only 10 Ph.D. students being trained, rather than a potential of almost 200 students, and no meaningful education programs aimed at this area.

As research groups came and went with the funding, post-docs were laid off and graduate students were transitioned to conventional computer science fields. Yet, universities are critical to commercialization. While companies work individually and compete against each other to produce proprietary tools, academics produce results and tools that all companies can use and improve upon, as well as trained experts who can work at companies. They are both necessary for the commercialization of quantum computing.

The challenge of bringing quantum computers to the point of usefulness cannot be underestimated, both in building reliable a machines and writing software. Professor Christopher Monroe talks about -- knows extensive expertise in the former. I am here to talk about the increasingly important role that computer scientists must take. Historical funding and theoretical software and quantum devices has created a chasm between the software, which assumes large, perfect hardware, and real hardware that is small and unreliable at this point.

NSF has recently recognized this issue supplementing their hardware initiative quantumly with a stat program that requires an interdisciplinary team that works to bridge this gap. One gap is in software development. There is a difference between a quantum algorithm and software that can solve a particular problem. Bridging this gap requires interdisciplinary teams such as exists at QxBranch. Deep expertise is necessary to figure out how to modify software that works in one specific context to another, much more so in quantum computing than in traditional computing. If this were furniture construction, what we have right now is piles of wood, screws and nails. An expert needs to figure out how to use those to create useful furniture. Instead, what we want in the future is for nonexperts to be able to go to quantum Ikea, get a prefabbed kit and easily modify it for their application. This exists for classical computing, but not for quantum computing.

Another gap is between software and hardware. Current algorithms are written for perfect hardware, but hardware on the horizon is very error prone. We are on a journey to that perfect hardware, but we are not there yet. It is like if you meticulously planned to prepare a gourmet meal for 10, but when you arrived, there were only supplies for six, and you could only use the kitchen for 2 hours prior to the meal, you would need to adjust your plans. Current and quantum computers that are on the horizon can only sustain computations for a limited time, and they are very small. Some modifications can be automated. However, for more advanced modifications, the plan needs to be rethought, thus, some of the specific hardware limitations, like the specific ways in which different technologies tend to introduce errors, need to be communicated to the programmers so they can figure out how to adjust their applications.

In order to realize quantum computing, Federal funding needs to be, first and foremost, consistent, directed at not just building hardware and developing algorithms, but to interdisciplinary teams that include applications developer and computer scientists. Spread across a range of agencies with different missions like NSF, DARPA, DOE, and DOD, directed not just at technology development, but to workforce development, so there are more people available to write applications and to perform the engineering work at these companies. And above all, supporting the K-12 STEM pipeline to train the next generation of innovators.

With a significant investment in hardware, software, and workforce development, I am confident the United States can maintain its dominance in computing.

This concludes my remarks. I appreciate this opportunity to speak with subcommittee members. And I am happy to answer any questions you might have.

[The prepared statement of Ms. Franklin follows:]

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Mr. Latta. Thank you very much.

And Mr. Brett, you are recognized for 5 minutes. Thank you.

STATEMENT OF MICHAEL BRETT

Mr. Brett. Thank you, Chairman Latta and Ranking Member Schakowsky, and members of this committee. I am thrilled to be here today to participate in today's hearing and discuss the opportunities and challenges presented by quantum computing.

My name is Michael Brett. I am the CEO of a company called QxBranch. We are an advanced data analytics company based here in Washington, D.C., also with teams in Australia and the U.K. We are a fast-growing team of data scientists, software engineers, and machine learning specialists who design algorithms for challenging data problems. We are at the cutting edge of creating algorithms that find patterns, detect anomalies, and uncover other business insights that help our customers reduce their costs and to serve their customers better.

Data analytics is already a rapidly advancing technology area delivering benefits to people all over the world, but we are particularly excited about what quantum computing can do for our business. As we have heard, quantum computers are not just a faster computer, they enable an entirely different approach to performing calculations. In the realm of quantum physics, there is some incredible and surprising phenomena that if harnessed, could allow us to solve some interesting and practically unsolvable problems, like simulating the interaction between molecules. As these molecules grow in size, the computational costs grows exponentially larger.

Our friends who build quantum computing hardware are in the process of creating machines that take advantage of these unique phenomena. And you heard a great example from Chris Monroe this morning at IonQ. These machines allows us as software developers to solve difficult problems using a different kind of mathematics, quantum math, much more efficiently than we he ever could on classical computers. And our ambition is simple: Quantum computers will allow us to solve some of the most intractable and most valuable computational problems that exist today.

These new quantum solutions will benefit Americans in ways they might not ever be aware of. Globally, the race is on to apply quantum computing to problems in transport, energy production, health science and pharmacology, finance and insurance, defense and national security. And we want our applications to be the first apps in a quantum apps store.

Looking forward to the kind of quantum computers that are likely to become commercially available over the next decade, there are broadly three classes of application that have become possible in the near term. The first are optimization problems, like logistics and transport routing, financial portfolio optimization. The second is in machine learning, where we can accelerate some of the most computationally expensive parts of training and artificial intelligence, to detect patterns in large and complex data sets.

And the third, is in chemical simulation where we can use a quantum computer to simulate the behavior of molecules and materials, and design new processes around them. Across these three applications, the potential value to everyday citizens is immense. Now let me give you a concrete example of where this could apply. QxBranch recently completed a study into quantum computing applications with Merck, the pharmaceutical company. We worked together to design a quantum algorithm and test it on today's available hardware, to look at an approach to optimizing the production of a particular drug. And the particular drug that they are interested in has an extremely challenging production optimization process involved. And quantum computing gave us the tools to look at the manufacturing process in an entirely different way that could radically change the efficiency of creating this drug and delivering value to the consumer. It is an applications such as this that we are focused on at QxBranch, breakthroughs enabled by a new approach in computing that allows us to change the way we think about business and manufacturing processes. There are some challenges ahead, though, in realizing this technology, and the Federal Government can help us create the environment for industry to lead.

The three biggest challenges I would like to highlight today, first the skills and workforce. As we have heard, if we are to be successful at bringing quantum computing to market we need a highly skilled, multidisciplinary, diverse workforce with core skills in quantum information science, computer science, data analytics, machine learning and AI, combined with germane expertise in finance, pharmaceuticals, energy and other industries. And we need American universities to send us graduates with these skills.

The second is an international cooperation. As American companies compete in this emerging ecosystem, we will achieve our fullest success through international cooperation. There is valuable scientific research and engineering development that is being made elsewhere, including in key allies such as Australia, the U.K., Canada, Japan, and Singapore. We need to be able to access the best talent and technology globally and this means partnering.

There will be national security considerations for this technology, of course, but if export restrictions are applied prematurely or without your consideration, it will stifle commercial innovation.

Finally, we need to maximize and leverage private sector investment into this technology area. Over the past 18 months, we have seen an incredible acceleration in corporate R&D and venture capital flying into this technology. It is an exciting time, but I must stress that we are just at the beginning of this technology development. And the government can maximize and leverage this investment through targeted Federal funding and coordination to reduce the gaps and overlaps in R&D and help accelerate technology.

So in closing, I would like to reiterate my appreciation for the opportunity to join you today and share a little about what we are doing at QxBranch and quantum computing. This subcommittee is addressing important issues that will help bring quantum computing to commercial reality and give us a powerful, new tool to create valuable software.

Mr. Latta. Thank you for your testimony. I appreciate all your testimony this morning, and that will conclude our witnesses' testimony this morning, and we will begin our questioning from the members. And I will now open with questions with 5 minutes. And pardon my allergies this morning, it is this time of year in Washington.

First, I really appreciated reading your testimony last night, and a lot of questions in 5 minutes. But if I could start, Dr. Putman, with you, if I may, because I really was interested, so what impact does quantum computer have on manufacturing in the United States? Because, like, in my district, I have a unique district, I have 60,000 manufacturing jobs, and I also have the largest farm income producing district in the State of Ohio. And in your opening statement, you had mentioned about on the manufacturing side, you talked about with drugs and agriculture, energy, and this committee deals a lot with all that, and not really on the agricultural side, but I was really interested in that. And I would like to know, especially what the impact would be on manufacturing? And also, am I correct that it would both create new opportunities while disrupting those existing industries that are out there today?

Mr. Putman. Thank you, Chairman Latta, my fellow Ohioan. This is, of course, extremely personal to me as well, being from Ohio and being from -- you know creating and trying to enable manufacturing work. What is important, I think, about your question, is that these are brand new industries. It is not just about disrupting current industries, it is been creating jobs that are for the next generation of technologies. And this is building, I think, interesting jobs as well for technologists of the future, and that goes through entire large factories. I mentioned the cost of a fab. It is not just the cost of building a fab, we would like to bring down the cost to build fabs. It is the opportunity for workers to be working with the latest of technologies. I think that the Midwest and the rest of the country as a whole can only benefit from this.

Mr. Latta. Thank you.

Dr. Monroe, what changes would be needed to ensure America has that workforce that is ready for quantum computing revolution? You will be hearing from the witnesses, you know, we have to have that workforce out there in the training. So how do we get to that point? Do we need on the educational side, especially at the university levels, do we need university that would specialize that in the field or what do we need to do?

Mr. Monroe. Well, thank you for the question, Chairman Latta. There are a number of things that we can do as a country to foster this gap, this connection between university and government laboratory research and I said, industrial production. At the university side, I am sorry to say that most engineering and computer science departments haven't really embraced this field as Dr. Franklin mentioned.

Mr. Latta. Why? Why not?

Mr. Monroe. Well, I have my own thoughts on that. I think -- actually my daughter is a computer science major at University of Maryland. And the computer science departments -- the students are keen to get a high-paying job right after they graduate. Quantum computing, not that it is not a high paying job, but it is a very speculative field. And it is hard to identify exactly what the marketplace is. And I think -- computer science departments and engineering departments, I think, they have not embraced this field as much as the sciences have. And I think that is changing at some places. My university, the University of Maryland is one of those, Chicago is another. There are several across the country that have done that, but it is not widespread. Many of these departments won't hire faculty that are doing research in this field. And I think Dr. Franklin mentioned the National Science Foundation is taking an active role in trying to change that by instituting new grant programs that foster the development of quantum computer science for instance.

So that is on the university side. On the industry side, it is a tough nut to crack, because this new technology as I mentioned involves very exotic type hardware that industry doesn't have so much experience with. And it is -- it reminds me of, in history in the 1950s, when semiconductor devices were being developed and scaled, the people who did this over the many decades that gave rise to Moore's law including Gordon Moore, who founded who Intel, these were not vacuum tube engineers who had instituted the previous generation of computers. So it takes time, and it takes risk, and it takes funding from these corporations to do that.

Mr. Latta. Well, thank you very much. And my time is about to expire, so I am going to yield back and recognize the gentlelady from Illinois, the ranking member of the subcommittee, for 5 minutes.

Ms. Schakowsky. I am starting to understand the much-used phrase taking a quantum leap, because really what you are talking about is of all the things that I think we have heard about the most disruptive, in a good way, and in a challenging way to the future. And so, I wanted to talk to Dr. Franklin about things I think I know more about, which is about education. And I do want to hear more about EPIC and the things that you are doing.

But first, I want to hear about your efforts with younger students in a minute, but I want to first hear about what is happening at the graduate and undergraduate level. You know, what I am hearing really from all of you is that workforce capacity is really a challenging issue. And if we are going to be competitive, and if we are going to keep up with countries that are making the EU and also China, then we need to get serious about making these public investments. But I am wondering if you can talk to me a little bit about the urgent need?

Ms. Franklin. Yes. So I think Dr. Monroe mentioned that computer science hasn't had as much quantum in it. And I think it all comes back to those funding lapses, because our group and other groups started and the way courses get created is that graduate students get trained in a field, they go out and become professors, create classes and train more students. Those students need to be able to have jobs in order to make it worth it for them to take those courses. If no Federal funding -- if a program gets canceled and you are two of six, and all of the Federal funding goes away, and then graduate students get put in other fields, you are not going to have an education program, and so that is what happened twice is that the Federal funding went completely away for the computer science portion of quantum computing. And so, groups that were active in getting into the field left the field.

And so now, with this new stack funding and the new EPIC program that we have, and we are planning educational initiatives at all levels, including tutorials for professionals, we have a tutorial in June and a tutorial in October for professors and graduate students who are already in the field who want to transition to quantum computing. There is an initiative in the institute for molecular engineering at UChicago that has an undergraduate degree with a quantum track. We are partnering with them to create some computer science to add to that hardware track. And there is a program --

Ms. Schakowsky. Is that the quantum engineering degree that you are talking about?

Ms. Franklin. Yes. There is a quantum track of the molecular engineering degree, yes. And they also have a program to embed graduate students that are working in all areas of quantum with commercial -- with companies. And so, we are participating in that. So we are trying to train other research groups so that they can start doing research in quantum.

Ms. Schakowsky. Given the potential, it seems to me that we have to have some sort of almost like a moonshot mentality about investment. And you are so right about all kinds of research. If it is not steady and consistent, then, you know, we either have a brain drain, people go elsewhere, or that research app grinds a halt.

But do tell me a bit about some of the things you are working on in the primary and high school level. That is also under your bailiwick, too, right?

Ms. Franklin. Right. So at the elementary and middle school level, we are looking at not doing quantum computing per se, but computer science in general, because in order to have a quantum computer scientist, you need a computer scientist first. And so efforts like CSforALL are critical in getting computer science early because in science, anyway, if a student isn't thinking about becoming a scientist by sixth grade, they are statistically very unlikely to become a scientist. And so we believe the same thing may be true for computer science. So we want to have those initiatives early.

On the physics side, we are looking at what are the aspects of quantum computing that are unintuitive when you get there? And one of them is this idea of measurement, Chris Monroe said that all the operations work fine until you look at them. And it is an issue that the measurement device actually perturbs the state. For example, if you had Matchbox cars and you wanted to see how fast they were going, you could put your hand out and feel how hard it hits your hand. But now that stopped the car. And so this idea that your choice of measurement actually affects the system. And in quantum computing you have no other choices. For a car you could video it and then calculate which one was faster, but we don't have that opportunity in quantum computing. And so those sorts of things that are very unintuitive can become intuitive if you just give the right examples at young ages.

Ms. Schakowsky. Thank you. I am pretty much out of time. I yield back.

Mr. Latta. Thank you. The gentlelady yields lack.

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

Mr. Kinzinger. Well, I thank the chairman for yielding. Thank you all for being here. I can understand about 50 percent of the things you say, so.

Mr. Brett, in your testimony you stated that quantum computers will allow us to solve some of the most intractable and valuable computational problems that exist. Can you explain how doing so will benefit everyday Americans?

Mr. Brett. Thank you, Congressman. There are some problems in computer science that as we add more variables to them, or more factors to them, become exponentially more difficult to solve. And so that means that the time that is required to solve that problem doubles every time we add a new variable to it. And so, we can reach a limit of our computational capacity to solve those kinds of problems very, very quickly, even with circuit computers and cloud computing that is available today.

So for everyday Americans that are problems like how do we optimize our financial portfolio in our 401(k) where the amount of computational work that is required to do that is already immense. But if we want to include more factors involved in that and get the most efficiency for our portfolio, the scale of computational challenge increases exponentially and so quantum computing can help with that. We can take on more complex and more difficult problems and solve them in a much shorter time with a new type of machine.

Mr. Kinzinger. Okay. Now I am going to be honest Dr. Putman, I really don't know what I am going to say here, so I am going to say it and hopefully you understand the question. Okay.

When you measure a qubit, it immediately changes its value to either a solid one or zero. So as I understand, which I don't, to manipulate a quantum computer, the operator needs to be able to make measurements indirectly without a qubit observing you doing so. How do you do that? And how does that match the capabilities of classic electronic computers and processors with billions of transistors?

Mr. Putman. This is one I feel like I should have one of the quantum computing experts answer. This is something that occurs in physics that has been measured for many, many years. So how it is implemented becomes our greatest challenge, and there are several different ways to do it. Generally, you want to be in a situation where you control the atmosphere. It is -- while it is observable in nature, it is not as controllable as dealing with information series stringing of zeros and ones which just adds up in sums. I think I would like to have someone else explain the actual technology of how it might work. Dr. Monroe?

Mr. Monroe. Sure. First I would like to add that you are in good company because Albert Einstein didn't -- he never accepted quantum mechanics. He didn't think it was complete.

Mr. Kinzinger. So I am basically like Albert Einstein. Thank you, sir. I agree.

Mr. Monroe. Analogies do wonders in all of science, especially in quantum mechanics. I agree with Dr. Franklin's statement that finding analogies, you can teach the concepts to young children in elementary school. I totally believe that.

Here is an analogy for a qubit. It is a coin, imagine a coin, when we flip a coin, it is in a definite state all the time, but we might not know what it is or want to know all the details, but if you think of a coin as being quantum in, say, both heads and tails at the same time. Imagine now it is in a black box and you are not looking at it, so it is both heads and tails at the same time, but I want to control that coin, I want to maybe flip it. Let's say it is a weighted coin, so it is 90 percent heads and 10 percent tails. I want to flip the odds to be 90 percent tails and 10 percent heads. Well, we can do this from the outside world by just turning the box around, in a sense.

Mr. Kinzinger. Actually, that makes sense.

Mr. Monroe. So we don't know what the state was, we didn't measure it, we didn't betray the quantum system but we controlled it. And so to Dr. Putman's point, this is pretty exotic hardware, because the quantum stuff is inside and we have to keep our distance when we control it. We have to do things without looking and put quotes. What it means is that the system is so extremely well isolated that we don't get the information out. So a quantum computation involves manipulations like that. They can be much more complicated. Flip one qubit depending on the state of another, for instance, without looking -- and it is possible to do that in a very small group set of technologies. Then at the end of the day, you unveil, you open the box, and you measure only one state, but it could be lots and lots of bits and that one answer could depend on exponentially many paths, exponentially many inputs in the device. As Mr. Brett mentioned, this can be put to use for real world problems, and logistics, and so forth.

Mr. Kinzinger. Awesome. Well, thanks. Nice work. I yield back.

Mr. Latta. That is a large statue of Albert Einstein, you know, down the street, Mr. Vice Chairman, in front of the State Department. So you might get your statue there some time.

The chair recognizes the gentleman from Kentucky for 5 minutes.

Mr. Guthrie. Thank you very much.

That was a good example. I am trying to understand this and move it forward. This is kind of in my family. I didn't get any of the genetics, but have a nephew at the University Chicago in the physics department going to CERN this summer. So he is in a different league than I am. So some of the discussion we hear is like he and my son talking to each other during Thanksgiving or whatever, he is a computer science and math person as well, working in Chicago, but in the financial industry.

So I guess I am trying to figure out, or take in the theory, not really theory but the things that you are talking about that is hard to understand and make it to the real world.

So first, Mr. Brett, I will go to you. Can you tell us a little bit about what your company is doing in the financial services area? That is where my son is in, in algorithms. He is in one of the quant guys, I guess, in hedge funds, but how quantum computing would be an improvement over classical computing. What difference does this make, I guess? And what is your firm doing in financial services to be better than what is currently there?

Mr. Brett. Thank you, Congressman. The financial services sector is already a huge user of cloud compute technology. So they are using immense amounts of computational work, either on public clouds, like AWS or Microsoft, or their own private service. And it is important to understand that quantum computers won't replace classical computers. They will exist side by side in the cloud. And quantum computers will run some the algorithms that they are most efficient at. So in a mixed compute environment of financial services company will run their daily operation around compliance, portfolio, optimization, understanding risks, but send some of the algorithms that are in the program to the quantum computer to be most efficiently run.

Mr. Guthrie. So what does that do different? In what way? I mean, how is that?

Mr. Brett. So a quantum computer cannot allow us to solve some particular algorithms that cannot be solved on a classical machine in a useful timeframe. So we might be able to solve it over many, many years, or decades even, but what if we need the answer today? A quantum computer can help give us that speed advantage.

Mr. Guthrie. So why wouldn't it completely replace the classical update if it gets to that?

Mr. Brett. It is too expensive, and also, there are some problems that quantum computers can't do. So quantum computers aren't particularly good, for example, at addition or subtraction, so we leave those to classical computers to do that work, and quantum computers specialize in what they are good at, which is optimization problems.

Mr. Guthrie. Okay. This is a little harder for my mental capacity to understand something that can't do math, but can do other things, but simple math, I guess. So I am at addition subtraction level. I am not an Einstein like my friend, Mr. Kinzinger.

So Dr. Putman, in your testimony -- I am trying to get back to reality -- you did find the problem scarcity as one that quantum computing could help solve. And how might quantum computing disrupt traditional models of how resources are created and distributed in an economy?

Mr. Putman. Thank you, Congressman.

Often, there is an enormous amount of waste in the way that we currently produce anything. This is not due to humans caring to produce waste, or a problem with this in general, it is due to the -- our inability to comprehend and to simulate and to build. The more precise we are on a molecular level, the better we are at being able to do that. The examples that I used such as fertilizer, for instance, or of material science, a classical computer gets very rough examples of how to actually build something and understand what is going on molecularly. The more we are able to do that in ways that quantum computing allows, the more we can explore the space of possibilities. When we explore that space and understand it, it gives us a chance to create it. This just is not possible with humans alone, or with our classic computing systems. This applies to many areas that we could go on about.

Mr. Guthrie. Okay.

Mr. Putman. But certainly in manufacturing, it creates an entirely different way of doing manufacturing when we are precise.

Mr. Guthrie. Okay. When we are doing votes in the cloakroom, I am going to let Adam further explain this to me. So I am willing to do that moving forward. Thanks.

I understand it is just such a difficult concept for people not in your space to understand, but it is exciting stuff. I have about 30 seconds. But Dr. Monroe, I know Dr. Putman mentioned about qubits, how many in quantum computers. But here is a question, is what is the signal-to-noise ratio per qubits? For which I mean, how many qubits does one need for a useful quantum computer? And of those, how many would actually be performing calculations?

Mr. Monroe. Ah, thank you for the question. I probably won't answer it to your liking.

Mr. Guthrie. To my understanding. Probably to my liking, just not to my understanding.

Mr. Monroe. We don't know yet how many qubits are needed for something useful that can displace conventional computers. However, a relatively small number of about 75 or 100 qubits is enough to show certain, very esoteric and narrow, maybe not useful, problems can be solved that cannot be solved using conventional computers. That doesn't mean they are useful. And so it is sort of a proof of principle, and that is going to happen very soon. But then the question after that happens, once we are beyond that milepost, the idea is to find something useful. And I think the only way to find something useful is to put these devices in the hands of people that don't know or care what is inside the devices, sort of like my smartphone. I don't really want to know what is inside. And to build these devices, I use the word "exotic" a lot; it is exotic hardware to build these devices. It takes a new generation of engineers. And it may be that we need hundreds, it may be that we need thousands or more of these qubits for something useful.

Mr. Guthrie. Thank you. I yield back.

Mr. Latta. Thank you. The gentleman yields back. The chair recognizes the gentleman from Massachusetts for 5 minutes.

Mr. Kennedy. Thank you, Mr. Chairman. Thank you for calling this important hearing. Thank you to our panelists today for being here. From what I can tell, all of you clearly believe in the future of quantum computing, that is great. Still there are some very smart people out there who are skeptical that quantum computing won't ever become a practical reality. They say for instance that quantum computers are too unstable and error-prone to be harnessed for real world problem-solving.

Dr. Franklin, and anybody else who wants to comment on this, how do you respond to those skeptics? And what do you see as the biggest hurdles to a real world application for quantum computing?

Ms. Franklin. Well, I think that if we made decisions based on that assumption then we clearly won't build a quantum computer. And if we are wrong, the stakes are far too high, because other countries will make one, and then our -- they will be able to decrypt all of the message -- there are so many advantages, if it can be realized, that we don't want to be the ones who decide early and then are wrong. And we are making great strides.

Yes, right now, quantum computers are very small and very error-prone. And so physicists like Dr. Monroe are working on making them more stable, larger longer running. And then there is the piece in between. It used to be that classical computers were very large in size, but very few bits and couldn't do very much. I mean, what we could do in the 1980s in supercomputers is on your smartphone now. And so we don't know what can be done, and we need to put the resources in to see where we can go, because the stakes are just too high.

Mr. Kennedy. Dr. Monroe.

Mr. Monroe. I would add on to that, I think, the question the same technology we used to build quantum computers is also used for quantum communication and quantum sensors. And these are real-world applications that can be and are deployed right now.

On the sensor side, the ability to be detect signals remotely, the optical techniques, or to detect mass, which means if you are underwater, you need to know where you are to navigate. If you are exploring for oil, you need to know what is underneath the rock. Is it oil? Is it water? Those sensors, the limiting signal to noise in those sensors is given by quantum, quantum mechanics, we actually exceed those seemingly fundamental limits, in some cases. And that -- I mention this because that same type of technology is used in quantum computers. So I am not -- I do believe that quantum computers are most disruptive of all these technologies, but along the path toward that, there will be other spinoffs.

Quantum communication is largely photonic, optics as we communicate now over long distance. You can also do this with single particles of light, photons. And photons can -- these are wonderful quantum bits that can be used for quantum computing in some cases, but they can also be used to send data in ways that are hack-proof. If somebody tries to observe it, they change it, they can cut the line always, they destroy your communication, but they can't intercept it and understand it. So what does that have to do with quantum computing? If you are going to build a big quantum computer, it is going to be a network. It is going to have probably optics that fiberize little modules on a computer. And all of this hardware -- none of this hardware really exists today to couple those photons to quantum memories in qubits. I would hang my hat on quantum computing being the most disruptive of all of them, but along the way many other technologies related.

Mr. Kennedy. Dr. Franklin, you started to get into something that I wanted to ask -- have got about 1 minute and 15 seconds left or so -- encryption and the application of quantum computing to encryption and the potential for it to render in encryption obsolete. Can you talk me through that and what is the reality of that?

Ms. Franklin. Yeah, so encryption is all based on the idea that doing one operation is much harder than undoing it. It is a lot easier to multiply two numbers than it is to divide or factor a number. And so there is a quantum computing algorithm that actually takes a lot this and so that is not one of the near-term applications, but that makes it so that factoring the very numbers that are used to create those keys that make it -- that are required to encrypt and decrypt, can be broken down very easily to their components, and their components are necessary to decrypt. And so if we get a quantum computer of that size, we are going to have to figure out completely new encryption algorithms that use mathematical functions that is a quantum computer cannot do quickly.

Mr. Kennedy. And is that time horizon, is that -- can you put a time horizon that actually takes a lot on that.

Ms. Franklin. Chris?

Mr. Monroe. So this factoring problem, it is among the hardest out of there. You probably need tens of thousands of qubits, quanta bits and millions, or more, maybe even billions of operations. I will say, however, the problem is so important that you need to know -- you don't want -- you don't want a quantum computer just to break messages. You want to know when one exists, that impacts how you encrypt now. We are talking political time scale, so if a computer exists in 30 years, that could impact how you encrypt things now, so you may want to be ahead of game and change the encryption standards based on when a quantum computer will exists, and it is very, very hard to predict 30 years in the future what technology will bring us.

Mr. Kennedy. If you can predict what is going to happen tomorrow, we should hang out more. Thanks very much. I yield back.

Mr. Latta. The gentleman yields back. The chair recognizes the gentleman from Florida for 5 minutes.

RPTR ALLDRIDGE

EDTR SECKMAN

[10:14 a.m.]

Mr. Bilirakis. Thank you. Thank you, Mr. Chairman. I appreciate it. I will be as brief as I can to get everyone else in.

Mr. Brett, in your testimony, you identify three classes of applications that are possible in the near term, and I know you talked about these earlier.

Can you briefly explain why you expect those to be the most possible in the near term?

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

With the earliest quantum computers, like the type that Chris Monroe is building at the moment, the first versions of these won't have error correction on them. And so the kind of applications that we can build need to able to accommodate errors and the potential imprecisions that come along with that. And so the kind of the applications that are best suited to early stage quantum computers are those which are the most tolerant or resilient to error. And those are things like optimization problems, working with chemical simulation and machine-learning-type problems because the kind of algorithms we run on there are based on probabilities. And so we already get a probabilistic-type answer from classical computers out of that, and a quantum computer best matches what is possible there.

So the early stage applications are those that are more probabilistic, more resilient to error. And then, as the computers become more capable and better, we will be able to take on the harder type problems that require error correction around that.

Mr. Bilirakis. Okay. Thank you.

This next question is for the panel. Will quantum computers be something that anyone can use, which is important, or will it require a highly sensitive operating environment, such as that only a handful would be able to operate?

Why don't we start from over here, from afar, please.

Mr. Putnam. Thank you, Congressman.

It has to be something that has user interfaces that are possible for everyone in order for it to be incredibly relevant. The physics and the hardware behind it, just like the hardware and the physics behind everything else we do, will have a lot of specialists involved with it. But it is important for us, it is a challenge and important for us that this is something that is in the hands of anybody.

So I think absolutely.

Mr. Bilirakis. So it is not going to require additional training or anything like that --

Mr. Putnam. Well, only to the extent that everything we do requires some amount of training until it becomes so commonplace that it becomes natural.

Mr. Bilirakis. All right. Very good.

If you could comment on that, please.

Mr. Monroe. Sure. Thank you for the question. I will be very brief.

I think the answer is it will be very much like current computers. The use of current computers to program in certain language takes some training. It will be a different type of a language.

But the fact that there are individual atoms in the device at the end of the wire will be lost on the user, and it should be. They don't need to know that. They need to know the rules, the programming language, and what it can solve.

So I think the answer will be affirmative.

Mr. Bilirakis. Very good.

Ms. Franklin. Yeah. I think there are sort of three levels. One is the hardware. I mean, we are seeing quantum cloud computation, so I think it is likely that you won't buy one and maybe have it in your pocket. But at least the cloud resources will be there.

And as a user, you may not even know that you are using a quantum algorithm. The services that you use will have programmers who have made some of the -- have a combination of quantum algorithms and classical algorithms and send that computation to the cloud. When you do a Google search, something like a hundred programs respond off for that one search to figure out, is it an airline, is it a mathematical -- you know, what -- all these different things.

In terms of the ability to program it, that is where the most work has to come in. Right now, the amount of expertise needed to program these is insane. I mean, it is a high level of expertise. But that is how it was when the first women programmers were given a spec of the first computer and said, "Here. Program this," right?

They did it from the hardware. That is essential where we are. It is very tied to the hardware. So we need to figure out what are those abstractions that are still useful computingwise but also understandable to people who are the current level of a traditional computer scientist or even an application developer.

Mr. Bilirakis. Okay. Very good.

Please.

Mr. Brett. Thank you for the question.

I fully agree with my fellow panelists that we believe that you shouldn't need to have a degree in quantum physics to program a quantum computer. And so that is exactly what we are doing at QxBranch, is building the software that enables regular software engineers and computer scientists to create applications and to do so without needing to know the intricacies of what exactly is happening down at the molecular scale.

I will also point out that quantum computing is already becoming accessible. So, in the cloud today, IBM, for example, have released a quantum computer that we can all access. It is at IBM.com/quantum. We can go there this afternoon, do a short course on quantum computing programming, and start to build up that knowledge and understanding of what is possible and start to build those skills for the future.

Mr. Bilirakis. All right. Very good.

I yield back, Mr. Chairman. I appreciate it.

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

And the chair now recognizes the gentleman from West Virginia for 5 minutes.

Mr. McKinley. Thank you, Mr. Chairman.

And, again, thank you for continuing to put before us in our hearings some very provocative thoughts and through this disrupter series. We have dealt with, over the past 2 years, some very curious and innovative and, for me, as one of two engineers in Congress, exciting possibilities where we might go with this. So I am fascinated with it, but I am also -- I took -- I am sorry that the other side of the aisle didn't show up today. But I was curious to hear more of what Kennedy was talking about, the skepticism, because when I looked a little into that, there is some skepticism. And one of the articles I was reading a couple days ago had to do with reliability of the results.

So I know from doing my own engineering calculation that we can -- at the end of the day, we know whether that result makes sense. But what happens when we use quantum computing if we get -- and I think, Monroe, I think you might have said if they are error prone, do we rely on the result? How do we question it? If we don't -- if we are relying on our computers to give us the answer and then we get the answer, how do we know it is wrong? Or how do we know it is right because of all the variables that we have -- you have all talked about here?

Do you want to answer that?

Mr. Monroe. Yeah. Thank you for the question. A very good one.

I think it speaks to the -- so far, the limited research of what a quantum computer is useful for. There exists problems, like the factoring problem; you can easily check it. Fifteen is equal to five times three. When that 15 is a huge number, you can't do it using regular computers, but you can do the -- you can multiple your answer together to check and see if it worked.

Mr. McKinley. Talk about encryption.

Mr. Monroe. Yeah. If you can factor large numbers, you can break the popular types of encryption algorithms out there now. And if you think you have a code breaker, you can check it quickly.

And so almost all applications of quantum computers, they are either checkable against some standard, or they could be better than any classical approach. Say, for instance, in the financial market or some logistics problem where there is a cost function, it is in real dollars, and you are trying to minimize the cost subject to an uncountable number of constraints and configurations of the marketplace, for instance.

Well, if your quantum computer comes up with a potential -- a result that has lower costs than any conventional computer could compute, then you found a different solution.

Mr. McKinley. Okay. Let me just -- a couple quick points here to follow back up.

I can see there is a lot more -- again, fascinating. I want to say -- I want to read more. This whole idea has triggered me to do a little bit more research in this as well.

But let's talk about the timetables. Right now, yes, there are -- some elementary units are out there. But where we -- what is the metric? Where is the goal? Where do we want to achieve? And how do we know that we have -- whether we are there? And, secondly with that, what is the role of Congress on this?

Is this just more money into research? Or is this -- you talk about building plants or facilities so that we could build these qubits? Is this what it is? What role is government?

Mr. Monroe. Well, thank you for the question.

Again, I mentioned the idea of a national quantum initiative and the crux of that initiative is to establish, indeed, a small number of hub laboratories. They are not new buildings.

Mr. McKinley. These are hub zones or hub lab -- yeah.

Mr. Monroe. Yeah. Quantum innovation laboratories. They could be at existing university, Department of Energy, or Department of Defense laboratories, collaborations with industry, hubs where students and industrial players are all in the same sandpit.

And each of these hubs -- there will be a small number of them -- they would focus on a very particular aspect of quantum information or sensing or quantum computing. Maybe develop particular brand of qubit, for instance.

And the point here is to foster the generation, a new generation, of engineers in that particular technology. Industry will be able to connect more vitally with the university and a potential workforce. Students could have --

Mr. McKinley. Are we trying to develop a standard qubit?

Mr. Monroe. I think it is too early to do that now. I think we have several different technologies, and they will probably all find different uses. Sort of like now we have a CPU on a computer. We have memory. We have -- there are all kinds of different components, different hardwares that are good for different things. And we will probably see that in quantum as well.

Mr. McKinley. Okay. Again, what is the timetable?

Ms. Franklin. Well, I think it depends on the application. I mean, encryption might be 30 years off. But we have got 50 qubit machines now that are growing. And so these near-term applications, like optimization, are on the horizon, maybe 5 years. I mean, the hardware is coming along very quickly. I think that -- and some software, but this is the first I have heard of a software company. I am very excited.

But that middleware. That -- there is software that needs to be created that makes it so that algorithms that assume perfect hardware can be modified to use this near-term hardware so that we don't have to wait as long and can help close that gap between the assumptions of the software and the realities of the hardware.

Dr. McKinley. Okay. Thank you.

I yield back.

Mr. Latta. Thank you. The gentleman yields back. And the chair recognizes the gentleman from Indiana for 5 minutes.

Mr. Bucshon. Well, thank you for being here. It is a fascinating subject. I was a surgeon before, so I am kind of a scientist, you know. I am interested in this. My daughter is sophomore at Cornell in computer science. So she is, obviously.

I am going to take a little different pathway here on questioning and stay away from the technical stuff and go towards research funding. And I was on a committee before that had jurisdiction over National Science Foundation. I am from Indiana. I went to all the universities and talked to the NSF funded researchers. And the one thing that I found is -- first of all, I support that, right? I am a big supporter of research. One thing I found is, if I said, "Hey, tell me why what you are doing should continue to get funding from the National Science Foundation." Just a simple question, right? I found probably 90 percent of the people that I spoke to couldn't, in a really tight way, explain that. And for me, you know, they can explain it in complex way. And I am like, "Oh, yeah. I get it."

But people like me have to explain this to 700,000 people that we represent in a way that if we are going to justify Federal dollars and taxpayer dollars, we have to be able to give a so-called elevator speech and say -- and one example, I think this is 4 or 5 years ago that was kind of in the press was about a funded researcher -- and this is not a criticism -- that was having seniors play video games.

And so it got in the press, and people said, "Well, why would you fund that?"

Well, as it turns out, it was Alzheimer's research. You see what I am saying? And very valid, very important research. But to try to explain that, you know, when it is written in a line, you know, government funds video game; you know, having people be better video game players doesn't play very well, and so people like me have a hard time explaining that.

So I guess what I am getting at is -- and I guess this will be primarily for the people from the universities -- is what is your pitch for more funding for quantum computing? That is something, you know -- I mean, I know that is -- you have already explained it to me, and I get it. But if we are going to explain it to the broader Members of Congress and our constituents, how do we explain that, why we should do that?

Does that make sense?

Mr. Monroe. Yeah, it does. Thank you for the question, Congressman.

Yes. I did speak at length about these very targeted type hubs. And it should be sort of self-evident what these are about. They are developing technology. They are more technology centers.

But there must be an undercurrent of foundational research, and this is something the National Science Foundation, they are a very special agency in that regard. Fundamental research is very inefficient, and we can never tell what is around the corner. And you can never predict what is going to hit and what --

Mr. Bucshon. Yeah. You don't know what you don't know, right?

Mr. Monroe. Yeah. That is right.

And as the Science Foundation takes all-comers and they will have to play an important role in any national quantum initiative in the future, because there may be quantum technologies that don't exist now. And maybe in 10 years, due to some surprise and some weirdo material, we see that, oh, they behave as wonderful qubits.

So, again, it is too bad that it is inefficient, but the home runs are far reaching, and this field will probably rely on those in the coming decades.

Mr. Bucshon. Dr. Franklin.

Ms. Franklin. Yeah. I mean, I think -- it depends on how long you are in the elevator. I think the pitch for quantum computers starts with the killer apps of, you know, drug design for Alzheimer's, right? It is projected that 40 percent of the Medicaid budget is going to go towards Alzheimer's by 2040.

So, I mean, these are real problems. And if we could model the molecules and figure out exactly how nitrogen gets fixed and put into fertilizer, we could have much more lower energy, you know, food production. And so these are big deals, right? And those are things that can't be done with classical computing.

Then the next step is you have to tie the researchers to those problems. And that is what sometimes researchers aren't good at conveying. But that is why I do think that the calls -- we are too -- we are at the cusp of commercialization, and it might be an appropriate time for even the NSF funding to be looking at the broader impacts more, you know. So our group is making tools that everyone can use, and so that is something that we can hang on to, right?

Mr. Bucshon. Okay. The other thing I am interested in is technology transfer, obviously, because that is, as you know, a huge problem, not only in this area but across the research fields. I mean, what percentage of research goes, you know, that is probably potentially commercially useful. It just goes into a black hole.

And I know I am short on time, but maybe, Mr. Brett, you can comment, I mean, how we can do better on technology transfer because it is a pretty big problem, really.

Mr. Brett. Thank you, Congressman.

And we agree. As a small business that is looking to commercialize some of these innovations, how do we get access to some of the great work that is being done at the universities and to incorporate that?

Mr. Bucshon. Because it is proprietary, right, sometimes? That is some of the problem maybe, right? People are willing -- if they put the research out there, they are worried somebody will steal it, so to speak, right?

Mr. Brett. We found -- an approach that has been particularly successful for us is being able to partner with universities on research grants and so for -- as an R&D business to also participate in the collaboration of that research and contribute to the science and the publication around that and share some of that intellectual property on a joint project together. And I think that that cross between the commercial sector and the research sector working together on funded proposals will enable a lot of that technology transfer.

Mr. Bucshon. Okay. My time is up.

I yield back.

Mr. Latta. Well, the gentleman yields back.

And I first want to thank our panel for being here today. One of the great things about serving on this committee and because we do have such wide jurisdiction, I always say it is like looking over the horizon 5 to 10 years, that we hear it here first. And we want to make sure that, you know, our Nation is on that cutting edge.

And I am going to say something about some of our folks that were asking questions. They were a little bit on the modest side. I have a former Air Force pilot, a West Point grad, an engineer, and cardiothoracic surgeon over here. So they are not limited in knowledge.

But what you gave us today was very, very informative because, again, we have to make sure that, as we go forward as a committee, that we are making the right decisions as we go on.

And the gentlelady also would like to make a comment too. So I just want to thank you all. But I will finish up the ending, but I will let the gentlelady right now.

Ms. Schakowksy. Thank you.

China is building a $10 billion quantum lab right now. And they expect to be finished by 2020. And the EU is investing about $2 billion in advanced quantum technology. So I think one of the answers in terms of why we should be serious about making investments may be decryption is -- and encryption is -- some decades away. But from a national security perspective, I think that there are a lot of reasons that we should take this seriously and make the investments. And, of course, all the practical things about agriculture and pharmaceuticals, et cetera, is very, very important, disease cures.

But it seems to me that, despite maybe some skepticism, there is enough evidence right now that this is -- really ought to be an important priority. So I just want to thank you very much. You really did enlighten me.

Thank you.

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

And seeing that we have no further members that are going to be asking questions today, pursuant to committee rules, I remind members that they have 10 business days to submit additional questions for the record. And I ask that witnesses submit their responses within 10 business days upon receipt of questions.

And, without objection, the subcommittee will stand adjourned.

Thank you very much for attending today.

[Whereupon, at 10:34 a.m., the subcommittee was adjourned.]