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RPTR ALLDRIDGE

EDTR CRYSTAL

THE RACE TO 5G AND ITS POTENTIAL TO
REVOLUTIONIZE AMERICAN COMPETITIVENESS

THURSDAY, NOVEMBER 16, 2017

House of Representatives,
Subcommittee on Communications
and Technology,
Committee on Energy and Commerce,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:58 a.m., in Room 2123, Rayburn House Office Building, Hon. Marsha Blackburn [chairman of the subcommittee] presiding.

Present: Representatives Blackburn, Lance, Shimkus, Latta, Guthrie, Olson, Kinzinger, Bilirakis, Johnson, Long, Flores, Brooks, Collins, Costello, Walden (ex officio), Doyle, Welch,

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Loeb sack, Ruiz, Dingell, Rush, Eshoo, Matsui, McNerney, and Pallone (ex officio).

Also Present: Representative Duncan.

Staff Present: Jon Adame, Policy Coordinator, Communications and Technology; Ray Baum, Staff Director; Samantha Bopp, Staff Assistant; Kelly Collins, Staff Assistant; Robin Colwell, Chief Counsel, Communications and Technology; Sean Farrell, Professional Staff, Communications and Technology; Margaret Tucker Fogarty, Staff Assistant; Adam Fromm, Director of Outreach and Coalitions; Gene Fullano, Detailee, Communications and Technology; Theresa Gambo, Human Resources/Office Administrator; Elena Hernandez, Press Secretary; Zach Hunter, Director of Communications; Tim Kurth, Senior Professional Staff, Communications and Technology; Lauren McCarty, Counsel, Communications and Technology; Alex Miller, Video Production Aide and Press Secretary; Dan Schneider, Press Secretary; Evan Viau, Legislative Clerk, Communications and Technology; Hamlin Wade, Special Advisor, External Affairs; and Everett Winnick, Director of Information Technology.

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Mrs. Blackburn. The Subcommittee on Communications and Technology will come to order just a little bit on the early side of 10:00 o'clock. The chair now recognizes herself for 5 minutes for an opening statement.

I want welcome everyone to the first hearing of this year that is devoted exclusively to the promise of fifth generation wireless service, or 5G, and to explore the potential impediments to its deployment and wide-scale development.

In the interest of time, I will submit my full opening statement for the record. Suffice it to say, the race to 5G is on across the world as we compete with other countries and regions. As in any competition, one can either lead, follow, or get out of the way. As chairman of the subcommittee, I look forward to working on a bipartisan basis to ensure that America is first to the finish line.

At this time I recognize the subcommittee ranking member, Mr. Doyle, for 5 minutes for an opening statement.

[The prepared statement of Mrs. Blackburn follows:]

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Mr. Doyle. Thank you, Madam Chair.

And I just want to comment that today is a notice for Pancreatic Cancer Awareness Month. And I see some of our friends in the audience and colleagues wearing purple today. And I just want to recognize that and acknowledge what a terrible disease that is, and hope we find a cure someday.

Chairman, thank you for holding the hearing. And I want to thank all the witnesses here before us.

I believe that 5G holds a lot of promise and a lot of potential to drive American innovation, competitiveness, and productivity. But before I get into that, there are a few matters that I think need to be mentioned related to the FCC and their open meeting and reports of their plans to vote for repeal of the Open Internet Order as part of next month's open meeting.

In regard to this month's open meeting agenda, many members, myself included, have expressed grave concerns about the Chairman's agenda and the impact that it will have on media ownership, the Lifeline Program, and the ATSC 3.0 broadcast transition, or lack thereof, and the Commission's item on copper retirement.

Each one of these items is terrible in its own right and will have grave impacts to the public. I would urge the Chairman to delay voting these items and seek bipartisan consensus and to

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chart a path forward that benefits all Americans, not just the biggest companies.

In regards to next month's open meeting and widely reported rumors that Chairman Pai plans to repeal the Open Internet Order, I would tell him to stop and consider the broader consequences.

The success of the internet and the internet ecosystem has to be based on open access and a level playing field where consumers can access the services they want and edge providers can access customers without having to pay to get permission from gatekeepers or having to pay tolls.

Removing these rules removes this essential protection and threatens the virtuous cycle of investment and innovation that has made the internet what it is today.

So putting that aside, and to the matter at hand, 5G, next-generation wireless networks have incredible potential to revolutionize our economy and our way of life. Think back to 2007 and 700 megahertz auction. The iPhone has just been introduced, but the promise of smartphone technology and ubiquitous high-speed access was still just a dream.

When Steve jobs announced the iPhone, it had to be connected to WiFi because 3G networks at the time weren't responsive enough. But today, nearly 80 percent of Americans own smartphones, and the global app economy has grown to be worth more than \$1.6 trillion a

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year globally.

In the same way that LTE has put the internet in our pockets, 5G has the potential to connect every aspect of our lives. From smart transportation and self-driving vehicles, to connected medical devices and predictive diagnosis, to virtual and augmented reality, the promise of 5G has the potential to bring these technologies into reach.

But to get to this promised land and to bring the future into the present, we need to chart a course that facilitates this technology by making new spectrum available and easing the deployment of new wireless infrastructure. My hope is that we can advance bipartisan legislation to free up additional spectrum to meet the needs of licensed and unlicensed industries.

On the other hand, I have seen draft legislation in the Senate, proposals at the State level, and heard rumblings from the FCC and their Broadband Deployment Advisory Council that all seek to preempt local government with a heavy hand.

To me, these approaches are all stick and no carrot. We need an approach that is collaborate, and we need to bring State and local governments into these discussions in a more productivity way.

I am happy to see a representative from San Jose here today. Reading your testimony, I see that your city has big plans:

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self-driving vehicles, smart infrastructure, and using technology to meet the challenges you face. I am proud to say we have been doing all of this in Pittsburgh for quite a while now, and I am glad to see Silicon Valley finally catching up.

My point is that great innovation is happening in cities all across the country, and local governments in cities like Pittsburgh, San Jose, and so many others have risen to meet these challenges. They don't need someone to run roughshod over them. They need partners that will help them meet the needs of their citizens.

I believe that there is much this committee can do to facilitate the deployment of 5G and wireless broadband. My hope is that we can do in a that way that is thoughtful and inclusive.

Madam Chair, I thank you, and I yield back.

[The prepared statement of Mr. Doyle follows:]

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Mrs. Blackburn. The gentleman yields back.

At this time, I recognize the chair of the full committee, Mr. Walden.

The Chairman. Thank you, Madam Chair.

And I have a very serious question for the gentleman from Pennsylvania. Do you know the way to San Jose?

That was an old song, for those of you who are kind of new to this. The old radio guy in me coming out here. Do you want to sing it?

Okay. I want to welcome our witnesses. Thanks for being here today. We really value your testimony as we learn a lot about the fifth generation wireless technology, often called 5G. So thanks for being here, and thanks for your testimony.

This is going to revolutionize America's competitiveness. In the interest of saving time, I will submit the whole statement for the record. But the chairman of the subcommittee is correct, we are in a global race to develop and deploy 5G networks. Let there be no mistake: The race to 5G is a sprint, not a marathon. Even as we speak, competitors in Europe, Asia, and elsewhere are working to steal the mantle when it comes to having the best, most robust, and fastest communication networks.

I do want to make one point regarding the promise of 5G to our competitiveness in manufacturing, healthcare, energy, smart

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cities, and autonomous transportation. None of the applications enabled by 5G technology will be possible without adequate spectrum, and all the rhetoric around the race to 5G will be for nothing if we do not update the Communications Act to allow the Federal Communications Commission to deposit upfront payments from prospective spectrum auction bidders directly with the Treasury.

Current law prevents the Commission from doing so. So I want to applaud the chairman of this subcommittee for including provisions in the FCC reauthorization bill to allow the Commission to do so.

I also want to recognize the bipartisan work of Representatives Guthrie and Matsui in introducing standalone legislation to do the same thing. Thank you for that. I think we are all on the same page here.

But let me be clear. Absent a change in law, the FCC can't hold any auction of consequence to bring about the 5G revolution that we must encourage. So we all need to work together on a bipartisan basis to change that law so the Commission can again hold meaningful spectrum auctions. The inability to do so will mean the loss of billions in auction proceeds for deficit reduction.

So, anyway, thank you for being here. Thanks for your testimony.

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And, Madam Chair, with that, I will yield back.

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[The prepared statement of The Chairman follows:]

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Mrs. Blackburn. The gentleman yields back.

At this time, I recognize the ranking member of the full committee, Mr. Pallone, for 5 minutes for an opening.

Mr. Pallone. Thank you, Madam Chairman.

This Congress, Democrats on this committee have focused on protecting security, providing economic opportunities, and promoting democracy. Faster wireless networks have a potential to do all three.

These technologies can make us safer by helping first responders react faster after an emergency or disaster. They can offer economic opportunity by helping people apply for jobs or train for a new career. And they can improve civic engagement by keeping people better connected with their government.

People increasingly connect to the government using only their smartphones. That is especially true for the most vulnerable among us. Unfortunately, when they try to reach their government for help, too often they find websites that do not work on their mobile devices.

And that is why I introduced the Connected Government Act earlier this year with Congresswoman Robin Kelly that was passed by the full House last night. Our bill ensures that all new Federal agency websites are designed to work well on mobile devices.

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And today I will look forward to discussing other ways that 5G networks can serve all of our communities. While we have heard a lot this year about the importance of broadband in rural areas, today's hearing focuses on new technologies best designed for urban centers. These 5G technologies could present new opportunities for low-income Americans in urban areas who often struggle to pay for their connections.

And I know that some say that speeding deployment of these networks means that we must sacrifice environmental protections, that we must undermine tribal sovereignty, and that we need to block our local governments. But I urge my colleagues to look passed these naysayers. Let's find a path that promotes broadband deployment while still respecting the public interest.

And I believe that the LIFT America Act, which was introduced by the Democrats on this committee earlier this year, does just that. Our bill ensures high-speed broadband deployment to 98 percent of the country without jeopardizing the environment, city governments, or tribal rights.

It is unfortunate that while we are working here today to bring high-speed wireless broadband to urban areas, the FCC is working against us. As we speak, they are voting to kill the Lifeline Program as we know it, effectively taking wireless phones out of the hands of the people who need them the most. They are

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acting to senselessly cut the wireless lifeline to 7.3 million Americans. And that is cruel, particularly when some of those Americans live in places that are still recovering from natural disasters.

So I hope they reconsider and work with Congress to help those who need it most. Mr. Doyle talked about all the terrible things that we expect from the FCC over the next days or weeks, and I want to join in his comments.

But with that, I thank the witnesses.

And I would like to yield the rest of my time, half to Congresswoman Matsui, and other half to Congressman McNerney. So I yield now to Congresswoman Matsui.

[The prepared statement of Mr. Pallone follows:]

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Ms. Matsui. Thank you, Ranking Member Pallone.

Additional spectrum will be critical for both 5G and advancements in technology and innovation. Carriers and broadband providers will need to find creative ways to free up bandwidth to meet consumer needs in a 5G-and-beyond world. This would be necessary to account for the Internet of Things economy, autonomous vehicles, virtual reality, and new innovations that we have yet to hear about.

A realistic 5G-and-beyond strategy will need to be creative and will not be a one-size-fits-all solution. I think that technologies like blockchain could play an interesting role for spectrum sharing and one that could potentially maximize the efficient use of spectrum bands.

Thank you. And I yield to Mr. McNerney.

[The prepared statement of Ms. Matsui follows:]

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Mr. McNerney. Well, I thank the ranking member, and I thank my friend and colleague from Sacramento.

I am basically going to repeat what the ranking member said. As we sit here today holding a hearing about increasing connectivity, the FCC is voting on an item that would do just the opposite; namely, a proposal to dismantle the Lifeline Program.

This will disconnect millions of low-income Americans. In my district alone, there are more than 56,000 households that participate in the Lifeline Program. The FCC Chairman's proposal will be absolutely devastating for those folks.

We all have constituents who rely on this program for essential communication services, all of us have constituents, such as getting in touch with family and friends and obtaining help during emergencies. We owe it to our constituents to help them stay connected.

While I look forward to the hearing and I appreciate the witnesses coming today, I can't help but think about how today will be a serious step backward for connecting Americans.

Mr. Chairman, I yield back.

[The prepared statement of Mr. McNerney follows:]

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Mr. Pallone. And I yield back, Madam Chairman.

Mrs. Blackburn. The gentleman yields back.

The Chairman. Madam Chair.

Mrs. Blackburn. Mr. Walden, you are recognized.

The Chairman. Well, with the indulgence of the committee, today likely marks the last day of one of our veteran staff members, David Redl, who has worked for the committee for the last 7 years, was my chief counsel on the telecommunications subcommittee, and continued on in that role under our current chairwoman until the administration decided to pluck him from us, rather slowly. But that was the Senate, actually. The Senate was slow.

But they have now confirmed him, and we have every reason to believe the President will sign the paperwork today and David Redl will go off into the administrative landscape of the NTIA where he will be on a completely faithful search for more spectrum to free up and make available.

So if we could honor our staffer, David Redl.

[Applause.]

The Chairman. And with that, Madam Chair, I yield back. And we get back his section of the payroll, too. So thank you.

Mrs. Blackburn. That is correct. And we wish Mr. Redl well. And we should send our friends in the Senate a case of Red Bull

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and encourage them to work more expeditiously as they approach the issues that he is going to handle for the administration.

This concludes the member opening statements. The chair would like to remind members that, pursuant to the committee rules, all members' opening statements will be made a part of the record.

At this point, I would like to ask unanimous consent to enter into the record the opening statement of Mrs. Brooks and other members who may want to submit.

Without objection, so ordered.

[The information follows:]

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Mrs. Blackburn. We want to thank our witnesses for being here today and taking the time to testify for the subcommittee and for preparing your testimony in advance.

Today's witnesses are going to have the opportunity to give their opening statements, followed by a round of questions from the members. We are fully aware that we are on an abbreviated schedule for today as the President will arrive at 11:30 for the Republican Conference meeting.

We want to welcome our witnesses. Chris Pearson, president of 5G Americas. Dr. Coleman Bazelon, principal of the Brattle Group. The Honorable Jonathan Adelstein, who has been with us so many times, former FCC Commissioner and the current president and CEO of the Wireless Infrastructure Association. Shireen Santosham, the chief innovation officer for the city of San Jose, California -- and she does know the way to San Jose. David Broeker, the founding CEO of the Indiana Biosciences Research Institute.

We appreciate that each of you are here today and for preparing your testimony.

We will begin the panel with you, Mr. Pearson. You are recognized for 5 minutes for an opening.

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STATEMENTS OF MR. CHRIS PEARSON, PRESIDENT, 5G AMERICAS; DR. COLEMAN BAZELON, PRINCIPAL, BRATTLE GROUP; THE HONORABLE JONATHAN ADELSTEIN, PRESIDENT AND CEO, WIRELESS INFRASTRUCTURE ASSOCIATION; MS. SHIREEN SANTOSHAM, CHIEF INNOVATION OFFICER, CITY OF SAN JOSE; AND MR. DAVID BROEKER, FOUNDING CEO, INDIANA BIOSCIENCES RESEARCH INSTITUTE

STATEMENT OF CHRIS PEARSON

Mr. Pearson. Chairman Blackburn, Ranking Member Doyle, and members of the subcommittee, thank you for having me here today. I am Chris Pearson, president of 5G Americas, an association representing mobile operators and vendors from around our region. 5G Americas' board of governors includes AT&T, Cisco, CommScope, Ericsson, HPE, Intel, Nokia, Qualcomm, Samsung, Sprint, and T-mobile.

5G Americas is also a Market Representative Partner of the standards forum 3GPP, where 5G is being standardized, and works with regulators around the world.

5G Americas represents our region in the Global 5G MOU Event twice a year in countries in Asia, Europe, and the Americas that are dedicated to winning the race to 5G. And next year, 5G

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Americas hosts our event here in the United States.

5G, or fifth generation of wireless technology, is comprised of three use cases: enhanced or faster Mobile Broadband; Massive Machine Type Communications, also known as the Internet of Things; and Ultra-Reliable Low Latency Communications, often called critical communications.

So 5G is just not about faster broadband, although it would be nice to download that movie in seconds before you board that plane. It is about other things as well. Machine Type and critical communications will enable connected, autonomous vehicles and revolutionize our industries and lives with enhanced productivity, smarter cities and homes, safer roads, and more effective healthcare. Our industry is expected to invest \$275 billion in 5G, resulting in \$500 billion in GDP growth and millions of new jobs.

But this revolution requires more spectrum and efficient siting of wireless facilities. So we are grateful for this subcommittee's leadership on spectrum and its continued focus on ensuring that there is adequate spectrum for 5G.

We support Mr. Guthrie and Ms. Matsui's spectrum auction receipts bill, which the FCC needs to hold any further auction, and urges the committee to act on that quickly.

Spectrum will be required for 5G in every range, low band,

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mid-band, and high band. Other countries around the world are making mid-band available for 5G, and the U.S. should, too.

The countries that make new globally harmonized spectrum available for 5G are the ones that are going to lead this race. And thanks to this subcommittee, the U.S. led the way in 4G because it made new spectrum available for auction at 700 megahertz and also in the mid-bands.

To create the global economies of scale that benefit U.S. consumers and businesses, we must have globally harmonized spectrum for 5G. In addition to allocating sufficient amounts of harmonized low-, mid-, and high-band spectrum, the U.S. must expedite siting procedures for the small cells that will be necessary for 5G. And for this reason, 5G Americas also supports the MOBILE NOW bill.

Mobile data traffic is expected to grow seven to eight times in just a few short years, and meeting that demand will require operators to densify their networks, requiring streamlined procedures for all those new small cells. As we will hear from Mr. Adelstein, we must have model siting procedures that allow network densification.

5G Americas supports the FCC's work in its BDAC advisory council bringing together stakeholders to recommend model codes for State and local government siting. And as necessary, should

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that effort not result in the streamlined siting required for U.S. leadership, 5G Americas supports this Congress or the FCC for establishing some sort of national standards for small cell siting.

Additionally, 5G Americas supports the FCC's order on eliminating separate historic review for replacement poles. 5G Americas urges the FCC to do even more to eliminate unnecessary reviews in rights-of-way without affecting the historic areas.

Again, thank you, and I look forward to your questions today.

[The prepared statement of Mr. Pearson follows:]

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Mrs. Blackburn. The gentleman yields back.

Dr. Bazelon, you are recognized.

STATEMENT OF COLEMAN BAZELON

Mr. Bazelon. Thank you.

I would like to thank the committee for the opportunity to testify today on this important topic.

I started my career as an analyst at the Congressional Budget Office just as the second generation cellular services were beginning to be deployed. The developments of third and fourth generation technologies have helped fulfill the promise of wireless.

The same will be true of, 5G which will bring unprecedented speeds and low latency to wireless networks, supporting new applications and development of an Internet of Things. And as with those earlier developments, additional spectrum is needed to fulfill the 5G promise.

Unlike the previous technological advancements, 5G combines new technologies with a new architectural model of how spectrum is deployed. The architecture of a robust 5G network will require spectrum in a variety of bands: low-band spectrum below 1 gigahertz for wide-area and long-range communications; mid-band

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spectrum between 1 and 6 gigahertz for applications that would benefit a combination of coverage and capacity; and high-band spectrum for short-range communications requiring fast data rates and low latency. All three pieces of this spectrum trifecta will be crucial for the successful deployment of 5G networks.

The Principle of Spectrum Reallocation states that when the value of a band of spectrum in a new use exceeds the value in an existing use, plus the cost of transitioning the frequencies, it should be reallocated.

This simple principle, that benefits should exceed costs, can face many obstacles in practice. Incumbent users, whether TV broadcasters or government agencies, tend to be reluctant to relinquish spectrum assignments. Consequently, mechanisms where incumbents are compensated are beneficial because they overcome resistance.

In fact, anything that can be done to smooth the transfer of spectrum is helpful. For example, the recently introduced Spectrum Auction Deposits Act, which overcomes impediments identified by Chairman Pai to holding spectrum auctions, will facilitate future auctions, and the Spectrum Reallocation Fund will help provide frequencies for those auctions.

The new 5G deployments will have profound implications for spectrum value. On the one hand, being able to integrate massive

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amounts of high-band spectrum into commercial mobile networks will flood the market with spectrum capacity, at least in dense or more populous areas and for applications that can utilize the higher frequency spectrum. On the other hand, these new networks will enable new wireless services and increase consumer expectations about throughput and reliability.

The net impact of these two offsetting effects is uncertain, and overall spectrum values could go up or down. But within the overall net impact on spectrum values, there is a clear implication for different types of spectrum from increased user expectations for throughput, mobility, latency that will be fostered by the new 5G deployments.

The value of mid-band spectrum used for capacity outside the areas served by high-band 5G deployments should increase because demand for network capacity, reset to a user experience based on a higher level of throughput in the urban areas, will be greater in those non-urban areas.

The Principle of Spectrum Reallocation is applicable to all bands that make up the 5G spectrum trifecta, but I will focus on mid-band spectrum, the connective tissue of 5G deployments.

In my accompanying paper submitted to the committee that CTIA released yesterday, I examined the value of making an additional 100 megahertz of mid-band spectrum available in the 1,300 to 1,350

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megahertz and 1,780 to 1,830 megahertz bands. After accounting for a moderation in spectrum value compared to recent highs, I find that a 50 plus 50 megahertz paired band would be expected to raise \$63 billion in auction receipts. Making those frequencies available is expected to cost up to an estimated \$8 billion in relocating existing users, providing them with at least equivalent and in many cases improved wireless infrastructure. Consequently, this band could be expected to raise \$55 billion in net receipts.

Admittedly, there is some uncertainty about forecasting future auction receipts. Frankly, it is not for the faint of heart. But as long as the auction of this 100 megahertz of mid-band spectrum raises more than \$8 billion, a paltry amount for so much spectrum that could be used for mobile broadband, reallocating the Federal users and auctioning the reclaimed spectrum will create value.

The application of the Principle of Spectrum Reallocation does not end here. For example, all or part of the 3.7 to 4.2 gigahertz band could be valuably deployed in support of 5G networks.

I have investigated this band and found that, even with conservative assumptions about the value of both the existing C band services and potential new deployments, reallocating some or all of this band would likely create value. A voluntary mechanism

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that ensures incumbents benefit from any transition will help facilitate making additional needed frequencies available for new 5G networks.

Thank you.

[The prepared statement of Mr. Bazelon follows:]

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Mrs. Blackburn. The gentleman yields back.

Mr. Adelstein, you are recognized for 5 minutes.

STATEMENT OF JONATHAN ADELSTEIN

Mr. Adelstein. Thank you, Madam Chairman and Ranking Member Doyle, members of the subcommittee, for the opportunity to testify. This hearing today is historic for a number of reasons, not just the topic, but because it is David Redl's last time on that side of the dais and not over here where he will soon be.

We congratulate Mr. Redl on his rapid confirmation by the Senate. And you wonder why I say "rapid." By my standards, what I went through, it is actually pretty quick. So it is all relative.

I represent the Wireless Infrastructure Association that represents companies that build, own, manage, and maintain wireless facilities across the country. And we applaud the leadership of this subcommittee on promoting wireless broadband deployment.

The wireless industry stands ready to make enormous investments, up to \$275 billion to build out 5G. It will lead to 3 million new jobs and \$500 billion to boost GDP.

And the U.S. is really well-positioned to lead 5G, especially

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with David Redl as head of the NTIA. It will be something that will face stiff competition, though. We have competition from around the globe. Fortunately, this subcommittee, the FCC, and the administration have all shown a clear commitment to policies that encourage 5G investment.

5G could prove one of the most transformational technologies in the history of technology. But as promising as the standard for 5G is, it is only as good as the infrastructure on which it is deployed. 5G will involve up to a hundred times more antenna locations than 3G or 4G, so all types of infrastructure are needed. And fully realizing the potential of 5G depends on how effectively it gets deployed. Responsible infrastructure deployment is key.

Our industry works very closely with local governments, like San Jose. But if a company carelessly circumvents localities, it rightly angers the community and creates resistance to siting new facilities, and that can slow 5G.

The WIA and its members seek to work in partnership with localities, because that is the best way to develop networks over the long-term.

This subcommittee has long promoted responsible deployment. In fact, the great example of that is Section 6409(a) of the Spectrum Act. The law clearly sped 4G deployment by allowing

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upgrades on cell towers without burdensome zoning reviews, and it will continue to provide relief for the deployment of 5G through colocation, which is preferred by localities.

Many communities welcome wireless deployments with streamlined siting policies. In fact, 13 States have passed laws to streamline deployment. I think Congress can bring all communities up to that same high standard by speeding the approval of permits and applications. Congress should provide a deemed granted remedy if a locality fails within a prescribed shot clock to approve an application.

The FCC system for working with tribes who indicate a possible historic cultural interest often far outside of tribal lands is not working properly. It should be updated to exclude deployments with no new ground disturbance and ensure that fees are reasonable and appropriate.

Congress should also modernize the historic preservation laws by excluding certain small cell deployments from unnecessary reviews. And Congress should revamp the Byzantine process of siting on Federal lands to speed deployment on rural areas, something we have concentrated on, on the BDAC, in the subcommittee I chaired.

Another barrier to 5G is the growing gap between the skills of today's workers and the skills needed to build tomorrow's

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wireless networks. Many of our members report they are having difficulty in filling positions with qualified applicants.

Now WIA is working to build bridges that will jump across that gap so that we can bring apprenticeships for the first time into the wireless industry. WIA is also developing training programs to support that, because we can't afford the lack of trained workers to slow the path to 5G.

We are encouraged that Congress and the administration are seeking new ways to partner with industry on job training and on apprenticeship programs, because thousands of new high-wage jobs await those with the proper skills.

The movement to 5G has the potential to unleash a wave of job creation, economic growth, and greater global competitiveness. That is why the subcommittee's leadership is so critical, and we are so grateful that you held this hearing today and invited me to testify. So thank you again for holding this hearing.

[The prepared statement of Mr. Adelstein follows:]

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Mrs. Blackburn. Thank you.

Ms. Santosham, you are recognized, 5 minutes.

STATEMENT OF SHIREEN SANTOSHAM

Ms. Santosham. Good morning, Chairman Blackburn, Ranking Member Doyle, and members of the subcommittee. I am Shireen Santosham. I am chief innovation officer for Mayor Sam Liccardo in San Jose, California, the largest city in Silicon Valley. Thank you for the opportunity to discuss how cities are creating favorable environments to speed deployment of broadband.

I want to particularly thank Congresswoman Eshoo for her focus on this issue and her excellent service for all Californians. We are truly fortunate to have her represent us.

Cities large and small are eager for increased broadband investment and competitive choices for our residents. We understand the benefits of broadband to economic growth and creating an on-ramp to opportunity for our young people to learn and participate in the jobs of tomorrow.

In San Jose we welcome technological advancement with open arms. This year alone we have launched an autonomous vehicle initiative, a crowdsourced civic challenge utilizing drones, entered into public-private partnerships with companies like

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Facebook. Just this past Monday our city council unanimously passed our broadband and digital inclusion strategy that includes several recommendations to streamline deployment and pave the way for technologies like 5G.

San Jose is excited and ready to welcome 5G to our community. But at the same time, we have 95,000 residents in our city without broadband access. Think about that. In the heart of Silicon Valley, nearly 10 percent of our residents don't have adequate access to the internet.

It breaks my heart every time I hear about children in our community who are trying to do their homework on a mobile device outside their school because they don't have internet access at home. They are losing the race before it starts.

So while I welcome this next generation of the internet, we can't leave people further behind in the process. How this technology is deployed and who benefits matters.

Unfortunately, much of the State-level legislation that recently passed in over a dozen States to streamline deployment goes too far and gives telecommunications industries the benefit of a public utility without the obligation to serve everyone at affordable rates.

I am going to tell you about one of these bills, SB 649, which was wisely vetoed by our Governor in California and

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highlights issues relevant to Federal action that we believe are important for you to consider.

The first is the extremely low caps that allowed cities to charge -- that were allowed for placing small cells in the public right-of-way at cost. In fact, upon an independent review, these rates were found to be below cost, resulting in the State obliged to reimburse cities for the difference had it been signed into law.

Not only would the bill cost cities, but it also stripped away the ability of local governments to incentive build-outs in traditionally underserved areas. In San Jose, we have digital deserts in the middle of our city where low-income Latino families live. By using market-based pricing of assets and negotiating citywide deployments, we can incentive the telecom industry to build out in these underserved areas. Preemption of local authorities to charge market rates and giving by-right access to industry removes these incentives.

Second, equipment size and scale matters. Although the industry describes small cells as the size of a pizza box, the dimensions listed under SB 659 for small cells were over 21 cubic feet, the size of a standard refrigerator. Such massive pieces of equipment need adequate safety review, and communities will want input if thousands are deployed on their sidewalks.

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Finally, the public benefits from local governments acting as a referee for the competing needs of the finite space in the public rights of way.

So how can we move forward? We need a balanced approach to ensure that we are speeding deployment while benefiting the public broadly. Cities can create one-stop shops for providers, co-create design standards with industry, negotiate citywide or batch process permits, and offer transparent and fair pricing.

On the Federal level, we must avoid preemption of cities if we want to see equitable and safe deployment. The Federal Government should instead focus on developing the capacity of local leaders to manage deployments in community-centric ways. The Federal Government should also be careful not to pick winners and losers through policy.

On behalf of Mayor Liccardo and the city of San Jose, I want to thank the subcommittee for inviting me to participate in this hearing today. I look forward to questions, and we are willing and able to help in any of your districts that are also struggling with some of these questions of deployment.

Thank you.

[The prepared statement of Ms. Santosham follows:]

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Mrs. Blackburn. The gentlelady yields back.

Mr. Broeker, you are recognized for 5 minutes.

STATEMENT OF DAVID BROEKER

Mr. Broeker. Good morning. Thank you, Committee Chair Blackburn, Ranking Member Doyle, and Congresswoman Brooks and other honorable members of this committee, for inviting me here today to talk about the impact of 5G on the future of life sciences and advanced manufacturing.

My name is David Broeker, and I am the founder and principal of a legacy bioscience consulting company. I help entrepreneurs and innovators in the life sciences area advance their ideas to the marketplace. And I am also the founding president and CEO of the Indiana Biosciences Research Institute.

Indiana is home to one of the most diverse, robust life science sectors in the country, with companies in biotechnology, pharmaceuticals, medical devices, agriculture, animal health, and diagnostics. Eleven percent of our workforce are employed by these companies.

The State has consistently been second to our colleagues from California as the largest exporter of life science products in the United States, exporting more than \$9.9 billion in products and

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contributing over \$62 billion to the Indiana economy in 2016.

Across life sciences today, biology and applied data science are converging to help researchers and scientists understand the genome and the massive amounts of data that are being generated every day. This convergence will require new capabilities and infrastructure like 5G to allow researchers to share these large data streams in ways that are better, faster, cheaper.

The ability to do this will enhance discovery for new medicines and treatments for patients and enable the Massive Internet of Medical Things that are upon us to create new innovation.

The development of the Massive Internet of Medical Things will connect patients to their physicians through telemedicine, augmented and virtual reality, interventions. It will make digital technologies like smart devices, wearables and sensors a part of the delivery of care to improve patients' lives. And when combined with other enabling technologies like blockchain, data standards, and encryption, it will create a shift away from place-dependent electronic medical records to virtual individual health records that will improve the quality of care through personalized medicine.

5G technology will enable life science manufacturers to create better and more secure supply chains that will connect

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patients and distribution partners as well as create opportunities to improve the quality and productivity of the research and development process and the ultimate tech transfer and manufacturing of these products.

For example, 5G technology will enable the real-time capture of appropriate patient information to improve safety monitoring and adverse event reporting. It will also allow for 100 percent tracking of product distribution to the patient.

It will improve the efficiency of clinical studies by providing 100 percent verifiable external data capture and exchange with researchers and development partners like contract research organizations. It will improve the technology transfer within companies between development teams and manufacturing operations to shorten timelines and bring innovations to the market faster.

5G will also create opportunities to connect the patient literally to the shop floor and integrate advanced manufacturing capabilities like 3-D printing to make customized devices, cell-based therapies and therapeutics.

Finally, 5G will result in more automation of manufacturing, improving the speed and efficiency, creating more manufacturing jobs, and enhancing the technology focus within the current manufacturing operations.

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Just like the Nation's interstate highway system made the fast and easy exchange of goods across the country possible, 5G technology will drive innovation in the life sciences by providing a better avenue for exchange of massive amounts of data being generated across the information-rich landscape of healthcare and life science innovation.

I would just like to leave you with one factoid that I researched in coming to the committee today.

I don't know how many people know what a zettabyte is. But a zettabyte is 1 followed by 21 zeros. So it is a pretty big number. And if you look at the major internet service providers today, they traffic a little over 1 zettabyte of information.

In the next 3 years, it is projected that that will increase by over fiftyfold. So think about that amount of data and the infrastructure that is required to exchange, connect, and the convergence that is possible in life science and manufacturing.

5G is critical enabling technology for America and will help drive new innovations in healthcare and increase competitiveness in advanced manufacturing.

Thank you, and I look forward to your questions.

[The prepared statement of Mr. Broeker follows:]

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Mrs. Blackburn. The gentleman yields back. This concludes our opening statements, and we are ready to move to questions and answers. And I will recognize myself for 5 minutes to begin that portion.

Mr. Broeker, I want to start with you. I am so pleased that you mentioned the manufacturing component. We have 341,000 Tennesseans who are in manufacturing. Last year, \$30 billion worth of exports. So we are not quite to where you are with your Indiana number.

But I want you to talk about this from two sides. You look at one of our States and you say: This is the potential if the investment is made, and this is what could happen if the investment is not made into 5G. Because I think this is something that we all are discussing. Mr. Johnson is working on broadband expansion. Mrs. Brooks is chairing the effort on 5G. So if you will take it from those two sides.

Mr. Broeker. Chairman Blackburn, a very good question.

I have been in and around life sciences my whole career, over 30, 35 years, and I actually started off as a manufacturing engineer. So I was one of those engineers running around the shop floor.

Manufacturing is both a capital-intensive and a people-intensive business. And currently, if you look at

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manufacturing, most companies can site that manufacturing anywhere in the world.

And so what really drives companies to make decisions related to that manufacturing are a favorable business environment, which includes things like tax policy; availability and access to a trained workforce and talent; and the infrastructure that is required to make all of those things work.

And so my point would be that if we don't do this, manufacturing will go elsewhere. It will start to -- continue to go outside the United States, because it is a global opportunity for companies to go other places to set up new manufacturing and manufacturing of the future.

So I think 5G enables us to become even more competitive than we have. And when you look at the future of the innovation that is possible, then we can capture that making it here in the great States that all of you represent.

Just yesterday, I saw that for the very first time the FDA has approved a digital pill. This is a pill that is a combination of a drug. You swallow it. When it hits your stomach, there is a sensor in the pill that releases information to your smartphone that can go to the patient, it can go to their family, it can go to your healthcare provider.

These are the kinds of things that are possible even today.

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FDA, as I said, just approved this digital pill yesterday. And so I think, without a technology like 5G and the infrastructure that this represents from a manufacturing standpoint, we have the potential to fall behind other countries that implement it better and faster than we do.

Mrs. Blackburn. Thank you.

And, yes, we had watched the development of this in the Software Act this committee passed out as a part of 21st Century Cures as a part of enabling that type technology to move forward with, I think it is, Otsaku is the company.

Mr. Broeker. It is Otsuka.

Mrs. Blackburn. Yes.

Mr. Broeker. It is a new medicine for schizophrenia.

Mrs. Blackburn. Which is a great opportunity.

Mr. Adelstein, I have got 19 counties, 10,000 square miles in my congressional district. And I was out last weekend talking with one of our county mayors and he was all about 5G, so excited about the potential that is there for 5G.

If you were talking to one of my mayors, and economic development, bringing jobs back is something they talk about, they also talk about healthcare and educational opportunity, if you were to kind of crunch it down, talk about that opportunity. How is this going to change what is happening in rural communities

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with the advent of 5G, what is going to be most significant and most notable?

Mr. Adelstein. I think probably, as you indicated, what is most significant is the economic development opportunity for rural areas. Suddenly rural areas have at their fingertips the vast amounts of data they can both communicate and receive, as anybody anywhere in the world, if they can have that level of technology available, if it gets deployed to rural America, which we hope it can as quickly as possible.

So there is opportunity for jobs to be located there, for people that are visiting to stay longer because they can get their work done there, for new businesses to locate there, where it is a better quality of life and lower cost of living and lower cost of doing business.

So it is really an opportunity to revolutionize the way that business is done in rural America. I think it is something that a lot of folks that I spoke with when I worked at the Rural Utilities Service, as the head of it, were so concerned about.

Mrs. Blackburn. Thank you for that.

And I am going to at this point yield 5 minutes to the ranking member.

Mr. Doyle. Thank you.

Ms. Santosham, you are a member of the FCC's Broadband

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Deployment Advisory Council, right? And San Jose is the only local government on this 30-member council. Is that correct?

Ms. Santosham. Actually, we were the only municipal representative when it was first appointed, but now they have added two more.

Mr. Doyle. Great.

Ms. Santosham. One from Kansas and one from Georgia.

Mr. Doyle. Tell me, what is the impact of local government representation? How do you think it is impacting the recommendations of the Advisory Committee?

Ms. Santosham. It has been a challenge in terms of both the process and the output of how we are working. And it is an issue that the National League of Cities, National Association of Counties, and U.S. Conference of Mayors, along with 237 bipartisan mayors across the country have written to Chairman Pai about.

And the numbers speak for themselves in terms of the approach to how we will deploy broadband. And we really do need more local government representation. And we are at the table, we are talking to the FCC. But we hope that we can get more representation.

Mr. Doyle. Thank you.

Commissioner Adelstein. Jonathan, welcome back. Good to see you.

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You are on the commission too, right?

Mr. Adelstein. Yes.

Mr. Doyle. How do you think local government input is being handled?

Mr. Adelstein. Well, there are also members of local government on the working groups that aren't on the full BDAC. There is also a State commissioner from the State of Massachusetts sits on the group. So there are a number of representatives of municipal and local governments.

I think the chairman is really seeing this as an opportunity for industry to work with localities to try to come up with consensus solutions. For example, a State code that would be a model, a municipal code that is a model. There has been a lot of good dialogue going back and forth between localities and the industry on that.

And we have the opportunity to take input from outside of the working group as well. I mean, we are listening very closely to localities. We feel that if we can't get a good State or local code that is a consensus document that really is working together, it is not going to get adopted anyway.

Mr. Doyle. Thank you.

Mr. Bazelon, let me ask you. In your testimony, you mentioned the challenges of freeing up the spectrum resources for

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deploying 5G networks. And when we look at the lower part of the C band, the 3.7 to 4.2 gigahertz band, do you think it is realistic that satellite users will totally vacate the whole band, as some in the wireless industry have suggested, or do you think it is more realistic that the FCC might be able to repack some part of the band to free up spectrum that could be used for mobile license usage.

I mean, I know in your heart of hearts you would like to have the whole thing. But I am just curious where you think reality lies given the complexities in the incumbent licenses.

Mr. Bazelon. Thank you.

So first the economist answer is that the value created by the band should be more than enough to compensate the existing users. And so from a social perspective, the band probably should be freed up. But there are stakeholders there, and they have legitimate and real concerns. And a process where they are working with the reallocation process is one that is more likely to be successful.

So a voluntary mechanism that allows them to share in the gains of their efforts to free up the spectrum is one that I think is more likely to be successful. Whether that ends up clearing the entire band or part of the band I think is for the people who know best in the band to figure out.

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Mr. Doyle. Thank you.

Mr. Pearson, in your testimony you talk about international harmonization of 5G bands. What part of the C band that I have just asked Mr. Bazelon about is being considered for global harmonization?

Mr. Pearson. I would have to go back and look at that and study it a little bit further. But what we are looking at in most countries around the world is they are looking at focusing on low-, mid-, and high-band spectrum, all three. And so the C band would be one of those things they are looking at. I would have to look at exactly where I would go to focus on that, a little bit more research.

Mr. Doyle. Okay.

Finally, Ms. Santosham, following up on my initial question to you. It seems like San Jose has been identified by some in the wireless industry as a problem child, that you are impeding the deployment of broadband technologies. Why do you think you are being labeled that way? I mean, from what I can tell, you and your city seem to be working very hard to advance the deployment of broadband technologies. Where is the disconnect there?

Ms. Santosham. Well, it was a surprise to us, to be honest. We are one of the leading cities on these issues, on technology issues broadly, as I talked about. And we recently hired Smart

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Cities' lead for our city, who has 25 years of telecomms experience, hadn't worked in government before, is coming in and completely retooling how our city is approaching broadband deployment in order to speed permitting.

So we were surprised that we were getting accused of charging fees and rates that were actually well in excess of what we actually do charge. And it was disappointing that we couldn't have a more collegial conversation about how do we actually deploy broadband.

Because cities around this country, we want it. We want investment. When I go to neighborhood associations with the folks in my community, they want neighborhood fiber, because they are not happy about the investment that has been made.

Mr. Doyle. Thank you.

Thank you, Madam Chair.

Mrs. Blackburn. Mr. Walden, you are recognized.

The Chairman. Thank you, Madam Chair.

Mr. Bazelon, in the report you released this week, I understand you estimated two bands of spectrum could raise us \$54 billion in net revenue to the Federal Government after relocation cost to incumbents. Even here in Washington we think that is a lot of money.

I know the focus of your paper was on mid-band spectrum, but

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are there potential low- and high-band spectrum bands we could combine with these in spectrum auction legislation?

Mr. Bazon. Certainly, as has been said, all three types of spectrum are needed. And to the extent that auctions would facilitate reallocations, that would be a good idea. But as with all bands, there are incumbent users, and it sort of depends on the specifics.

I would suggest that, at the low band, the television frequencies are still ripe for the economic tests I suggested about the value in new use versus current use, but also appreciate that is unlikely to be an area of focus any time soon.

And the FCC, I don't know what time it is, but they may have just reallocated more spectrum from the high band. And should any of those be auctioned, that would be about a useful addition.

The Chairman. All right.

And, Mr. Pearson, do you have any thoughts on this matter?

Mr. Pearson. Yeah. I think that, as you said, there is a lot of money at stake here, because if you put in auction processes and rules that make that spectrum, whether it is low, mid, or high, it is very valuable spectrum for the mobile wireless industry.

I know there has been a lot about 5G just being a millimeter-wave story. And if you look at internationally

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specifically, if you go to China, if you look at Japan, if you look at Korea and Europe, they are looking at this in all the bands.

And so specifically, the mid-bands and the millimeter coupled together become part of the story of 5G. It is a bigger story than just millimeter-wave.

The Chairman. All right.

And, Mr. Bazelon, there is a perennial debate around here about authorizing specific bands for auction versus providing the FCC with blanket auction authority. The most recent estimate from the CBO, Congressional Budget Office, said that if we just gave blanket authority, it would raise a very small amount of money compared to what you have put forward. A blanket extension, I think, would be around a billion dollars.

A billion dollars is still a lot of money. But when you put it up against the potential for \$54 billion net to the Treasury just for those two bands, do you have a view on whether we should give blanket authority or reserve it for auction?

Mr. Bazelon. There is no reason that the FCC shouldn't have blanket authority, and the two are not actually in conflict.

The reason, my understanding, and now I have put on my green eyeshades from my CBO days as a budget scorer, the reason blanket authority today has such a low score is because, in essence, the

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low-hanging fruit of what can be reallocated and auctioned has already happened.

So that is why it is important that the incumbents are incentivized to cooperate, whether that is through government diktat or through a market mechanism, and typically that takes additional legislation. But those additional efforts by Congress would create a positive score even if --

The Chairman. Are you sure? We did that in 2012, and AWS-3 auction came back at zero from CBO, and it sold for \$44.4 billion. So I don't have a lot of faith in taking away our tools, relying on others.

Mr. Bazon. I don't think that whether there was blanket authority or not would have changed that score. So it is an issue. And as I said, it is a very difficult thing, forecasting receipts, and also the clearing costs. But I don't think the blanket authority is what is actually creating the problem there.

The Chairman. All right.

Mr. Pearson, do you have any comment on this? Do you care about this issue?

Mr. Pearson. I don't have any comment to add any further, no.

The Chairman. All right. Well, I just think we worry up here about losing the incentive to do a lot of this work if we

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don't get a score out of it. I think that is a driving force really.

We want to continue to make spectrum available, don't get my wrong. But you have to put a lot of work into a lot of issues, and I am afraid if we give blanket authority, CBO is going to say: Well, there went your money in the future, and that 54 billion you have identified may be there, but you don't get to count it. And we have things we are going trying to get done.

So I think it does present -- Mr. Adelstein, do you want to --

Mr. Adelstein. One thought for CBO is that the Guthrie-Matsui bill would allow an auction otherwise the chairman is saying can't take place. So it seems to me, if CBO is being accurate, they should give a very good score to that, because that auction for high frequency bands could yield a very large sum for the Federal Treasury.

The Chairman. And just one, maybe, for the record, because I know my time has expired. But is anybody looking at -- I heard a discussion the other night about, literally, AM radio side bands and new technology to do compression on the down wave side that doesn't get counted.

Is anybody looking at that? Are you aware of any of that?
All right.

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It was an interesting new theory. Thank you.

No, no, no. I was hoping to get more information.

Thank you, Madam Chair.

And thanks again to our witnesses for being here.

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RPTR TELL

EDTR CRYSTAL

[10:58 a.m.]

Mrs. Blackburn. The chairman is reminding us that he has that broadcast knowledge and information.

Okay, Mr. Welch, 5 minutes.

Mr. Welch. Thank you very much.

Mr. Adelstein, I think I will start asking questions to you.

When you describe what the potential benefit is in rural America, that is really the heart of my concern, because we have to have the build-out in rural America. We don't have it. Mr. Latta and I have started a bipartisan caucus, the Rural Caucus.

And the real issue here is, frankly, my skepticism that the investments that will be required for 5G will be made in rural areas. And specifically, as I understand it, you need more towers with 5G. They don't have the penetration powers, the signal penetration is shorter, and it is much more vulnerable to obstacles.

So the worry I have is that the same cost-prohibitive obstacles to build out in rural areas under existing technology will persist with 5G technology. So can you address that major concern and how those of us who do represent rural areas can be

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just absolutely certain we are not going to get the short end again?

Mr. Adelstein. Well, I think you identified a very legitimate issue. I mean, basically the biggest problem with rural deployment is economics. The industry builds to where there is demand, and they build where there is a return, especially when it is very costly to build these networks and there --

Mr. Welch. No, no, we all understand that. It doesn't pay economically. So what do we need for build-out rules if, in fact, the rural America is going to get the benefits that you described are right there if we have the system in place?

Mr. Adelstein. Well, every dollar spent on needless regulation is a dollar that can't be spent on rural America. There is limited capital budgets. And so if we are getting caught up --

Mr. Welch. Wait. No, no. Wait. I get it on regulation. But you said something that is obviously true. If the market isn't there, it is sort of like electricity, there is no incentive, regulation or not, for an investor to go to rural Vermont as opposed to urban Burlington, let's say, right? That is just economics.

So there has got to be some public policy. And let's assume we have a favorable regulatory system, as you see it, because I

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don't want extra regulations. How do we guarantee that there will be build-out in rural America when there is no money in it for the big players?

Mr. Adelstein. The primary mechanisms for policy are the Universal Service and the Rural Utilities Service that work in concert. As a matter of fact, when I was administrator of the Rural Utilities Service we provided a grant to VTel in Vermont that was --

Mr. Welch. So what would we need? I mean, look, all of us here represent rural America, okay, and this is a problem. So let's just say we agree on regulations because we don't want to make it more expensive, but there has got to be some money that goes into it without the rural America having to beg for everything. I mean, are we entitled to the same level of services in urban areas or not? That is the question.

Mr. Adelstein. Well, the Communications Act says comparable service and comparable rates, and that is the purpose of Universal Service. So it is in this committee's jurisdiction to try to ensure that Universal Service builds it out.

Mr. Welch. Right. But, actually, I loved your testimony, but you are not reassuring me, because I am asking the "how" question.

All right. Dr. Bazelon, how about you?

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Mr. Bazon. So there are lots of benefits to living in rural areas. One of the costs is that some things cost more there. When there is a public policy to make sure that is provided to rural areas the government is going to have to step in and assure it.

Mechanisms in the past where there have been internal cross-subsidizations from urban to rural areas have been shown to be rather costly, and we have moved away from that model to more directly, if you want to create demand in a rural area, you subsidize the cost to providing the service. Once that is in place, though, and there is demand from people in rural --

Mr. Welch. How do we get it in place? I mean, the build-out expenses, as I understand it, in rural areas is going to be high, and there is not going to be the incentive for the investors to do that because they don't get their return.

So how do we avoid making the same mistake? A lot of rhetoric about the benefits of this build-out in rural America but no follow-through.

Mr. Bazon. It is a Universal Service-type program where the difference in the cost of serving those customers and what is considered a reasonable price needs to be made up from other users or from the public. So that will create the demand. With the demand the carriers will come and build to them.

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Mr. Welch. Mr. Pearson.

Mr. Pearson. Well, the only thing I would like to add to the discussion is when you say it is going to cost more to build out a 5G in these areas, really when you look at building out 5G, if you lose the low bands or the mid-bands, it is not necessarily more costly to go. We already have one carrier that got spectrum from the 600 auction, and they have said that they are going to build out 5G in that band, and it carries waves that will cover --

Mr. Welch. All right. My time has expired.

I just want to say one thing, Madam Chair. I think we need, those of us who represent rural America, some concrete build-out rules that can give us concrete confidence that somehow, some way, the system is going to serve rural America.

I yield back.

Mrs. Blackburn. So noted.

At this time, Mr. Lance, you are recognized, 5 minutes.

Mr. Lance. Thank you, Chairman.

Dr. Bazon, Congress, and specifically this committee, recognized the need to address more commercial spectrum that resulted in the 2012 Spectrum Act, and it spurred three auctions. Now that these auctions have run their course, is it your view that we need a new spectrum pipeline initiative to meet America's future spectrum needs?

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Mr. Bazon. As I think has been pointed out numerous times, it takes a long time from when an idea becomes law even to the time that the spectrum is reallocated, so the sooner we start the better. But, yes, we need more spectrum. We should be thinking not just about the next 5 years but the next 10 and 20 years of how we are going to transition incumbent users out to be able to make frequencies available.

Mr. Lance. Thank you very much.

In your recent paper you noted there is skyrocketing global demand for mobile wireless services. And with the coming of 5G it is important to find spectrum to fuel that growth.

The two bands you discuss are complementary to AWS-3 spectrum, which was auctioned for over \$40 billion. You estimate the two bands you have discussed could auction over \$62 billion. What drives the price so high for these particular bands?

Mr. Bazon. In this case I actually start with the prices paid and the AWS auctions and reduce them a little bit to recognize that increased supply would reduce prices. In the case of this auction, there is about twice as much spectrum being auctioned, but I am only estimating about a 50 percent increase in price.

Mr. Lance. Would you insist that they be auctioned together?

Mr. Bazon. The current estimate is based on the idea that

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they are auctioned together and paired so that you have the uplink, downlink architecture in place, and I think that is still the highest valued use for the spectrum. At some future time, and it depends how far in the future, that may not be as important, but for now I think if you want to maximize the value you should pair them.

Mr. Lance. How would the mid-band spectrum identified by the Commission in its recent NOI fare in this type of auction in your opinion, Dr. Bazelon?

Mr. Bazelon. I am not sure which specific frequencies you are referring to, but the need, I mean, I think as many of us have said, the need for mid-band spectrum in this new architecture is going to be high.

This is the spectrum -- imagine in the denser areas, it doesn't have to be just urban but anywhere where there is enough people to deploy the high frequencies, there is going to be an expectation of large bandwidth, low latency, high connectivity, and as you move outside those areas you are not going to want your devices to stop working. That is actually going to put increased demand on these mid-band spectrum frequencies.

Mr. Lance. Thank you.

Mr. Pearson, as you mention in your testimony, several countries in Europe and Asia are taking concrete steps to make

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lower portions of the mid-band, specifically frequencies between 3 and 6 gigahertz, available for commercial 5G deployment.

Do you believe policymakers here in the United States, including us, are doing an adequate job to make similar bands available for 5G?

Mr. Pearson. I think we are making progress in the United States, and I think we need to do more. If you look at most of these countries, they are very proactive and aggressive in their planning processes and where they are directing their industry to go and their governments to go with the mid-bands, and specifically I would say the 3.5 band.

Recently I think we have made some steps here with the CBRS band to improve maybe the opportunity for investment in that, whether it is going to be LTE or 5G, and that is helpful. But I do think we need to do more in the United States, if you look at the competition from around the world and what they are doing, and the economies of scale that are going to happen in that band.

Mr. Lance. Thank you.

And, Chairman, I yield back 40 seconds.

Mrs. Blackburn. The gentleman yields back.

Ms. Matsui, you are recognized.

Ms. Matsui. Thank you, Madam Chair.

Congressman Guthrie and I recently held a Spectrum Caucus

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event on 5G, and we had a great panel made up of leading wireless providers and a leading chip manufacturer, a leading software company, and a small rural wireless carrier.

Now, 5G will include spectrum but also rely on advanced chip sets, software capabilities, and other innovative technologies.

Mr. Bazelon and Pearson and perhaps Mr. Broecker, do you think that blockchain, since you mentioned it, also will play a role in 5G and, specifically, to make efficient use of spectrum sharing?

Mr. Bazelon. I haven't examined the use of blockchain in spectrum sharing. Clearly mechanisms that allow more users to share the same frequencies are going to increase the productivity of band to spectrum, and as demand on spectrum is increasing, anything that will help in that way will be useful. But I wouldn't want to comment specifically on blockchain.

Ms. Matsui. Right. We are at the beginning stages then is what you are saying with that. Thank you.

Would you like to comment on that.

Mr. Broecker. I can't tell you what the technical details are around blockchain, but I can tell you that it is going to be an important technology, just like the internet. The internet is the portal for communication and information, and I think blockchain will be the internet of value and asset exchange.

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And so I think that the technical details are still -- blockchain is a still a cumbersome technology. But there are other companies that are rapidly trying to advance that technology to make it more widespread. And so I think just basic infrastructure requirements will have to increase, and I think 5G will be a part of that.

Ms. Matsui. Okay. Great. Thank you.

And also things like advanced chipsets and software capabilities I believe will play an important role, too. Is that right?

Mr. Bazelon. It has been compared to magic, this technology. That is more true as time goes on.

Ms. Matsui. Okay.

I know we have been talking about the mid-band spectrum, but it has unique propagation characteristics that make it ideal for reliable satellite distribution and particularly valuable for terrestrial mobile use. Wireless, fixed wireless, satellite services, and others have identified certain mid-range bands as ideal for 5G operations. But we know there is considerable disagreement over the best mechanism to enable 5G deployments to utilize the spectrum, including in the C-band.

Mr. Bazelon, what would a market-based incentive that would allow incumbents to voluntarily clear portions of this band look

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like?

Mr. Bazon. So I understand that a joint proposal by Intel and Intelsat was put forward that would allow the incumbent users -- give them the authority to negotiate with new terrestrial wireless users. And although I have worked with those companies on this issue, I have not developed -- worked on developing the mechanisms.

But the principle behind it, that the incumbent users will benefit from their efforts of participating in the process and making the spectrum available I think is the key part to having it happen in a timely manner.

Ms. Matsui. So you think it is possible to devise rules for these bands so that you can protect incumbent operations while also allowing mobile broadband use?

Mr. Bazon. Yes. I mean, in some cases it is about, say, cordoning off geographic areas that are going to be protected. It may be about taking an earth station out an urban area and moving to it a rural area and then connecting it back with a fiber optic cable and that way you are able to geographically partition the spectrum.

These are really all quite complicated issues with how this band could evolve, and it is the incumbent satellite carriers and the new terrestrial wireless carriers that will know best how to

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work that out.

Ms. Matsui. One of the spectrum bands the FCC is examining in its mid-band inquiry is -- wait a minute. No, I want to go this one here.

The Citizens Broadband Radio Service, the 3.5 megahertz band, as co-chair with Representative Guthrie of the Spectrum Caucus, we are very focused on the opportunity that this particular band will offer. A mix of low-, mid-, and high-band spectrum is necessary both for wireless coverage today and to build network capacity in the future; 3.5 gigahertz can be a significant component of mid-range bands that facilitate 5G network deployment.

Mr. Pearson, do you think there is a way to ensure this band is open to every innovative wireless opportunity it intends to promote?

Mr. Pearson. Yeah. Number one, I think when you talk about the opportunity for that band in 5G, it is a band that, again, is a great emphasis if you go around the world.

Now, as far as the improvements that can be made in that band for investment, I mean, from a mobile wireless industry side, I think we need, as we have seen, longer license terms, larger geographic areas, and so forth, and the expectation of renewal on those licenses. That is where you get investment in our industry.

And if you go around the world there are very few other

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geographic or other countries that have some of the issues that we have with the Navy radar and so forth. So they are looking at that as pretty much clean spectrum of them moving forward with for 5G.

Ms. Matsui. Okay. Great.

Thank you very much, and I yield back.

Mrs. Blackburn. Mr. Shimkus, you are recognized, 5 minutes.

Mr. Shimkus. Thank you, Madam Chairman.

I am glad Peter Welch is still here, and I hate to say he is right sometimes, but all he does is kind of give voice to frustration in rural America that we just don't get there. But I would also argue that there are still some regulatory issues with maintaining copper wires that we should have a discussion about, reforming the Universal Service Fund. I think Mr. Adelstein talks about RUS.

I mean, there are tools, it is just we have got to refine those, and I would be happy to work with you on those things. So it is very frustrating out there.

Ms. Santosham, I mean, the real debate for me is industry getting in or the concern of municipalities blocking. So how large is San Jose?

Ms. Santosham. It is a little over a million people.

Mr. Shimkus. And these other communities are now

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part -- they must be smaller. Do you know the size of the Kansas --

Ms. Santosham. Lanexa and Valdosta. I think Valdosta is about 40,000. I am not sure about Lanexa.

Mr. Shimkus. Okay. And so your 5G, for lack of a better word, desert, or areas that you want to go to that are not served, the Latino community that you were mentioning, do you know the population area of that.

Ms. Santosham. I don't, but I am happy to get back to you on that.

Mr. Shimkus. My basic point is that is probably bigger than most of my communities. That area that should be of your concern. I am not saying as a municipal leader. If I was a municipal leader I would be concerned about that. And sometimes in rural America that is bigger than -- I have a county that only has 5,000 people in it.

So it goes to that debate of how do you get there and get deployed. This is a different era than coaxial cables and access to poles, which is kind of how this original -- how did municipalities then give right-of-ways, leverage for dollars and access, versus affixing pizza boxes or refrigerators in local communities to provide this service.

So in 2009 the FCC said we should have a shot clock to help

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some deployment, and that shot clock was -- the Supreme Court supported that in a decision in 2013 and which is kind of the law of the land.

But, Mr. Adelstein, even with the shot clock and the ruling and with the Supreme Court, are you still perceiving that there are problems in market entry?

Mr. Adelstein. Well, there is still a problem with the shot clock if it is not deemed granted at the end, because you have to go to Federal Court, and then it is an endless loop that you end up there.

This committee was responsible for, as I mentioned, enacting 6409(a), which allowed the FCC the authority, clear authority to say at the end of the process, if a locality won't allow a colocation, it is going to be deemed granted, and that means it gets done. We haven't had any pushback on that.

But on these other shot clocks we have had numerous examples. As a matter of fact, the tendency is for the community to go beyond the shot clock and for our industry not to sue because we know we will be back at that community again later, and we know that the Federal court mechanism is not a particularly effective one. So we could use additional authority of the FCC to allow for deemed granted.

Mr. Shimkus. And how would you -- so, I mean, I guess you

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answered it. Deem granting would be the provision that you think would help in that.

Ms. Santosham, you wanted to commend on that.

Ms. Santosham. Yes, I just want to take a little bit of a step back.

So the infrastructure that we are talking about now to deploy 5G is largely light pole infrastructure, infrastructure that is traditionally used for lights, maybe you put a banner up, right? They are not always structurally sound to put a heavy piece of equipment on, and they oftentimes need remediation.

Mr. Shimkus. That is true, but if I may, in previous hearings here we had talked about the ability of some of these things to be placed on the side of buildings.

Ms. Santosham. Yes, but by and large it will be mostly street lights because of the density that you need to deploy the networks. And so when communities -- when we say that the communities are taking a little bit longer it is partially because we are taking this 200-year-old infrastructure and then we have got to change the way that we have permitted and used that infrastructure.

Mr. Shimkus. I only have 12 seconds left, and I appreciate that. I guess what we are trying to find is we need to have a balancing act. You want your folks to have 5G. We want our folks

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to have 5G.

Mr. Adelstein.

Mr. Adelstein. One quick point on San Jose. The State of California enacted a deemed granted remedy for shot clocks. So San Jose is under that. And so if California can do it, the United States can do it.

Mr. Shinkus. Thank you, Madam Chairman. I yield back.

Mrs. Blackburn. Mr. McNerney, you are recognized for 5 minutes.

Mr. McNerney. I want to thank the chairlady for the hearing. And I thank the witnesses. It has been interesting to hear what you have had to say.

Mr. Pearson, in your written testimony you emphasized the importance of U.S. leadership in the global race for 5G. At a hearing earlier this fall we heard that the Sinclair merger could delay the repack of the 600-megahertz band, slowing down 5G deployment and U.S. competitiveness.

Do you agree that it is important the FCC not take steps to delay the clearing of spectrum for 5G? Do you believe that that would hurt us?

Mr. Pearson. I think that we should do everything we can to clear the spectrum to put it to the best use, in this case mobile wireless. I think connecting society is some of the best uses.

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Mr. McNerney. So the Sinclair merger, which may delay that, would be an impediment in this case?

Mr. Pearson. I would have to research that.

Mr. McNerney. I know you are not an expert on that. I just wanted to make that point. Thank you.

Where are we in the standards-making process for 5G?

Mr. Pearson. In the standards?

The standards are making great progress. What we are actually looking at is a draft of the first release of what is called -- I don't want to get too technical -- but of a first release of 5G at the end of this year. So everyone will know what kind of chipsets and silicon to start producing.

That will be completed in early 2018. The second phase of 5G will then be December of 2019, just in time for ITU to do their blessings in 2020.

Mr. McNerney. So is cybersecurity being taken into account in the standards process?

Mr. Pearson. Pardon me?

Mr. McNerney. Cybersecurity, is that a significant part of the process?

Mr. Pearson. Yes, it is. It is part of it. 3GPP has two different areas that are working on -- well, actually several, but several areas that are working on that and security is a mainstay

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for our industry, as well as the standard.

Mr. McNerney. Okay.

Ms. Santosham, in your written testimony you noted that the city of San Jose has deployed an Internet of Things network. How important is IoT data security, for example, that devices be patchable and downloadable?

Ms. Santosham. It is incredibly important. You know, data is the new oil, and cybersecurity is incredibly important to our cities. Cities will be obviously a target for cyber threats. And privacy is also of concern.

Mr. McNerney. Good. I personally believe that digital device security is critical and that we are late in the game on this process.

Earlier this year I introduced the Securing IoT Act, which would require that cybersecurity standards be developed for IoT devices and that those devices be certified. I hope that the committee takes up this legislation soon.

Ms. Santosham, I am aware of the many benefits that the 5G has to offer, including faster speeds, but I am worried about the costs. For my constituents, there is a real concern because more than 21 percent of my households earn less than \$25,000 a year. How do you expect the 5G deployment to impact the cost of wireless services?

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Ms. Santosham. Today there are no guarantees that cost to consumers will go down, and cost of service and cost of devices are the top two barriers to digital inclusion. And I think when we are talking about subsidizing infrastructure deployment rates for large corporations we should be asking for something back.

Mr. McNerney. Well, you mentioned, I think, you had 75,000 residents that don't have broadband access in San Jose. If the Federal Communications Commission eliminates the Lifeline program today, how would that impact these and other residents in San Jose?

Ms. Santosham. Twenty-nine percent of our low income residents only have access to the internet through mobile phones. And so if Lifeline goes away that will have a significant impact on their ability to be connected.

Mr. McKinley. Thank you. That is what I thought.

Mr. Adelstein, you testified that the U.S. is in a position to retain our lead moving into 5G. Could you explain what that means exactly? What does it mean quantifiably that we have a lead in 5G?

Mr. Adelstein. Well, the important thing is that other countries are making it very easy to move forward. In Japan and Korea, for example, that are moving quickly toward 5G, they could site anything, anywhere, any time. And I am not saying we need

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that here because we have always worked in close partnership with localities, but some unreasonable impediments are going to slow down the deployment.

Mr. McNerney. What does leadership mean? What does that mean?

Mr. Adelstein. Usually it would mean that we would be the first to implement the network. We would be ahead in terms of the chipsets, as we already are with our leading chipset manufacturers. We would be ahead with the devices that we get into the hands of consumers.

Mr. McNerney. I mean, could we include rural access as a part of that definition of leadership in this field?

Mr. Adelstein. Ideally it would. I mean, we talked earlier about the issues with rural, which is expensive. I mean, the greater costs you have to deploy this, the less likely we are to get to rural and the longer it will take.

I mean, rural historically has been the last to get these devices, and it is unfortunate, but the costs are extremely high to provide this type of network. And we need to do everything we can to lower those costs to allow that capital budget that the companies do have, which is the largest of any industry, 30 billion a year being invested, and a lot of that in rural America.

Mr. McNerney. My time has expired, and I am sure the chair

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is anxious to move on. So thank you for the answer.

Mrs. Blackburn. The gentleman yields back.

Mrs. Brooks for 5 minutes.

Mrs. Brooks. Thank you Madam Chairwoman. Thank you so much for holding this hearing today.

Mr. Broecker, wonderful to have you here. You noted in your testimony the exponential growth of the Internet of Things, which we have talked about a bit -- smart devices, wearables, and sensors, and thank you for sharing with us the issue of the new discovery and use of the digital pill -- will increasingly be part of the delivery of care to improve patients' lives. We have had quite a discussion also about rural America.

How do you believe that these innovations are going to have the power to bring better care, better healthcare to patients in rural areas? I represent rural areas, as well, in central Indiana. And do you have any specific examples of scenarios where 5G can improve that doctor-patient relationship and improve the delivery of care in rural areas?

Mr. Broecker. Absolutely. You know, there is an emerging trend, and it is increasing, and it is the notion of telemedicine where patients don't actually have to go to a hospital or to a doctor's office and through internet connection and other technology-enabled solutions they can have a consult.

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There is robotic surgeries occurring where surgeons in completely different parts of the United States can be doing surgery in a hospital someplace else.

So as I mentioned in my testimony, healthcare is going to be driven less about place and more about the connection to a healthcare system, and that doesn't necessarily need to be right next door. I mean, it is great if it is, but there are going to be technologies and solutions and innovations that are going to allow people and patients and healthcare systems and physicians to be connected in completely different ways.

Mrs. Brooks. Switching gears a little bit to the focus that you put on automation of manufacturing and that 5G will result in even more automation, some become nervous about increased automation as it relates to jobs and the people on the manufacturing floor, so to speak. And we also know automation increases speeds and efficiency of manufacturing to create these jobs.

Are there any policy areas Congress should be looking at to help the workforce adapt as we continue to push and believe in the importance of implementation of 5G to the world of innovation, automation, and manufacturing? What should Congress be doing for the workforce and how do we help the workforce adapt?

Mr. Broecker. I mean, the general trend is toward STEM

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education and enhanced STEM education and starting early in a student's life, whether that is in grade school or high school and getting involved in things like robotics and getting familiar with technology. You can now do biology genome experiments in eighth grade, whereas before you needed to have a Ph.D. and be at MIT, where I went to school. These things are now possible.

But it really gets back to an educated workforce, starting with the next generation. But it also means skills and developing the skills amongst the current workforce to be able to do that.

You know, I said I started off in manufacturing, and I saw lots of innovation come over my 20-plus-year career. And the same debate was argued, you know, okay, we are going to get all these fancy pieces of equipment and machines to do the work. It never replaced people. At the end of the day it still took people overseeing, managing, making sure that the machines did what they were supposed to do. But it takes an educated workforce in order to do that.

Mrs. Brooks. Thank you very much.

I am going to yield back the balance of my time so others can ask their questions. Thank you.

Mrs. Blackburn. Thanks.

Ms. Eshoo, you are recognized for 5 minutes.

Ms. Eshoo. Thank you, Madam Chairwoman.

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And thank you to all of the witnesses. It is good to see Jonathan again.

And a very warm welcome to Ms. Santosham from San Jose, California. I think you gave very important testimony today. And I appreciate the warm words that you directed toward me, and I return them to you.

First, I want to make a couple of comments about the whole issue of 5G. I believe that it has -- it holds the potential for many benefits, and several of you have mentioned them, and how it will lead to competition and bridging the digital divide and unlock the Internet of Things.

So I think that it represents a real opportunity for all of us. And of course I always say I am not satisfied with America being 5th or 12th or 17th. I want us to be number one and lead the world in whatever it is, whatever the undertaking is, and whatever the sector is. And obviously we are all going to have to work together to move in a direction that is going to make this a reality.

But I am also concerned that there are some things that are being pushed aside in the race to 5G. And I want to associate myself with some of the comments that both our ranking member, Mr. Doyle, and also Mr. Welch made.

We have two problems, two big problems. And I think that as

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we move forward with this and any other initiative that has anything to do with spectrum, which is the gold in all of this, because there is an insatiable appetite for it, and as we continue to innovate, you have to have spectrum. Spectrum is the platform, it is the fuel that makes everything go.

But Mr. Welch spoke about one. How do we assure that there is accessibility in rural communities? No matter what we do, this issue keeps coming up. We are not making progress there. I mean, it is like the 10,000-pound gorilla in the room.

I also have concerns about how we are going to deal with local communities. I have a reverence for local government. I came from it. I spent a decade in local government. We cannot run roughshod over local government. And I think that there is, most frankly, a rush to do that.

In fact, what Mr. Doyle raised about how did San Jose get this reputation and this attack on them for being whatever, I don't know where that came from. But it seems to me, because you raised your voice about, wait a minute, we have to be considered in this, we have citizens that we need to respond to, and you can't just run roughshod over us.

So to Ms. Santosham -- first of all, I want to ask for unanimous consent to place in the record a New York Times editorial by the mayor of San Jose, Sam Liccardo, dated 10/3/17,

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Mr. Chairman.

Mr. Lance. [Presiding.] So ordered.

[The information follows:]

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Ms. Eshoo. Wireless providers have been accused of redlining certain neighborhoods, a practice that obviously exacerbates the digital divide. And I would like you to comment on that, but also tell us what the importance of cities like San Jose is implementing market-based infrastructure leases to ensure that private industry is enhancing broadband access for all communities.

It is not just San Jose. San Jose is speaking up. But they have an issue, and they are not rural, of 95,000 people in their city that have nothing. They have no access to it. This is the largest city in Silicon Valley.

So would you comment on that? Because I find that deeply disturbing.

Ms. Santosham. Yes. So, first of all, market-based rates and incentives are things we should all believe in. And there is a little bit of an irony that we as a city government are asking for market-based rates and the private sector is asking for cost-based.

And market-based rates allow us to incentivize buildouts, especially when we are allowed to build out entire communities. So we are able to say: Hey, here is all the space in the city we would like to build out, and we will give you a discount on some of this infrastructure if you are willing to go to the communities

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that need to be served.

And so I think that is what is missing in this conversation, is by speeding the deployment and running roughshod over local government you are then taking away the ability to shape and manage where deployment happens in communities so that communities benefit.

Ms. Eshoo. So is the BDAC the place where this will be decided?

Ms. Santosham. The BDAC? I don't think so, but I am concerned about the direction there because of the lack of representation both on the voting body and in the subgroups.

Ms. Eshoo. I wrote to the chairman about that. And I think if you have mostly industry people then it is just going to be weighted that way. I am not opposed to industry people, but you have to have some kind of balance in this. And that is another red flag.

Thank you to all of you.

I think, Mr. Chairman, that more work needs to be done in the areas that have been raised. They are legitimate concerns. I don't think it is a Republican or a Democratic concern. I think they are concerns that we need to build in solutions so that they are addressed.

And I think that then the promise that is being spoken of

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here today about 5G will be kept. Otherwise we are going to have another new generation but plagued with the same issues that we keep talking about.

So thank you. And I thank you for your patience in giving me extra time.

Mr. Lance. Thank you very much.

The chair now recognizes the gentleman from Pennsylvania, Mr. Costello.

Mr. Costello. Thank you.

Could all of you share a little bit about WiFi enabled by unlicensed spectrum and what role that may play in the 5G world?

Mr. Pearson. Well, if you look at the standard in what they are going to be doing in 5G, they are actually including unlicensed spectrum in the 5G.

Now, when you start specifically, you say WiFi, well, WiFi is actually integration -- has integration capabilities right now with LTE. There is also LTE in a license, again separate from WiFi.

So all of these things are being done for basically to provide the consumer the best experience they can. Sometimes it is anchored with what would be LTE today and at some point would be 5G. Sometimes it is specifically unlicensed, which would be only WiFi. And other times it is actually another type of

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aggregation tool of interoperating. But it is usually one or the other.

Mr. Bazon. WiFi is a very important access technology, and unlicensed spectrum is very important to allow for that. And there is clearly a lot of demand for it. And it should be something that grows. Whether or not it ends up being actually integrated in with the commercial mobile networks I think is just an open question.

Mr. Adelstein. Some of the high frequency spectrum that is being set aside is being set aside for unlicensed use, and that allows for individuals to use that to offload some of the demand that is going on in the broader networks that are being designed by the cellular industry. So it is very helpful to have unlicensed and licensed in a proper balance.

Ms. Santosham. I am going to defer to my colleagues here who know much more about the issue than me.

Mr. Broecker. Same.

Mr. Costello. We have heard a lot about State and local impediments to the deployment of wireless infrastructure. Is the same true for next-generation wireline infrastructure?

Mr. Adelstein. Well, fiber is a major part of 5G. I mean, 5G really can't function to its highest potential without fiber because of the latency requirements.

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So virtually every one of these little antennas is going to have a fiber connection. We are talking about potentially millions of antennas, if not hundreds of thousands. The estimates range between those. And so you are talking about very many antennas close to the end user, all of which require fiber connections.

So impediments to the deployment of fiber are impediments to the deployments of 5G. And we do see those. We see those as well as -- sometimes I think when the antenna gets attached at the end there is even more resistance for a number of different reasons from localities, even though they provide such a great opportunity for consumers and there is so much demand for it.

So we do need policies, such as Dig Once, that allow for a fiber deployment to take place rapidly, because I think we are going to see another huge build-out of fiber in the United States preparing for 5G.

Mr. Costello. So your testimony is that wireline equipment does also face delays in permitting and access to rights of way?

Mr. Adelstein. It certainly does, yes.

Mr. Costello. I have one more question. Can you, Mr. Adelstein, share with me your familiarity with the way that spectrum transactions between various companies and the need to be able to do through like kind exchange?

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Mr. Adelstein. The FCC has done a very good job of allowing for a very fluid secondary market in spectrum, and they readily approve transactions that are within the caps that they have placed that are informal. They can go beyond that if they have to. So they have really done a great job on a bipartisan basis and under both administrations of allowing for a very fluid secondary market.

I mean, our concern right now is getting more spectrum into market. And the issue is with 5G, you have understood there is this bill that is needed to get it done. Because we would like to see by December 2018 the opportunity for the FCC to hold an auction of these high frequency bandwidths. And if it is possible the chipsets will be ready by then, the equipment will be ready, the standards will be in place. So if we can get the Guthrie-Matsui bill through that would pave way for even more high frequency spectrum that could then be put into that mix.

Mr. Costello. Good. Thank you. I yield back.

Mr. Lance. Thank you very much, Congressman Costello.

Does anyone else on the committee wish to ask further questions?

Seeing there are no further questions from members, I thank our witnesses for being here today. It has been a very informative panel by a distinguished group of guests.

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Before we conclude, I ask unanimous consent to enter the following letters into the record.

The recently released white paper from the Brattle Group.

[The information follows:]

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

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Mr. Lance. A letter from Mayor Kevin Davis of Hardin County, Tennessee.

[The information follows:]

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Mr. Lance. And thank you, Dr. Bazelon, for the white paper.

Ms. Eshoo. Mr. Chairman?

Mr. Lance. Yes.

Ms. Eshoo. May I just add my best wishes to everyone here -- I know the committee is all gone, but in absentia -- for a wonderful Thanksgiving. We have much to be grateful for in our great and good country. So happy Thanksgiving.

Mr. Lance. Thank you, and I share that sentiment. And among the major holidays it is my favorite holiday because it is the traditional American holiday.

And to all in the audience, I certainly agree with Congresswoman Eshoo.

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 the questions.

Seeing no further business before the subcommittee today, without objection, the subcommittee is adjourned.

[Whereupon, at 11:40 a.m., the subcommittee was adjourned.]