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

HEARING

BEFORE THE

SUBCOMMITTEE ON COMMUNICATIONS AND TECHNOLOGY

OF THE

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HOUSE OF REPRESENTATIVES

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THURSDAY, NOVEMBER 16, 2017

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON COMMUNICATIONS AND TECHNOLOGY,
COMMITTEE ON ENERGY AND COMMERCE,
Washington, DC.

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, Loebsack, 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.

OPENING STATEMENT OF HON. MARSHA BLACKBURN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF TENNESSEE

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 serv-

ice, 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:]

PREPARED STATEMENT OF HON. MARSHA BLACKBURN

Welcome to the committee's first hearing this year devoted exclusively to the promise of fifth generation wireless service, or "5G," and to explore the potential impediments to its development and wide-scale deployment. It is imperative Congress tackle these challenges. This hearing is entitled: "The Race to 5G and its potential to Revolutionize American Competitiveness." Let there be no mistake, the race to 5G is on across the world; and as in any competition, one can either lead, follow, or get out of the way. As Chairman of this Subcommittee, I look forward to working on a bipartisan basis to ensure America is first to the finish line.

The promise of 5G cuts across diverse industries and sectors of the economy. The potential benefits include: enhanced mobile broadband that can provide speeds that are 10 to 100 times faster than what exists today; ultra-low latency communications that are necessary for mission-critical applications like autonomous vehicles and remote surgery; and the massive machine-to-machine communications that constitute the "Internet of Things." According to Cisco, there will be nearly 50 billion IoT devices connected by the year 2020. Taken together, the applications of 5G promise to revolutionize manufacturing, healthcare, transportation, city management, power generation and distribution, as well as law enforcement and emergency response.

As we gaze towards the promise of 5G, we must also be mindful of the impediments to its deployment. Potential speed bumps along the way pertain to the harmonization of international technical standards, the availability of spectrum, and the strangling red tape of small cell siting requirements at the federal, state, and local levels.

Importantly, we must keep in mind that 5G is only part of the communications landscape that will ensure our competitiveness moving forward. 5G networks will exist alongside LTE networks, unlicensed spectrum necessary for Wi-Fi, as well as traditional cable and landline networks, fiber optics, as well as satellite technologies. Each of these will continue to play prominent roles as our nation transitions to 5G wireless connectivity.

Information is power, and history makes clear that countries with the best communications have the highest economic growth, and a distinct competitive advantage. 5G will play a major part in continuing our nation's leadership in communications. I am pleased to convene this hearing to explore the promise of 5G, and to examine the challenges to its development and deployment. I look forward to the testimony of our witnesses.

OPENING STATEMENT OF HON. MICHAEL F. DOYLE, A REPRESENTATIVE IN CONGRESS FROM THE COMMONWEALTH OF PENNSYLVANIA

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 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 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: 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:]

PREPARED STATEMENT OF HON. MICHAEL F. DOYLE

Thank you Chairman Blackburn for holding this hearing and thank you to all of the witnesses for appearing 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 today, and reports of their plans to vote to repeal the Open Internet Order as part of next month's Open Meeting.

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Each one of these items is terrible in its own right and will have grave impacts on the public. I would urge the Chairman to delay voting these items and seek bipartisan consensus—and to chart a path forward that benefits all Americans and 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 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 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.

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 the 700 Mega-hertz auction. The iPhone had just been introduced, but the promise of smartphone technology and ubiquitous high speed access was still a dream. When Steve Jobs announced the iPhone, it had to be connected to Wi-Fi because 3G networks at the time weren't responsive enough. But today, nearly 80% of Americans' own smartphones and the global App economy has growth to be worth more than $1.6 trillion a year globally.

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On the other hand, I've 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 pre-empt local government with a heavy hand.

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

Mrs. BLACKBURN. The gentleman yields back.

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

OPENING STATEMENT OF HON. GREG WALDEN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF OREGON

Mr. WALDEN. 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?

OK. 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 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.

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

[The prepared statement of Mr. Walden follows:]

PREPARED STATEMENT OF HON. GREG WALDEN

Thank you, Madame Chairman. I want to welcome our witnesses to this hearing on fifth generation wireless technology, often called "5G," and its potential to revolutionize American competitiveness.

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 communications networks.

Mobile, cellular technology was developed in the United States first. We have seen it evolve from first generation networks that were only capable of voice service, to digital second-generation networks capable of voice and text, to third generation networks capable of voice, text, and basic Internet, to today's fourth generation LTE networks that unleashed true mobile broadband and video service. Approximately every 10 years American consumers have seen a generational leap in wireless connectivity and applications. Just as we were the first to deploy mobile technology, so we must be first to deploy 5G throughout the ecosystem of networks, services, and applications that constitute our communications architecture.

So, what is 5G? In short, 5G represents the next generational shift that will provide broadband speeds faster than existing wireless networks by at least an order of magnitude. It will do so by combining existing low- and mid-band spectrum with higher, millimeter-band frequencies previously thought to be unusable for mobile broadband. It is only through combining low-, mid-, and high-band spectrum that we can realize the full promise of 5G in urban, suburban, and rural areas.

It's been noted that 5G will enable enhanced mobile broadband, ultra-low-latency, and massive machine-to-machine communications. Examples of these benefits are in power generation and distribution through smart grid technology such as sensors on substations to report outages, as well as supply and demand readings on transmission lines that will allow dynamic pricing on smart home meters—potentially saving consumers hundreds of dollars annually on their power bills. We also anticipate increased efficiencies in the manufacturing sector through the application of 5G enabled sensors, controllers, and data analytics that allow for greater automation, predictive maintenance, and supply chain management.

One of the most prominent examples of 5G applications is in autonomous vehicles. Earlier this year, our committee, and then the full House, unanimously voted for the first self-driving car legislation ever considered by Congress—the SELF DRIVE Act. This bill is critical to the development and deployment of self-driving car technology, which has the potential to save tens of thousands of lives each year. But the regulatory certainty provided by the SELF DRIVE Act will depend on the availability of spectrum. If America is to win the race to 5G, then we must figure out how to make more spectrum available for commercial service in addition to the regulatory reforms and international harmonization necessary to making this technology a reality.

Lastly, and most importantly, I want to emphasize that 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 (FCC) to deposit upfront payments from prospective spectrum auction bidders directly with the Treasury. Current law prevents the Commission from doing 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 stand-alone legislation to do the same

thing. Let me be clear: absent a change in law, the FCC cannot hold any auction of consequence to bring about the 5G revolution. We must all work together on a bipartisan basis to change the 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.

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.

OPENING STATEMENT OF HON. FRANK PALLONE, JR., A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW JERSEY

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 Web sites 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 Web sites are designed to work well on mobile devices.

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 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:]

PREPARED STATEMENT OF HON. FRANK PALLONE, JR.

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 the potential to do all three.

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With that, I thank the witnesses, and I would like to yield one minute of time to Congresswoman Matsui and one minute of time to Congressman McNerney.

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.

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.

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

Mrs. BLACKBURN. The gentleman yields back.

Mr. WALDEN. Madam Chair.

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

Mr. WALDEN. 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.]

Mr. WALDEN. 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 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:]

PREPARED STATEMENT OF HON. SUSAN W. BROOKS

Thank you, Mr. Chairman.

I'm thrilled to be here today for this important hearing and would like to thank all of the witnesses for being here. I'm especially thrilled to have a Hoosier witness here, David Broecker, from the Indiana Biosciences Research Institute representing the great innovations occurring in our state.

I have become increasingly engaged on efforts to empower 5G for a number of reasons. I'm proud that Indiana is one of thirteen states that have enacted state legislation to streamline the deployment of small cell networks, Indianapolis is an AT&T test site for 5G evolution build-out, and we have brilliant leaders like David working to innovate and build our communities.

As the saying goes, innovation waits for no one, and for our economy to move at the speed of innovation, we must support new and emerging technologies. I recently co-founded the 5G Caucus with my colleague Congresswoman Debbie Dingell as a means to educate members and staff about how 5G will revolutionize our communities and the role we, as policymakers, need to play to empower 5G. Unfortunately, Congress isn't known for moving fast, and it is difficult for Congress to keep up with the speed of innovation.

Establishing a pipeline of new spectrum auctions to help meet America's mobile needs, promoting infrastructure reform to unlock tens of billions in 5G investment, and ensuring that wireless operators have rights to access municipal infrastructure in a timely manner are all key aspects as we work to unleash the power of 5G. Any regulations we consider should act like guardrails—not roadblocks or speed bumps—so that 5G pioneers can create the next generation of advancements within the guardrails—instead of having to navigate around a roadblock that would stifle or even prohibit technologies that improve the way we live our lives.

5G means the opportunity for faster emergency response times that can save lives, smart cities, remote surgery, and unleashing the potential of the anticipated 50 billion new internet of things connected devices coming online by 2020.

I look forward to leading with Congresswoman Dingell on this issue and working together to advance sound policy that unlocks the economic potential of 5G and maintains and strengthens US leadership in next-generation technology.

PREPARED STATEMENT OF HON. LEONARD LANCE

Thank you Madam Chairman and welcome to our distinguished panel. Thank you for being with us here today.

Wireless services have come a long way over the last 50 years. The jump in capabilities from the first iteration of cellular technology, developed largely from the work done at Bell Labs in New Jersey, to the current 4th Generation LTE has been immense. However, these past innovations pale in comparison to the potential 5G has to revolutionize wireless communications. From improved data rates and speeds for consumers, to commercial applications in industries such as health care, agriculture, energy, education and manufacturing, 5G's potential applications are almost limitless.

As countries around the globe compete to lead in 5G, the district I serve is a hub of 5G development, thanks to the companies such as Verizon, AT&T, Nokia, Qualcomm and Samsung. Because of companies like these, New Jersey is leading the effort to maintain the United States as the leader in wireless innovation.

American companies have already invested billions of dollars into 4G LTE and as they continue to invest in 4G, they have promised to invest hundreds of billions more in 5G. According to a recent report by Accenture, Americans will use five times more mobile data in 2021 than they do now. 5G has the potential not only to help networks manage this unprecedented data demand, but also to add over 3 million jobs in the next seven years and support 22 million jobs by the year 2035.

However, private investment alone will not win us the global race to 5G. Policymakers in Congress and the Federal Communications Commission must pursue policies to create regulatory regime that is conducive to the deployment of 5G infra-

structure and ensure there is sufficient spectrum available for commercial use to meet future needs. We must help facilitate innovation by fueling the spectrum pipeline and removing regulatory barriers to deployment.

Wireless networks are complex and require a mix of different types of spectrum to meet coverage and capacity requirements. As our demand for wireless connectivity continues to skyrocket, the FCC and Congress must examine spectrum use in high, mid, and low bands.

Thank you again for being with us here today and I look forward to your testimony and discussion on this important topic.

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.

STATEMENTS OF CHRIS PEARSON, PRESIDENT, 5G AMERICAS; COLEMAN BAZELON, PRINCIPAL, BRATTLE GROUP; JONATHAN ADELSTEIN, PRESIDENT AND CEO, WIRELESS INFRASTRUCTURE ASSOCIATION; SHIREEN SANTOSHAM, CHIEF INNOVATION OFFICER, CITY OF SAN JOSE; AND 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 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, 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 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.

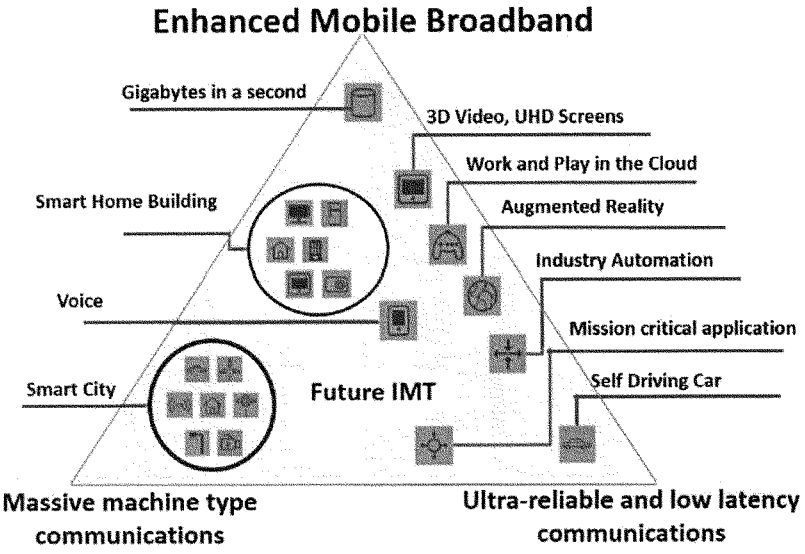
Additionally, 5G Americas supports the FCC's order on eliminating separate historic review for replacement poles. 5G Americas urges the FCC to do even more to eliminate unnecessary reviews in rights-of-way without affecting the historic areas.

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

[The prepared statement of Mr. Pearson follows:]

5G Americas is pleased to address the Communications and Technology Subcommittee on "The Race to 5G and its Potential to Revolutionize American Competitiveness." The mission of 5G Americas is to advocate for and foster the advancement and full capabilities of LTE wireless technology and its evolution beyond to 5G throughout the ecosystem's networks, services, applications and wirelessly connected devices in the Americas. 5G Americas is a Market Representative Partner of the standards forum 3GPP, where 5G is being standardarized, and works with regulators and associations around the world to foster deployment of wireless technologies. 5G Americas represents operators and vendors from around the region, not just in the United States. 5G Americas' Board of Governors members include América Móvil, AT&T, Cable & Wireless, Cisco, CommScope, Entel, Ericsson, HPE, Intel, Kathrein, Mavenir, Nokia, Qualcomm, Samsung, Sprint, T-Mobile US, Inc. and Telefónica. 5G Americas represents our region in the Global 5G Event, held biennially in countries in Asia, Europe and the Americas that are dedicated to winning the race to 5G.

Leading countries within Asia and Europe understand that 5G will revolutionize their competitiveness. We are pleased the Subcommittee is also examining this link. 5G Americas believes the deployment of 5G use cases will indeed revolutionize American competitiveness. 5G – or the Fifth Generation of wireless broadband - is actually comprised of three broad areas of use cases, or applications: enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC) (also known as Internet of Things or IoT) and Ultra-Reliable Low Latency Communications (URLLC). The image below diagrams this 5G triangle, which helps to demonstrate the broad impact on global competitiveness 5G will have:



From autonomous, connected cars, to augmented reality in manufacturing, massive IoT deployments, smart cities and smart homes, 5G deployments will enhance productivity, contributing to Gross Domestic Product increases. 5G applications will have important societal benefits as well, such as remote surgery and robotic care for shut-ins or the elderly. Hearing or visually impaired citizens will be more mobile through the use of self-driving cars and smart, safer homes. The Subcommittee should understand that many of the productivity and societal benefits of 5G will be available in the immediate and near-term in use cases made possible by 5G's foundation, LTE Advanced and LTE Advanced Pro.

The economic benefits of 5G have been estimated by several analysts, including Accenture, which concludes that 5G could add $500 Billion to the U.S. GDP, through $275 Billion in investment, resulting in 3 million new jobs, and result in savings and other economic benefits to local communities of $160

Billion.[1] With the right spectrum framework and expediting local permitting, 5G could add $1.2 Trillion in long-run consumer benefits, according to the American Consumer Institute.[2]

The Energy & Commerce Committee has historically led the process for repurposing spectrum to a more economic use, whether from one commercial use to another, or from government to commercial use. Repurposing additional spectrum is the best way to ensure the U.S. will continue to lead the race to 5G, whether through additional spectrum auctions or government sharing. The U.S. led the way in 4G because it made newly accessible spectrum available at 700 MHz, through this Subcommittee's efforts to repurpose the broadcast spectrum in the band, transitioning broadcasting to the more efficient digital television of today.

This Subcommittee is familiar with the growth in wireless broadband. Our members forecast that the mobile data traffic in just three to four years out will be 7-8 times more than today.[3] The mobile industry continues to improve the spectral efficiency of wireless broadband technology, including through antenna, filter, virtualization, slicing and interference cancellation technologies. But ultimately, accommodating 7-8 times more mobile traffic will require more spectrum. Ideally, most of the new spectrum will be in licensed bands, with additional unlicensed spectrum used to offload traffic from licensed bands. Licensed spectrum can offer a guaranteed level of service, and facilitates the operator's congestion management and load balancing. Licensed spectrum traditionally has been mutually exclusive, and therefore subject to auctions under the Communications Act.

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[1] Accenture Strategy (January 2017).
[2] American Consumer Institute Center for Citizen Research (ACI), available at https://www.techrepublic.com/article/how-5g-could-add-533b-to-us-economy-by-2024/
[3] Ericsson Mobile Report June 2017; Cisco VNI Mobile, 2017.

For this reason, 5G Americas supports Rep. Guthrie and Rep. Matsui's Spectrum Auction Receipts legislation, which the Commission needs enacted to hold any further spectrum auctions, and urges the Committee to act on that quickly, as well as encourage a companion bill in the Senate.

Spectrum sharing is another opportunity to make sufficient spectrum available for 5G, particularly where for an array of reasons, relocation of government or commercial incumbents is unusually challenging. Incumbents that don't utilize their spectrum very often in both the temporal or geographical domain could share those channels with mobile services when the incumbent is not operating. As the Committee considers spectrum policy, it should bear in mind that future spectrum should be allocated in bands where it can provide the most benefit to wireless consumers.

It is now widely understood by policy makers such as Members of the Subcommittee that all ranges of spectrum will be needed for 5G applications and services. No single band will provide a complete solution for 5G requirements, given the diversity of future applications and their requirements for wider bandwidth, reduced latency and extended coverage area. Adequate amounts of low, mid- and high-band spectrum will be needed, and necessary to win the *Race to 5G*. Spectrum from 3 – 6 GHz easily supports mobility, and provides a balanced mix of bandwidth and coverage, something that high and low-band frequencies alone can't offer independently. Most of the frequency ranges below 6 GHz are suitable for all deployment scenarios, because of low and mid-band's wider coverage. The lower part of the new "Mid-Band", the 6-24 GHz range, can be used in similar scenarios as the spectrum below 6 GHz, and the upper portion has similar characteristics as the spectrum above 24 GHz.

Very high frequencies in the millimeter waves (30 GHz) support higher data rates, and the lower frequencies (1 GHz and below), with their ability to penetrate walls, ensure reliable indoor services. The propagation characteristics of spectrum in the 24-86 GHz range are suitable for certain applications, mainly outdoor hotspot and indoor micro and pico-deployment environments. The possibility of

identifying bands within the 24-86 GHz range for wireless broadband is currently being studied by the United Nations' International Telecommunication Union ("ITU") for decision at the next World Radiocommunication Conference in 2019 (WRC-19), as well as by the FCC in its *Spectrum Frontiers* proceeding. Because of its allocation of mmW spectrum thus far, the FCC has positioned the U.S. very well for the WRC-19 negotiations.

Infrastructure

As 5G Americas noted in a filing to the FCC on wireless broadband infrastructure, a streamlined small cell siting is critical for U.S. leadership on 5G. Our federalism has been a benefit in so many areas of economic activity. But other nations, particularly those focusing on 5G, have a more top-down approach in communications policy. Japan, South Korea and China all have uniform, streamlined processes for cell siting. The European Union, which has some of our challenges in federated action, is working on a model code for cell siting.[4] Congress in its oversight and legislative capacity should ensure that the Commission take necessary steps to accelerate 5G deployment, and to provide additional tools, if needed, to preserve the U.S. lead in deploying advanced networks.

While American innovation has flourished in our decentralized, market-oriented governance, when it comes to government siting processes, the more efficient the better. Accordingly, 5G Americas supports the FCC and other stakeholders' work at its advisory council, the Broadband Deployment Advisory Counsel, in recommending model codes for state and local government siting of broadband stations like small cells. As necessary, should that effort not result in the streamlined siting required for the U.S. to lead in 5G, 5G Americas supports this Congress or the FCC establishing national standards for the siting

[4] EUR. PARL. DOC. (COM(2016) 590—2016/0288 (COD)).

of small cells needed for 5G network densification. Additionally, 5G Americas supports the FCC's proposed order on eliminating historic review for replacement poles to support wireless antennas. 5G Americas urges the FCC to do more to eliminate unnecessary reviews in rights-of-way and in other areas with no possibility of adversely affecting historic properties.

The Global Race to 5G

The *Race to 5G* will be won in the countries that have allocated the most useful spectrum for 5G. To date, countries in Asia and Europe have identified bands in the mid-band range of 3.4-3.8 GHz and in either the 26 GHz range or 28 GHz range. Because of the identification for 5G in that mid-band range in leading countries around the world, 5G Americas advocated to the FCC that it revised the existing rules for the 3550-3700 MHz band to make the licenses 10 year, with market-size licenses, and power limits that encourage investment for 5G. Accordingly, 5G Americas is pleased with the Commission's Notice of Proposed Rulemaking that propose these changes.

Below is a review of the what other regions are doing in their race to 5G:

Europe

Europe's Radio Spectrum Policy Group (RSPG) is a high-level advisory group that assists the European Commission in the development of radio spectrum policy. The RSPG developed an opinion on spectrum bands for next generation wireless systems (5G) as agreed to in the RSPG Work Programme for 2016. The opinion was finalized November 2016 and identified a strategic roadmap for 5G in Europe. In particular, the roadmap identified the following main building blocks for 5G spectrum: 1) Medium bandwidth spectrum at 3.4-3.8 GHz as a "primary" band, which will provide capacity for new 5G services and 2) High-bandwidth spectrum at 24.25-27.5 GHz as the "pioneer" millimeter wave band to give ultrahigh capacity for innovative new services, enabling new business models and sectors of the economy to benefit from 5G.

With respect to individual European countries, **France's** spectrum regulator announced plans to allocate spectrum for 5G by the September 2017 timeframe in the 3400-3800 MHz range. The plan is to establish band plan allocations of more than 300 MHz of contiguous spectrum by 2020. Additional reorganization is planned to extend the amount of spectrum to 340 MHz by year 2026.

Germany's federal network regulator published a framework document on June 28, 2017, with plans for 5G spectrum. In 2018, the 3400-3700 MHz band will be awarded as national licenses in 10 MHz blocks. The 3700-3800 MHz band will be awarded at a later stage depending on demand for local/regional licenses. The regulator also announced plans to develop an application procedure to allow access to the 26 GHz (24.25 GHz-27.5 GHz) band for 5G. Other millimeter wave bands may be considered over time.

Ireland completed its 5G auction in the 3.6 GHz band, which included 350 MHz in the 3475-3800 MHz band. Three Ireland CEO Robert Finnegan stated that the company wanted to acquire the optimum bandwidth for 5G of 100 MHz in the auction, in a band that was internationally recognized as capable to support 5G use cases below 6 GHz.

The **United Kingdom's** regulator is taking a leading role internationally in identifying spectrum bands for 5G and has published a report on 5G Spectrum in the UK." The telecom regulator has already begun the role of identification and allocation of spectrum for 5G. In the mid-band, Ofcom has taken action in the 3.4-3.6 GHz band, where 150 MHz is ready for auction later this year. Ofcom also released a consultation in October 2016 proposing to repurpose 116 MHz in the 3.6-3.8 GHz band. A further consultation on this topic is planned for later this year. In the millimeter wave band, Ofcom has said that it fully supports the identification of the 26 GHz band by the Radio Spectrum Policy Group and has started efforts to determine what actions are necessary to make this spectrum available for 5G.

The Americas

In addition to our own FCC, Canada's regulator is looking at the same bands for 5G that the FCC adopted in 2016. **Canada**'s Innovation, Science and Economic Development (ISED) issued a consultation for spectrum in the 28 GHz, 37-40 GHz and 64-71 GHz frequency bands to support 5G deployments. 5G Americas urged ISED to make those bands available for 5G, as the FCC has done, in order to promote global economies of scale.

Asia

China

In July 2017, China's Ministry of Industry and Information Technology (MIIT) approved the 4.8-5.0 GHz, 24.75- 27.5 GHz and 37-42.5 GHz bands for China's 5G technology research and development testing.21 This action follows MIIT approval of the frequency band 3.4-3.6 GHz in January of 2016, which is to be used for 5G trial in both Beijing and Shenzhen. These tests are meant to verify the various aspects of the 5G technologies and provide a foundation to facilitate early ecosystem development. In June 2017, the Ministry of Industry and Information Technology Radio Administration expanded the frequency range to 3.3-3.6 GHz, with 3.3-3.4 GHz limited to indoor use and 4.8-5.0 GHz. It also issued a public consultation to seek comments on the spectrum use for 5G.

Japan

Japan's analysis of potential frequency bands nevertheless indicates that the frequency ranges which currently have priority for 5G in the millimeter wave bands are 24.25-29.5 GHz, 37.0-40 GHz and 40.5-43.5 GHz, with 27.5-29.5 GHz receiving priority attention. In mid-band spectrum, Japan is currently considering 3.6-4.2 GHz and 4.4-4.9 GHz for 5G. Japan also has already allocated spectrum in the 3.5

GHz band. After summer 2017, its Ministry of Internal Affairs and Communications plans to identify which bands will be available for 5G initial deployment and when that will happen for mobile broadband.

South Korea

South Korea plans to launch a 5G network at the 2018 Winter Olympics, which will be held in Pyeongchang in February 2018. In a press release, SK Telecom announced in June 2017 that it has successfully demonstrated 5G communications using the 3.5 GHz band. SKT plans to use both the 3.5 GHz and 28 GHz bands for 5G network rollouts. A national broadband plan was published early 2017 and indicates 3.4-3.7 GHz and 27.5-28.5 GHz, with the latter possibly to be extended by up to 2 GHz to give a total of 3 GHz, 26.5 – 29.5 GHz. There is an interest in more spectrum for 5G in the longer term, though not decided which frequency band.

Australia

In February 2016, the Australian Communications and Media released the paper *5G and Mobile network developments—Emerging issues*. It recognized that supporting international harmonization played a critical role in leveraging the economies of scale achieved and the resulting benefits for Australia arising from lower device costs. The Australian Communications and Media Authority (ACMA) also issued a discussion paper seeking comment on whether and how to proceed with making the 3575-3700 MHz band available for mobile broadband services. ACMA is also interested in examining spectrum form 3400-3700 MHz.

Other regions' fiscal investment:

5G Americas does not seek any government funding – it simply requests adequate spectrum and supportive regulatory policy. But for insight into other regions' view of 5G as industrial policy, we note that in Europe, up to 700 million Euro in public funding is appropriated for 5G, with the goal to match that 700 Million Euro by the European private sector, including a leveraging factor of 5 of additional private investment. Together, the planned European investment results in private value of about 3.5 billion Euro.

Internationally Harmonized Spectrum

Spectrum is internationally harmonized both in our own regional spectrum committee, the Organization for American States' Committee on International Telecommunications ("CITEL") and in Geneva at the United Nations' International Telecommunication Union ("ITU"). Every four years, the ITU hosts a World Radiocommunication Conference ("WRC"), at which U.S. vendors and operators hope to harmonize spectrum for wireless broadband. The U.S. prepares for these quadrennial WRCs through CITEL. So U.S. participation in CITEL is crucial for delivering U.S. consumers innovative and affordable wireless services. At the last WRC, in 2015, the U.S. had the most proposals to CITEL on WRC agenda items, and CITEL had the most wins at the WRC. So being well-organized at CITEL is in the economic interest of U.S. consumers.

The benefits of global harmonization are not limited to situations where all regions have identical spectrum allocations. These benefits can also be derived from "tuning range" solutions, in which adjacent or nearly adjacent bands can be considered harmonized so long as equipment can be reconfigured to operate over multiple bands. In other words, they are within the same "tuning range." Such operational flexibility may sometimes involve radio equipment that operates across a superset of

band allocations over several regulatory jurisdictions. It may also entail using specific hardware configurations that are tailored for one or more markets. In considering spectrum allocations, therefore, policymakers should consider not only frequencies that can be allocated domestically, but also the possibilities provided by such global tuning range solutions. Based on early 5G strategic plans detailed in the previous section, there are several immediate possibilities for global harmonization, considering the "tuning range" for bands 3.3-4.2 GHz, 24.25-29.5 GHz and 37- 43.5 GHz. Specifically, 3GPP has included 24.25-29.5 GHz in its 5G Non-Standalone NR that will be part of its Release 15 to enable large-scale trials and commercial 5G deployments as early as 2019. This 3GPP 5G NR is expected to cover the spectrum blocks 27.5-28.35 GHz (U.S., Japan, Sweden, Estonia), 26.5- 29.5 GHz (Korea) and 24.25-27.5 GHz (EU, China). These are considered for potential 5G deployments by different administrations around the world, enabling a larger 5G ecosystem to facilitate service adoption, roaming and achieve greater economies of scales.

Necessary Regulatory Actions

Since 5G is targeting improvements across three fronts, enhanced mobile broadband, massive-scale connectivity, and ultra-reliable low latency service, there are different spectrum requirements than previous generations of cellular technology. To meet the new and emerging use cases it will most likely be best to utilize a portfolio of spectrum assets consisting of low-band, mid-band, and mm-Wave spectrum.

Low-band spectrum, with its propagation and penetration characteristics, could be used to provide in-building coverage in urban areas and wide-area coverage in more rural areas. Mid-band spectrum could be utilized for capacity and high speed in both urban and suburban zones. The large bandwidths available in the mmWave bands can achieve high data throughput speeds but the somewhat limited

propagation distances and penetration at these higher frequencies could possibly confine usage to more concentrated areas. It is therefore important that regulators take actions to ensure adequate spectrum resources are available in all bands and allocate adequate bandwidth to support the varied use cases of 5G.

Therefore, Congress, the FCC and NTIA should consider how 5G services can be harmonized internationally, even if identical allocations cannot be used everywhere. To that end, Congress, the FCC and NTIA should consider specific allocations within a broader globally harmonized and licensed band that accounts for the needs in various regions or countries. Under this approach, each country would apply the tuning range concept, with a focus on specific bands appropriate for its needs. The near-term bands for mid-band and high-band consideration are 3.3-4.2 GHz, 24.25-29.5 and 37-43.5 GHz. Beyond these bands, it is proposed that global harmonization remain as a priority in the identification and allocation of spectrum for 5G, especially bands that have been identified under WRC-19 Agenda Item 1.13.

Conclusion

The 5G use cases of enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC) and Ultra-Reliable Low Latency Communications (URLLC) may have different spectrum requirements to a varying degree. However all the use cases need spectrum both below and above 6 GHz. Below 6 GHz, mmWave bands, and the Mid-Band range of 6-24 GHz, the subject of the FCC's recent Mid-Band NOI, are all important spectrum resources for 5G deployments. One key characteristic of all of these potential 5G spectrum resources is that they are mainly shared spectrum and require clearing and/or development of sharing mechanisms. This leads to the need for the FCC, NTIA and federal users

to take concrete, measurable actions to make sure that a reasonable amount of licensed spectrum becomes available for initial 5G deployment in licensed spectrum.

Exponential growth in mobile data demand in conjunction with the spectrum needs of upcoming bandwidth intensive applications envisioned for 5G necessitate the availability of new licensed spectrum pools. To date, the FCC has largely made spectrum available for 5G in the mmWave spectrum, at 28, 37 and 39 GHz, and not as much spectrum below 6 GHz. Several 5G Americas Members hold or are pursuing through secondary market transactions licenses for the 28 GHz and 39 GHz ranges. Yet, 5G use cases have varied spectrum needs and effectively require spectrum across all bands. 5G Americas is pleased that the FCC has proposed changes to the 3550-3700 MHz band rules, and initiated the Mid-Band NOI, because it is critical that low-band, mid-band and mmWave spectrum resources are available for the initial 5G rollouts. In that regard, the U.S. is fortunate that 600 MHz auction winners have announced that once 5G network equipment and handsets are available, they plan to upgrade from 4G to 5G in that new spectrum. 5G Americas is also pleased that the U.S., led by the FCC, has encouraged other countries in our region and globally to examine both the 600 MHz and the 3300-3700 MHz band for mobile broadband. Likewise, one Member of 5G Americas that holds a significant amount of 2.5 GHz spectrum has announced that they will deploy 5G in the band, once 5G equipment is available.

As mentioned, it is highly desirable to have globally harmonized spectrum allocations for 5G applications and thus the FCC should allocate spectrum with international harmonization as a consideration. The benefits of global harmonization are not limited to situations where all regions have identical spectrum allocations. These benefits can also be derived from "tuning range" solutions, in which adjacent or nearly adjacent bands can be considered harmonized, so long as equipment can be reconfigured to operate over multiple bands. With the above actions, the U.S. will be well-positioned to win the *Race to 5G*, and benefit from services and applications that will ensure American competitiveness.

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 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 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 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 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:]

Testimony of Coleman Bazelon before the U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Communications and Technology

November 16, 2017

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 fulfil the promise of wireless. The same will be true with 5G, which will bring unprecedented speeds and low latency to wireless networks, supporting new applications and the 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" spectrum between 1 and 6 gigahertz for applications that would benefit from a combination of coverage and capacity; and "high-band" spectrum for short range communications requiring fast data rates and low latency. To effectively use these spectrum bands, a 5G network will require the deployment of millions of small cells along with a growing number of macro cells. 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 its 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 help overcome resistance. In fact, anything that can be done to smooth the transfer of spectrum is helpful. For example, the recently introduced Spectrum Auctions Deposit Act—which overcomes impediments identified by Chairman Pai to holding spectrum auctions—will facilitate future auctions and the Spectrum Reallocation Fund should help provide frequencies for those auctions.

These new 5G deployments will have profound implications for spectrum value. On the one hand, being able to integrate massive amounts of high-band spectrum into commercial mobile networks will flood the market with spectrum capacity, at least in denser, 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 are clear implications for different types of spectrum from increased user expectations for throughput, mobility and latency that will be fostered by the new 5G deployments. The value of mid-band spectrum used for capacity outside of 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 examine the value of making an additional 100 MHz of mid-band spectrum available in the 1,300–1,350 MHz and 1,780–1,830 MHz bands. After accounting for a moderation in spectrum value compared to recent highs, I find that a 50 + 50 MHz paired band would be expected to raise $63 billion in auction receipts. Making those frequencies available are expected to cost up to an estimated $8 billion to relocate existing users, providing them with at least equivalent and, in many cases, improved wireless infrastructure. Consequently, this band would be expected to raise $55 billion in net receipts. Admittedly, there is some amount of uncertainty when forecasting future auction receipts. Frankly, it is not for the faint of heart. But so long as an auction of this 100 MHz of mid-band spectrum raises more than $8 billion—a paltry amount for so much spectrum that can 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 GHz band could be valuably deployed in support of 5G networks. I have investigated this band and found that even with conservative assumptions about value of both existing C-band services and potential new deployments, reallocating some or all of the band would likely create value. A voluntary mechanism that ensures incumbents benefit from any transition will help facilitate making additional needed frequencies available for new 5G networks.

Thank you.

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 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 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 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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Testimony of

Jonathan Adelstein
President and CEO, Wireless Infrastructure Association

Before the

Subcommittee on Communications and Technology
Committee on Energy and Commerce
United States House of Representatives

Hearing entitled

"The Race to 5G and its Potential to Revolutionize American Competitiveness"

November 16, 2017

Chairman Backburn, Ranking Member Doyle, and members of the Subcommittee, thank you for holding this important hearing and for the opportunity to testify on the future of 5G and American competitiveness. I am the President and CEO of the Wireless Infrastructure Association (WIA), the principal organization representing the companies that build, design, own, and manage wireless facilities in the U.S. and throughout the world. Our members include infrastructure providers, wireless carriers, equipment manufacturers, and professional services firms. WIA focuses on ensuring that the infrastructure is in place to make 5G a reality. Our mission is to expand wireless broadband everywhere.

The United States has been a leader in mobile communications and 4G. There is no guarantee, however, that the U.S. will stay on top as 5G rolls out. The wireless infrastructure industry is honored to work with this Subcommittee on sound policies to encourage deployment of broadband for all Americans so that the U.S. can remain on the cutting edge of wireless deployment, including 5G. This Subcommittee has shown great leadership in promoting broadband deployment and the wireless industry applauds your efforts.

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The Wireless Data Crunch

America is facing an economic and technological challenge that can be described as the wireless data crunch. The challenge is to meet consumers' increasing demand for mobile data while keeping up with the network's capacity to deliver it. According to Cisco, over the next five years, mobile data traffic in the U.S. is set to increase five-fold.[1] Much of that growth is coming from smartphones, which account for most of the wireless connections today. But the number of machine-to-machine connections and machine- or device-to-Internet connections is growing exponentially. Cisco found that the number of Internet connected devices will increase three-fold by 2021, with smartphone traffic exceeding PC traffic over the next five years.[2]

These statistics underscore the need for government policies that consider the growing demand for mobile data and address the challenges of meeting it by efficiently deploying wireless infrastructure. This tremendous growth in demand is both encouraging and sobering at the same time. The issue for the wireless infrastructure industry and for this Subcommittee is how to meet this demand. The projections should serve as a wake-up call that industry and the government at all levels need to continue to work together to maintain the U.S.'s position as the global leader in wireless innovation, as this Subcommittee has long recognized.

To address the wireless data crunch, there are three basic ways to deliver more wireless data: (1) additional spectrum; (2) increased technological efficiency; and (3) more wireless infrastructure, or densification. All three are essential.

We certainly need more spectrum – as much as we can get, as quickly as we can get it. The mobile carriers paid high prices for spectrum in the recent auction, which is understandable because there may not many available opportunities for significant new spectrum in the near future, other than very high-frequency spectrum. With the successful close of the 600 MHz Incentive Auction, the last scheduled auction, it is more important than ever to plan for future spectrum needs. Technological efficiencies will also help ease the wireless data crunch. But even as we build out 4G and soon 5G, traffic immediately diverted to these new and more efficient standards—there's lag time here, too, with old 3G and even 2G handsets still in use. 5G will also require new handsets that will take many years and significant expense to get into consumers' hands. While carriers can incentivize customers to use new and more efficient handsets, this

[1] VNI Mobile Forecast Highlights, 2016-2021, *available at* https://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/#~Country (Cisco VNI).
[2] The Zettabyte Era: Trends & Analysis, *available at* https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html.

takes time. Technological innovation alone will not enable the wireless industry to meet growing consumer demand, even when combined with any new spectrum.

Wireless infrastructure immediately addresses the wireless data crunch as soon as it is deployed, but deploying infrastructure also takes time. And even with more spectrum or increased technological advancements, far more infrastructure is needed to deliver sufficient bandwidth. The massive growth in the number of connected devices will strain the capabilities of the infrastructure we have today. Supporting the demand for more infrastructure will require major investments. We need additional cell towers and poles and more antennas of all types and sizes that attach to structures of all sizes. And we need the all-important fiber networks that connect all these technologies. We simply need more wireless infrastructure so that these massive amounts of data can seamlessly move from point to point. In the 5G world, with the explosion of data demand, having robust wireless infrastructure becomes even more important.

Benefits of 5G

The benefits of 5G for economic growth, job creation and American competitiveness are well-documented. The wireless industry stands ready to make the necessary investments to make 5G a reality. In fact, Accenture estimates that wireless operators will invest as much as $275 billion nationwide over seven years as they build out 5G.[3] This investment could create direct impacts of 350,000 new construction jobs and a total of 850,000 jobs in the U.S. when considering suppliers and other partners cumulatively over the seven years of network build-out.[4] The broader economic benefits from 5G could create an additional 2.2 million jobs in communities across the country.[5] In total, about 3 million new jobs could be created by the 5G revolution and lead to a $500 billion boost to the GDP.[6]

5G networks will be up to 100 times faster and five times more responsive than today's networks. It will be able to support 100 times more wireless devices. It will bring faster speeds, greater value, and more choices for consumers. 5G will spur life-altering innovations in telemedicine, distance learning, improved public safety response, mobile banking, and a host of industrial and manufacturing functions.

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[3] *How 5G Can Help Municipalities Become Vibrant Smart Cities*, Accenture Strategy (Jan. 12, 2017) *available at* https://newsroom.accenture.com/news/new-research-from-accenture-strategy-highlights-economic-and-societal-impact-of-investing-in-5g-infrastructure.htm (Accenture Study).
[4] *See* Accenture Study.
[5] *Id.*
[6] *Id.*

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Communities, big and small, will also benefit from 5G. "Smart Communities" will emerge across the country, providing municipalities the ability to improve quality of life for their residents and saving significant taxpayer money. 5G solutions applied to connected cars and the management of vehicle traffic and electrical grids could produce $160 billion in benefits and savings through reductions in energy usage, traffic congestion and fuel costs.[7] These 5G attributes will provide cities and towns with opportunities to reduce commute times, improve public safety and generate significant smart grid efficiencies.

The U.S. can lead in 5G. Several 5G trials are ongoing across the country, and the Federal Communications Commission (FCC) opened nearly eleven gigahertz of high-band spectrum that serves as an important down payment on the spectrum needed to support 5G. America is well-positioned, but there is growing competition from around the world. If U.S. policy does not evolve to encourage 5G investment, then other countries will surpass us and we will have missed an opportunity to create millions of jobs and hundreds of billions in economic activity.

I am confident U.S. policy will rise to meet the challenge. This Subcommittee clearly recognizes the challenges and is addressing it. Chairman Pai, all the Commissioners, and the staff of the FCC has also risen to the challenge, establishing an aggressive agenda to promote infrastructure deployment. The Trump Administration has also taken a strong stand to promote infrastructure, including a focus on broadband, and clearly indicating their intention to include broadband in the upcoming infrastructure initiative. Given strong leadership we are seeing from Congress, the FCC and the Administration, it is clear there is significant policy support that will enable the U.S. to lead the world in 5G deployment and innovation.

Congress' Role in Encouraging 5G Deployment

5G could prove to be one of the most transformational standards in the history of technology. As promising as the 5G standard is, it is only as good as the infrastructure on which it is deployed. Building the networks of tomorrow requires sound policies from all levels of government today.

Accenture estimates that the network deployment build of 5G will involve ten to 100 times more antenna locations than 3G or 4G, meaning that all manner of infrastructure will be required, including traditional towers, small cells, distributed antenna systems (DAS), and unlicensed Wi-Fi offload. While the opportunities of 5G deployment present an exciting and historic opportunity, we must be mindful of potential warning signs. 5G buildout is capital intensive, and operationally demanding. Fully realizing the economic growth and international competitiveness of 5G, depends on how efficiently the 5G infrastructure will be deployed. Therefore, Congress

[7] *Accenture Study.*

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and the FCC need to enact policies that allow the wireless industry to invest finite private capital responsibly and efficiently.

Congress and the FCC need to speed the approvals of permits and applications so that companies can make the needed 5G investments. And we need local governments to recognize how crucial access to public rights-of-way to deploy antennas on existing structures will be as we move into the next phase of wireless deployment.

In addition to antennas on towers, poles and the sides or tops of buildings, new networks will rely on what is commonly known as "street furniture." Bus stops, man-hole covers, park benches, mail boxes, the lights at a local high school or even a gazebo in a public park are all candidates to host cellular antennas. Policies need to recognize that all manner of infrastructure are needed to reap 5G's benefits.

There are several specific steps Congress can take that will speed 5G deployment. First, Congress can look at Federal pole attachment rules that promote the deployment of broadband access and the new technologies that enable it, while providing fair treatment for pole owners. Among other things, Congress added "provider[s] of telecommunications services[s]" to the category of attachers entitled to pole attachments at just and reasonable rates, terms and conditions under Section 224 of the Telecom Act. This section has been modernized through action by the FCC, which has helped to provide greater access to poles for wireless attachers, shortened timelines for make-ready and other work, and rates in greater harmony with other like attachments. However, many local jurisdictions have been slow to adopt the FCC's standards. In these states, the telecommunications industry must re-legislate, re-litigate, and otherwise relive the efforts taken before the FCC's action. Greater national certainty and clarity with respect to the rights of wireless attachers in these jurisdictions would spur 5G broadband deployment.

Next, Congress should look to address the byzantine process of siting wireless broadband infrastructure on Federal lands. This Subcommittee on a bipartisan basis has expressed interest in this issue and we appreciate your leadership, along with your colleagues in the Senate. The Federal government owns or administers nearly thirty percent of all land in the U.S., as well as thousands of buildings, many of which are in desirable locations. Broadband providers currently face significant challenges when working to secure access to Federal lands and buildings. Deploying wireless infrastructure on these properties is critical for 5G rollout. Wireless facilities can be sited on Federal property in an environmentally responsible way that is sensitive to areas historic significance.

In addition, some state and local authorities are erecting barriers to broadband deployment that could prevent the full deployment of 5G. For example, some localities are charging fees that are

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discriminatory, are not technology neutral, or exceed reasonable application processing costs, including demands to obtain expensive business licenses for cell sites. The current statute does not define "fair and reasonable compensation" and some localities have used fees as a revenue-generating measure. Still others impose high costs for unnecessary third-party consultants or require unreasonable escrow fees. Congress should clarify that right-of-way use and management charges should not include fees based on gross revenues, third party consultancy or review fees, travel expenses, business licensing fees, or unreasonable escrow fees.

An additional concern is that some localities require unreasonable amounts of information from applicants, some of which is completely unrelated to the application. Some localities also require an applicant to perform services unrelated to the wireless facility for which approval is sought. These requirements cause unnecessary and costly delays to the deployment of wireless infrastructure and could impede 5G. Congress should look at ways to limit the amount and type of information that is required by local governments in siting applications and Congress should prevent local governments from requiring an applicant to perform services unrelated to the wireless facility for which approval is sought.

Further, the shot clocks created by the FCC under Section 332 of the Telecom Act require an applicant to file a lawsuit in court if the locality does not act within the timeframes established. While helpful, there are still opportunities within the process that introduce substantial delay where the parties unnecessarily end up in court. This process can drag on for years. Congress should amend Section 332 to include a deemed granted remedy if a locality fails to act within the applicable shot clock.

Beyond local concerns, Congress can improve a number of Federal policies to expedite 5G. For instance, the FCC's Tower Construction Notification System (TCNS) aids in connecting wireless infrastructure providers with federally recognized Native Nations that have expressed an interest in the area in which the deployment would take place. The process as it stands today is fraught with inefficiencies and lacks the clarity and certainty needed to efficiently build out 5G networks. The TCNS process applies to deployments where a tribe has indicated that they may have a historic, cultural interest in the underlying site. Congress should update the TCNS system to proactively exclude those deployments that have no new ground disturbance, should clarify procedures to better enable completion of the consultation process in a reasonable timeframe, and should ensure that fees are assessed only when appropriate, and that where fees are assessed, those fees are reasonable.

In addition, FCC rules and programmatic agreements implementing Section 106 of the National Historic Preservation Act (NHPA) have created a time-consuming process, often taking many months without effective mechanisms in place to close the process. The FCC revised its rules in

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2014 and recently amended the Nationwide Programmatic Agreement for the Collocation of Wireless Antennas to categorically exclude certain collocations, including many small wireless antennas on existing structures. However, these exclusions do not cover many common and low-impact collocations or associated support poles. Congress should amend Section 106 of the NHPA to specify that the installation of small wireless antennas, including associated equipment and support poles, on existing towers, buildings, or other structures, or in a public right-of-way, is not an "undertaking" subject to Section 106 review.

Similarly, while collocations of small cells are categorially excluded from certain environmental reviews under FCC rules, associated support poles may still require an environmental review and both the small cell and the pole are still considered major Federal actions. Congress should amend Section 102 of the National Environmental Policy Act to specify that the installation of small wireless antennas (including associated equipment and support poles) on existing towers, buildings, or other structures, or in a public right-of-way, is not a major Federal action subject to NEPA review.

Along with Federal policy, several states are also looking to expedite 5G infrastructure deployment. In 2017, nearly two dozen bills have either been enacted or introduced that remove regulatory barriers, reduce delays, and rationalize fees. These bills also promote responsible deployment, creating height limits and other policies incentivizing deployment in specifics areas, including the right-of-way and on existing infrastructure.

With the appropriate regulatory guidance, today's wireless industry can better plan for the network of tomorrow. Too often, misunderstandings and misrepresentations about wireless infrastructure can stall the deployment of these life-changing technologies. 5G infrastructure will have the power to transform a municipality in economic decline into an innovation hub. It can breathe new life into aging commercial zones, and provide rural areas the ability to compete in the innovation economy.

Collocation and Responsible Deployment Are Important to 5G Deployment

American wireless networks are the envy of the world. When I speak with industry and governments around the globe, I am often asked how we did it. A major reason is the collocation model that has become the industry norm in the U.S. This shared infrastructure model works well for both the wireless industry and for local communities. Sharing is more economically efficient and promotes smart planning. Collocation also lowers barriers for new entrants, which leads to competition and innovation. And it supports environmental, historic and cultural preservation throughout local communities.

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Congress, and this Subcommittee, have enabled the improvement of the collocation model by approving Section 6409(a) of the Middle Class Tax Relief and Job Creation Act of 2012. That law expedited deployment of 4G networks by allowing carriers and infrastructure providers to upgrade equipment on cell towers without having to undergo onerous zoning proceedings. Section 6409(a) is going to provide similar relief in the deployment of 5G networks.

5G will not only be provided through small cells. The entire network, on all frequencies and antennas, will be upgraded to 5G as time and capital allows. In fact, swapping out 5G antennas on traditional towers will provide a rapid and efficient means to get the 5G signals to the widest swaths of the U.S. population. Further refinements to Section 6409(a), along with the facilitation of small cell siting, will provide a further boost to the deployment of 5G networks.

One way to promote collocation to help boost 5G deployment is to streamline the process of compound expansions. The 2004 Programmatic Agreement excluded from review construction of a replacement structure that did not substantially increase the size of the existing tower and that did not expand the boundaries of the leased or owned property surrounding the tower by more than thirty feet in any direction or involve excavation outside these expanded boundaries. This relief has worked well. However, any site expansion to accommodate additional equipment associated with the collocation of a new antenna or transmission equipment still requires a full review, even if the expansion is as little as one foot. This unnecessary requirement is expensive, time-consuming and could slow down 5G. Providing the same thirty-foot allowance exclusion for compound expansions for collocation as currently exists for replacement towers, would have a significant impact in reducing delays and expenses.

As the U.S. moves to 5G, it is important to maintain a commitment to responsible infrastructure deployment. Siting a wireless facility can be a time-consuming and expensive process. Often, a vocal minority of residents express displeasure, or outright disapproval, of locating facilities in their communities. The wireless infrastructure industry works very closely with local governments and communities to meet their unique needs in terms of location, aesthetics, height, type of structure, and many other considerations. If a company carelessly comes into a community and circumvents local consultation, it rightly angers community residents and the local government. This can lead to a moratorium, either explicit or *de facto*, on siting new facilities in that community. A siting moratorium hurts responsible companies and creates resistance on the drive to 5G. It prevents consumers and communities from enjoying all the benefits that come with wireless services. WIA has long supported responsible infrastructure deployment in partnership with localities because it is the best way to develop the networks, including those that will enable 5G.

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Creating the Wireless Workforce of the Future

5G deployment could create three million new jobs across the economy. Nevertheless, there is a dramatic skills gap between U.S. workers and the technical and professional skills needed to build wireless networks. This gap could lead to thousands of jobs going unfilled and dramatic increases in labor costs. We are already beginning to see this.

Wireless jobs are changing incredibly quickly. Many of our member companies report that they have difficulty filling positions because the applicants do not have the skills they need. A recent white paper published by WIA's Innovation and Technology Council found that government and industry should work together to develop training and educational programs to draw workers into the industry, and to provide the advanced skills needed to improve the safety and quality of wireless deployments.[8]

WIA is leading the fight to combat this skills gap so that the wireless industry can continue to grow and all communities can benefit from 5G. WIA is the National Sponsor for the Telecommunications Industry Registered Apprenticeship Program (TIRAP) to bring the apprenticeship model into the wireless industry for the first time.[9] WIA has also developed training programs that will support apprenticeships, bolster efforts to train veterans, and provide a baseline of knowledge about radio frequency issues among the wireless workforce of the future.

The wireless industry and multiple Federal agencies recognize the critical role apprenticeships and workforce development programs can play in bridging the skills gap. On November 28, WIA and TIRAP will convene with representatives from the FCC, the Department of Labor, OSHA and senior executives from the private sector to celebrate the significant accomplishment of adding 1,000 registered apprenticeships to the wireless industry and explore the role apprenticeships and training and education will play in developing the skilled workforce the U.S. needs as it prepares for the widespread deployment of 5G mobile networks.

WIA is proud to support H.R. 3174, the CHANCE in Tech Act. This bill would reform the registered apprenticeship program by creating technology apprenticeships and help forge public-private partnerships to serve as intermediaries between employers participating in the registered apprenticeship program, industry, training partners, and government entities. Each intermediary would assess and train potential apprentices in coordination with local and regional workforce

[8] The Skills Gap in Wireless Infrastructure Education: A Strategy for Improvement *available at* https://wia.org/wp-content/uploads/The-Skills-Gap-in-Wireless-Infrastructure-Education.pdf (May 2016).
[9] *See* http://www.tirap.org.

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demands. The CHANCE in Tech Act would help shrink the skills gap by revitalizing the registered apprenticeship program and providing students and workers with the hands-on, experiential learning needed to compete in today's economy.

The only way the U.S. is going to keep up with the ever-increasing demand for more capacity is through more wireless infrastructure, which will require a workforce with the skills to deploy wireless across the U.S. We cannot afford the lack of skilled workers to slow the path to 5G, so WIA looks forward to working with Congress to bolster efforts to train our workforce to expand high wage, high skilled jobs in our industry.

Broadband Deployment Advisory Committee (BDAC)

On January 31, 2017, FCC Chairman Ajit Pai announced the formation of a new Federal Advisory Committee, the Broadband Deployment Advisory Committee (BDAC). The BDAC's mission is to make recommendations on how to accelerate the deployment of broadband by reducing or removing regulatory barriers to infrastructure investment. I was fortunate to have been selected to serve on the Committee and was chosen to chair the Streamlining Federal Siting Working Group. The BDAC met and approved significant recommendations on November 9, including the entire report my working group and numerous suggestions from the others. My working group recommended that fees and rates for deployment on Federal lands need to be streamlined and that agencies should keep some of the revenue to help address staff constraints. My group also suggested implementing a 60-day shot clock, with a deemed granted remedy at 180 days for new builds or 90 days for collocations on Federal lands. Another issue with Federal land siting is that varying applications and processes exist across different Federal agencies. We recommended harmonizing applications and processes across agencies. All agencies should use the same application. Congress mandated that the General Services Administration create a common application but two years after the common form was released, not all agencies use it. Congress should require that the common form be used.

Some of the other working groups made additional recommendations to speed up the permitting process for 5G infrastructure and to ensure broadband networks reach all communities. I commend Chairman Pai for convening this Committee and I know he is committed to using all FCC's tools to promote broadband deployment and adoption.

Conclusion

Wireless broadband helps drive America's innovation economy and fuels the nation's economic future. The U.S. has always been the global leader in wireless broadband innovation, and private investment in wireless infrastructure is a big the reason for our success. Continuing to upgrade

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America's wireless infrastructure is a necessary component of connecting more Americans with broadband and to 5G deployment.

The move to 5G has the potential to unleash a wave of economic growth, job creation and greater global competitiveness in virtually every sector of the U.S. economy, bringing benefits well beyond the wireless industry. And wireless infrastructure will enable 5G. This enormous opportunity will only happen, however, if sound policies that encourage investment and innovation are enacted. Otherwise, the U.S. will fall behind the rest of the world and will not realize the full potential that next generation broadband will bring. That is why the leadership of this Subcommittee is so critical. You can make the difference by removing obstacles to deployment and improving Federal law to enable this industry to upgrade wireless networks.

We are deeply grateful for the bipartisan recognition of the importance of infrastructure by this Subcommittee, by Congress, by the FCC and the Administration. All have implemented policies to promote wireless broadband deployment, and all are working to build on recent successes.

Thank you, again, Chairman Blackburn and Ranking Member Doyle for holding this hearing and inviting me to testify. I look forward to continuing to work with you and the rest of the Committee to make additional progress on these very important issues.

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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 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 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 mid-

dle 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.

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:]

STATEMENT OF SHIREEN SANTOSHAM, CHIEF INNOVATION OFFICER,

SAN JOSE MAYOR'S OFFICE OF TECHNOLOGY AND INNOVATION

BEFORE THE HOUSE SUBCOMMITTEE ON COMMUNICATIONS & TECHNOLOGY

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

NOVEMBER 16, 2017 WASHINGTON, DC

Good morning, Chairman Blackburn, Ranking Member Doyle and members of the Committee. I am pleased to be here to discuss how cities are leading the country in creating an environment to speed deployment of next generation networks. And, how reinforcing local government rights to manage the public rights of way, rather than circumventing these rights, will result in faster, cheaper, and higher quality broadband for all Americans.

Personal background

I am Shireen Santosham, Chief Innovation Officer for Mayor Sam Liccardo in San José, California which is the 10th largest city in America and the largest city in Silicon Valley. In my role, I lead efforts to make San José the most innovative city in America by embracing technology to improve the lives of our residents. In the past two years, we launched efforts to expand broadband for all of our residents, pilot autonomous vehicles on our streets, deploy an "internet-of-things" network, and activate our start up community to tackle civic challenges. I also currently serve as an alternate representative for Mayor Liccardo on the FCC Broadband Deployment Advisory Committee charged with advising the FCC on how to speed broadband deployment throughout the United States.

Prior to joining the City of San José, I worked for GSMA, the mobile network operator association representing 800 wireless companies globally and an additional 300 companies in the broader mobile ecosystem. While there I conducted primary research in over 20 countries and authored several reports on how to bridge the digital divide for women at the base of the pyramid globally through mobile technology and access to the mobile internet. This research was presented at Mobile World Congress in Barcelona, the United Nations Commission on the Status of Women 59/Beijing +20, and several other forums around the world. In addition, I have worked on several innovative initiatives while working with McKinsey & Company, multiple nonprofit organizations, and as an impact investor for Microsoft co-founder Paul Allen's Vulcan Capital. My background working across sectors, on different sides of the table with the wireless industry, government, and with communities affords me the unique opportunity to look at broadband deployment from a holistic perspective.

I want to thank the Committee for calling attention to the importance of broadband deployment in our communities by holding this hearing and appreciate the opportunity to provide the critical perspective of cities and our role in promoting broadband deployment. I want to particularly thank Congresswomen Eshoo not only for her focus on this issue, but for her excellent service for all Californians – we are truly fortunate to have her represent us.

Cities are embracing technology to improve their communities

No one wants broadband deployment and competitive broadband choices more than local communities. We understand the opportunities that broadband presents for our local communities and our residents in terms of public safety, economic development, healthcare, entertainment, and education. For years, communities of all sizes around the nation have taken innovative steps to increase the deployment of broadband infrastructure, both wired and wireless, while protecting public safety as well as providing a fair approach to use of the public rights-of-way.

We live in an exciting time from a technological perspective. I often say I have the most fun job in the City of San José because I have a front row seat to the latest and greatest technologies Silicon Valley has to offer and get to shape policies to usher in the next generation of the internet.

In San José we welcome technological advancement with open arms. This year, we launched an effort to bring autonomous vehicles to San José – our initial call for proposals garnered 30 submissions from leading companies around the world. We are currently evaluating a short list of companies and will make announcements about pilots early next year. We also launched a civic challenge called "Unleash Your Geek" to crowdsource solutions from our residents to improve our city. The first challenge was to tackle the graffiti problem in the city – an issue that causes us to spend up to $60,000 every time we have to shut down a highway to clean a freeway overpass. Out of 140 entries, the winner was a husband and wife couple who built a human-controlled, spray-painting drone prototype in their living room for less than $5,000 that has the potential to save millions while keeping workers safer in the long term. The couple is now working with CalTrans to prove out the solution and scale.

Additionally, we have several experiments underway to bridge the digital divide and get connectivity to our low-income population. Our innovative "demonstration policy" allows us to test and iterate pre-commercial products in partnership with private sector on a temporary basis. Through this program we are collaborating with Facebook to demonstrate and launch their Terragraph network early next year that, if it works, has the potential to provide free, outdoor gigabit-speed internet access to our downtown. We are also partnering with our largest school district, via a public technology bond, to fund the private sector to provide internet access to the children on the east side of our city so they can do their homework at home if they cannot afford to pay for a service themselves.

As the largest city in Silicon Valley, we understand inherently how powerful technology can be to drive economic growth and competitiveness. Broadband infrastructure is foundational to unlocking this potential. Just this past Monday, we released our Broadband and Digital Inclusion Strategy for the city which included recommendations to speed broadband deployment through streamlining our own processes, allowing for companies to work with a single point of contact to deploy small cells, and creating incentives for them to invest in underserved areas of our city through dynamically pricing our infrastructure assets which passed unanimously through our City Council. We know that working together with broadband providers is the only way we will be able to provide high quality service to our residents and bridge the digital divide and are actively looking for ways to streamline our own processes.

We are not alone in our approach to creating a more welcoming environment for the private sector to work with us and to deploy networks more quickly. The City of Boston has already approved or installed 656 small cells with 90% approved within 10 business days, 100% within 28 business days. Their program is based on the following five principles, which are a good example for all cities: 1)

standardized license agreement, 2) cooperative design process, 3) multiple pricing models, 4) community communication, 5) simple, online application system. Many cities have, or are in the process of, developing guidelines for small cell deployment that create a balanced approach that speeds deployment for corporations while allowing cities to retain local management over the public rights-of-way to ensure that public safety and aesthetic needs are being met, ensuring taxpayers are fairly compensated for use of infrastructure they paid for, and incentivizing equitable build out in areas traditionally underserved by the industry.

Given our innovative approach to technology as a city, and the work of cities across the country broadly on finding creative ways to ensure their residents get high quality, affordable broadband, we were surprised when our forward-leaning city was held up as an example by industry of local government bureaucracy and of how cities act as regulatory barriers to broadband deployment—including inaccurate claims around the prices we charge for access to our light poles. Certainly, there are always ways to improve processes to speed deployment, especially since cities often lack the capacity and funding to retool quickly when new technologies like small cells hit the market. But cities and local governments alone are not the root cause of slow broadband deployment – and pre-empting their authority will likely result in unintended consequences that hurt consumers in the long run. Industry players, structural barriers, and competitive dynamics in the American broadband market also contribute to the challenges of broadband deployment and these concerns should be carefully considered when holistically addressing this issue.

Incentivizing equitable 5G deployment

Embracing 5G and similar forms of millimeter wave technology is a part of the approach we are taking in San José to enable this next wave of innovation to occur. Ushering in a gigabit future will no doubt have wide ranging benefits – from enabling new advances like connected and autonomous vehicles, unlocking augmented and virtual reality, and creating other new markets. But, there are two critical issues around the technology that should be considered, first that 5G and millimeter wave technology is in early stages of development, and second, how this technology is deployed and who benefits matters.

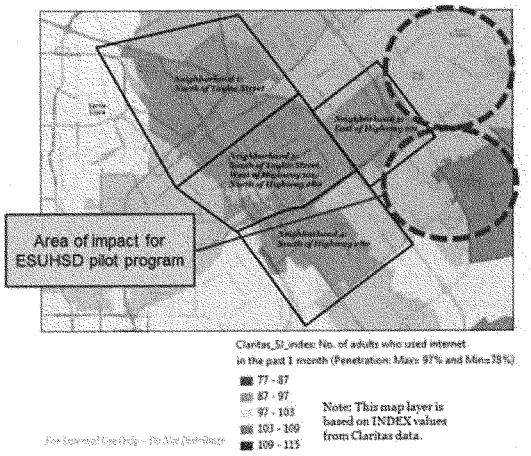
Although the promise of 5G is widespread, the standards won't be set until 2019. So we still will need to see proof points around the technology. While it delivers lightning fast speed in labs and early trials, there are real-world problems of scale still to overcome. Generally, as you move to higher frequencies, transmission range gets shorter—hundreds of meters rather than kilometers. And signals are unable to penetrate walls easily, sometimes even windows treated to block UV rays. Further, some experts remain skeptical on the evolution of the technology and the ability to invest at the levels needed to deploy at scale.[1] So, how this technology plays out remains to be seen and we should all be cautious about making drastic changes to how we historically manage the public rights-of-way in order to accommodate one, yet unproven technology that may only serve a narrow portion of our residents.

A piecemeal approach where service providers can pick and choose where they service a city also has another unintended consequence – it is likely to result in wealthier, denser, more profitable areas serviced first and more traditionally digitally excluded neighborhoods serviced last (if they are serviced at all). In San José, historically, we took a laissez faire approach to our broadband market, which unfortunately resulted in several neighborhoods underserviced by broadband providers mostly in low-

[1] https://www.rcrwireless.com/20160616/carriers/5g-bear-case-tag28

income Latino communities. It also resulted in low fiber-to-the-premises and little competition in the market leading to lower quality of service, consumer choice, and higher prices for our residents. This trend is not unique to San José. According to the Federal Communications Commission, only 22 percent of Americans have more than one option for fast broadband.[2] Americans also tend to pay more for broadband than their counterparts in other developed nations and are less satisfied with their service.[3]

Current state: San Jose's primary digitally-excluded group is low-income, Latinos without college degrees living near downtown

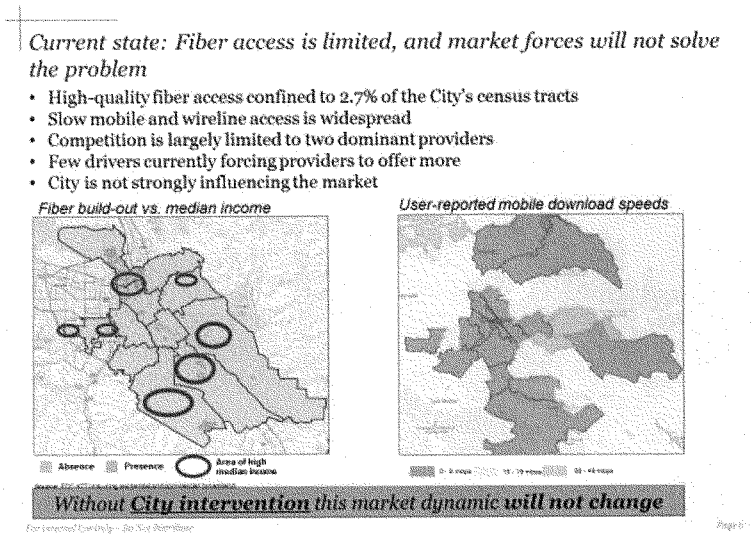


- This analysis examined **the digitally-excluded areas of the City** by zooming in on "hotspots" of digitally-excluded residents
- Our analysis generated **four zoomed-in neighborhoods**, as seen at left
- The area of focus of ESUHSD is indeed a "high" priority area, but appears to **miss an adjoining "very high" area** of need
- Several City buildings (libraries, community centers) exist in these areas that could **anchor City interventions**

[2] https://arstechnica.com/information-technology/2016/08/us-broadband-still-no-isp-choice-for-many-especially-at-higher-speeds/

[3] http://www.slate.com/blogs/future_tense/2014/11/21/cost_of_connectivity_study_2014_americans_pay_more_for_slower_internet_access.html

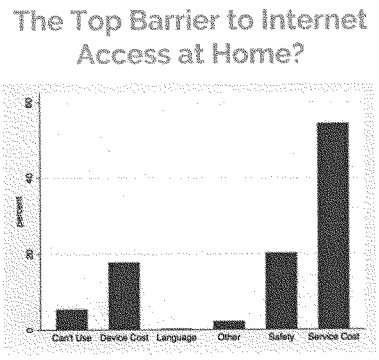
http://www.theacsi.org/news-and-resources/press-releases/press-2017/press-release-telecommunications-2017

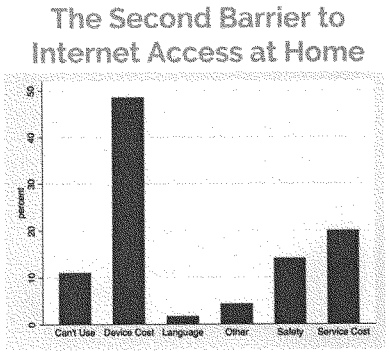


Source: Price Waterhouse Coopers Broadband Strategy for San José

Stories of low-income students with no internet access sitting on the steps of their schools at night trying to access free Wi-Fi to do their homework are unfortunately widespread in San José. The City José is now taking a new approach. We are working with service providers to build out all areas of our city through agreeing to batch processing of permits, network-level planning, and discounts on fees and rates based on digital inclusion provisions that benefit both the companies and our residents.

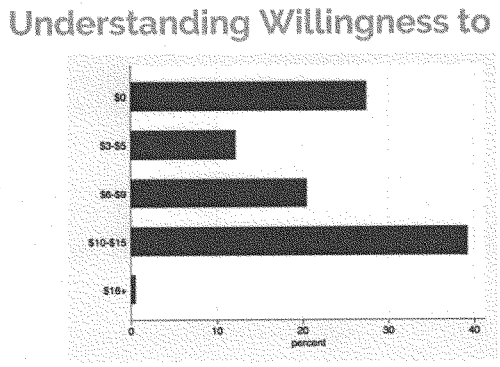
We take our need to accelerate digital inclusion efforts seriously. We recently completed a survey, in partnership with Stanford University, of close to 700 low-income families with children to understand how to close the "homework gap" and ensure all our residents have an on ramp to opportunity. It shows that the cost of service and cost of devices are the top two barriers to broadband access for low-income populations. And, we have 95,000 residents without broadband access in our city.





Source: San José Digital Inclusion Report 2017, Stanford University & Great Nonprofits.

Further, of those in our city without broadband access at home, 60% say they cannot afford even $9/month to pay for access to broadband. This means that low-cost plans offered by most service providers are still out of reach for a large proportion of our unconnected population.



Source: San José Digital Inclusion Report 2017, Stanford University & Great Nonprofits.

Taken together, what this means as we look to 5G is that local communities and local governments have a role to play to make sure that equitable deployments happen. And, if we are to give breaks to corporations on use of public assets, we need to make sure that those benefits go back to the public in

terms of lower prices coupled with access in traditionally excluded neighborhoods. Unfortunately, much of the current regulation introduced in states across the country strips away local input over the public rights of way and is fundamentally flawed as it does not ensure that the benefits of broadband reach everyone. And, there are no guarantees that the public, not shareholders alone, will benefit.

What we learned from SB 649

There is currently legislation sponsored by CTIA introduced in 20 states around the country, approved in over a dozen, that aim to streamline permitting processes for small cells and, often, pre-empt local control over the public rights of way by giving companies "by-right" access to public infrastructure. One such bill, SB 649 was introduced in California in this last legislative cycle.

Fortunately, Governor Jerry Brown vetoed the bill. In his veto message, he stated "There is something of real value in having a process that results in extending this innovative technology rapidly and efficiently. Nevertheless, I believe that the interest which localities have in managing rights of way requires a more balanced solution than the one achieved in this bill."

We believe the governor hit the right chord with this message – although we actively embrace new technology, the rights of local governments and communities to manage the rights of way must be preserved to benefit the public broadly. Below I will highlight issues with the bill.

Cost-recovery fees don't cover costs & can widen digital divides

In SB 649, the cap on annual pole fee was $250. The flawed legislation also proposed an additional cost recovery based pole attachment rate that failed to consider many of the actual costs involved with installation attachments to poles such as structural and electrical remediation. The independent California Department of Finance assessed that even in totality these rates were, in fact, below cost and would result in the state having to reimburse cities for the difference under California law.[4] Their analysis also highlighted the concerns that digital divides could widen under this bill stating, "The bill gives telecommunications providers the power to determine where they deploy small cell technologies, which can be highly localized. Providers may cover high-demand neighborhoods first, while low-income neighborhoods may be left underserved. This arrangement follows in the path of high-speed internet service, which has led to uneven access for rural and lower-income areas. Under current law, cities and counties can require, as part of their permitting process, that small cell providers incorporate rural and lower-income areas into their service networks. By pre-empting local government authority, this bill also limits city and county tools to address those equity issues."

Small cells are not well-suited for rural areas

Small cells are best suited to deploy in dense urban and suburban environments given their shorter, more powerful signals that require greater density than traditional tower infrastructure. 16%, or over 2 million California households, live in rural areas and therefore this legislation did not fully address the needs of this community.

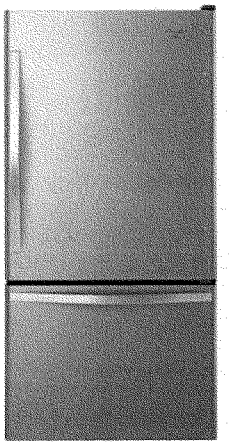
[4] http://www.ca4safertech.com/wp-content/uploads/2017/09/CA-Dept-of-Finance-Bill-Analysis.pdf

Small cells are not "small"

Although the industry describes small cells as the "size of a pizza box," the actual dimensions listed in SB 649 for a small cell were 21 cubic feet (c.f.) for equipment on the pole plus up to a 6 c.f. antenna. Additionally, ground-mounted equipment could take this number up to 35 c.f. To put this in perspective, below is a screenshot of a refrigerator's dimensions pulled from the internet. Note that the dimensions of this large refrigerator match that of what could have be mounted on a pole under this bill, not including the additional equipment. Imagine if a telecommunications firm could, by-right, mount refrigerator-sized equipment anywhere in a city. In San José we estimate that demand for small cells will be around 5,000 in the next 1-2 years. Obviously, these dimensions are concerning from an aesthetic point of view in a city for residents. And, equipment of this size mounted on a pole also requires substantive safety review to ensure structural integrity. Local communities must continue to have the ability to control how and when objects of this size are placed in the public rights of way.

Whirlpool - 21.9 Cu. Ft. Bottom-Freezer Refrigerator - Stainless steel

Model: WRB322DMBM **SKU:** 3928039 4.5 (367) 69 Questions, 154 Answers



Pre-emption of local governments led to widespread opposition

Over 300 cities in California came out in opposition of the bill, including the mayors of the largest cities in California. Editorials and op-eds appeared in many of the major newspapers in the state opposing the legislation including in the LA Times, Sacramento Bee San Francisco Chronicle, and the Mercury News as well as the New York Times. Additionally, groups like AARP and the Labor Federation also opposed the bill. This opposition highlights how contentious these bills can be and the potential for litigation in coming years if legislation is not more carefully designed.

In summary, our experience with SB 649, highlights a number areas relevant for federal action that we believe are important to consider. First, pre-emption of the right for local governments to charge for

access to the public rights of way also takes away the ability to incentivize build outs in low-income or otherwise marginalized areas. If the industry would like to be charged rates like a public utility, then they should also be responsible to serve everyone at affordable prices to consumers. Most of the legislation today is unfortunately too one-sided with the industry asking for the benefits of a public utility without the obligations.

Second, aesthetic concerns matter to local communities and bills that are overly permissive in equipment size and scale are shortsighted. No community will want thousands of refrigerator-sized equipment placed throughout their city with no say in the process.

Finally, there is a real public benefit to local governments acting as a "referee" to manage the public right of way. The public right of way is home to water, sewer, electrical infrastructure as well as traffic lights, streetlights, pedestrians, cars, *and telecommunications equipment.* Only local governments understand local needs, preferences, and how best to balance the aesthetic, safety, and wellness needs of their communities against *all* these competing interests. No one company or industry will act in the overall interest of the community in the way a local government can act – and rightfully so. Companies are incentivized to maximize shareholder value, not public value.

The way forward – a "balanced approach"

So, how can we move forward? Obviously, there is tremendous benefits to local governments and industry working together to speed broadband deployment and bridge digital divides for all Americans.

On the local government level, several common-sense approaches make sense to pursue. Jascha Franklin-Hodge, CIO of Boston, recently laid out several steps that cities should consider when adopting 5G:[5]

1. **Process:** To make 5G economically viable, cities will need base station review and approval processes that are efficient, predictable, and fair. A well-designed process can protect the public interest without subjecting installations to uncertain timelines and excessive negotiation at each individual location.
2. **Design:** To be accepted by residents, ubiquitous wireless infrastructure must blend in, and not undermine accessibility, safety, or historic preservation. With our grounded local knowledge, city government can help providers develop designs that blend into the urban fabric and win the acceptance of residents.
3. **Competition:** Policies that promote a level playing field, and which prevent squatting, exclusive access, and land grabs can ensure that 5G is a competitive market, not just a new monopoly.
4. **Compensation:** While competition is a public good, cities should not give away valuable public assets to private for-profit companies. Companies should provide cities fair market compensation through some combination of payment, in-kind services, and direct community support.

San José is adopting these principles and implementing common sense policies such as dig-once, reorganizing staff to manage our poles in a one-stop-shop to ensure safe, timely, and predictable wireless attachment permitting and installation. As previously mentioned, we are also piloting new millimeter wave technology and community-based free Wi-Fi to our low-

[5] http://statescoop.com/will-5g-allow-cities-to-kill-broadband-monopolies

income families to bridge the digital divide for our residents where the industry is not incentivized to do so.

On the federal level, pre-emption of local governments, either as a result of FCC regulations or new federal legislation, will likely have negative unintended consequences for the public. Below-market fees and rates charged to telecom companies are essentially a public subsidy, without guarantees that these companies build out everywhere and lower prices to consumers. Allowing local governments to continue to charge rational market-based rates and transparently price assets to incentivize build out in traditionally underserved areas would be more productive. Cities can also incentivize designs for deployments that meet the aesthetic needs of their communities and drive innovation over time towards smaller equipment. Federal efforts are better spent educating and building the capacity of local governments to understand how best to manage deployments of these technologies in ways that work for their community. The federal government should work with organizations such as the National League of Cities, The United States Conference of Mayors, the National Association of Counties and others to expand local knowledge and best practices.

Additionally, federal advisory commissions, such as the FCC Broadband Deployment Advisory Committee, of which I am an alternate member on behalf of our Mayor, would greatly benefit from increased local government and community input as pointed out by Congresswomen Eshoo as well as the National League of Cities, National Association of Counties, and the United States Conference of Mayors.[6]

The federal government should also be careful not to pick winners and losers through law or regulation. If Congress or the FCC encourages particular technologies, it will remove incentives to develop better technology. For example, prioritizing the deployment of "small cell" wireless infrastructure, which covers only a small area of service may have negative consequences. Affording these technologies advantages under federal law could limit the deployment of technologies that would provide greater coverage and be less physically impactful on our environments.

Closing remarks

On behalf of Mayor Liccardo and the City of San José I want to thank the Committee for inviting me to participate in this hearing today. I will offer any ongoing assistance of my city as you examine ways to increase broadband deployment responsibly across our nation. I urge you to consider local governments as strong partners in ensuring that broadband services are available to all Americans. Thank you again. I look forward to any questions you might have.

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[6] https://eshoo.house.gov/issues/telecommunications/eshoo-urges-fcc-chairman-to-include-more-local-government-input-on-broadband-deployment/

https://naco.sharefile.com/app?/#/share/view/sc363022922a467c9

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 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 now 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 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 organi-

zations. 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.

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:]

House Energy and Commerce Committee
5 G Testimony
David A. Broecker
CEO
Indiana Biosciences Research Institute
November 16, 2017

Key Points:

5G is an important technology for enabling future medical innovations in life sciences and to support advanced manufacturing of medical devices, pharmaceuticals, and diagnostics.

Convergence of biological and applied data science will require capabilities and infrastructure like 5G to send massive amounts of information better, faster, cheaper. This enables the Massive Internet of Medical Things (MIoMT) and creation of new innovations.

5G technology will enable life science manufacturers to create better and more secure supply chains that will connect patients and distribution partners and create opportunities to improve the quality and productivity for the development and manufacturing of products.

House Energy and Commerce Committee
5 G Testimony
David A. Broecker
CEO
Indiana Biosciences Research Institute
November 16, 2017

Chairman Blackburn, honorable members of the committee, thank you for inviting me to join you today to discuss the impact of 5G on the future of life sciences and advance manufacturing.

My name is David Broecker, and I am the founder of Legacy Consulting and the Founding President and CEO of the Indiana Biosciences Research Institute.

Indiana is home to one of the most diverse, robust life sciences sectors in the country, with companies in pharmaceuticals, medical devices, agriculture, and diagnostics. The state has consistently been the second largest exporter of life sciences products in the United States, exporting $9.9 billion in products and contributing $62 billion to the Indiana economy in 2016.

In today's life sciences, biology and applied data science are converging to help scientists understand the massive amounts of data being generated. This convergence will require new capabilities and infrastructure like 5G to allow scientists to share these large data streams in ways that are better, faster, and cheaper. The ability to do that will enable the Massive Internet of Medical Things (MIoMT) and create new innovations.

The development of the Massive Internet of Health things will connect patients to their physicians through telemedicine and virtual reality nterventions. 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 block chain, data standards, and encryption, it will create a shift away from place dependent, electronic medical records to virtual,

individual patient 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 patients and distribution partners, as well as create opportunities to improve the quality and productivity for the development and manufacturing of products.

For example, 5G technology will enable the real-time capture of appropriate patient information to improve safety monitoring and adverse event reporting. It also will 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. 5G also will create opportunities to connect the patient 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 of manufacturing, creating more manufacturing jobs, and enhancing the technology focus for current positions.

Just as 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 the exchange of the massive amounts of data being generated across the information rich landscape of health care and life science innovation.

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 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. 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 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 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.

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 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.

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. OK.

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 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.

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

Mr. BAZELON. 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.

Mr. WALDEN. All right.

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

Mr. PEARSON. Yes. 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 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.

Mr. WALDEN. 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 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——

Mr. WALDEN. 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. BAZELON. 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.

Mr. WALDEN. 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.

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

Mr. WALDEN. 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.

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.RPTR TELLEDTR CRYSTAL[10:58 a.m.]

Mrs. BLACKBURN. The chairmanis reminding us that he has that broadcast knowledge and information.

OK, 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 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 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, OK, 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?

Mr. BAZELON. 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. BAZELON. 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.

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. Bazelon, 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?

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

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. OK. 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. OK.

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 like?

Mr. BAZELON. 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. BAZELON. 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 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. Yes. 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 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. OK. 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 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. OK. 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 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 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 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. SHIMKUS. 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.

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 for our industry, as well as the standard.

Mr. MCNERNEY. OK.

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?

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 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 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.

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 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, OK, 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.

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 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, Mr. Chairman.

Mr. LANCE [presiding]. So ordered.

[The information appears at the conclusion of the hearing.]

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

Mr. BAZELON. 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.

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?

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.

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 appears at the conclusion of the hearing.]

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

[The information appears at the conclusion of the hearing.]

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.]

[Material submitted for inclusion in the record follows:]

The New York Times https://nyti.ms/2xPW7UU

Opinion | OP-ED CONTRIBUTOR

Why Does Verizon Care About Telephone Poles?

By SAM LICCARDO OCT. 3, 2017

SAN JOSE, Calif. — Like every other 8-year-old whom I tutored at a local school, Omar didn't know anything — and didn't care much — about high-stakes disputes over net neutrality, free speech and privacy that have consumed much of the news coverage of the telecommunications industry in recent years. Yet the inability of Omar's parents to afford broadband internet access lies at the heart of a battle that will have a far greater impact on his future: the fight over street poles.

Public street poles may not look like much, but to wireless service providers, they're valuable real estate. Companies like Verizon want low-cost access to them to install equipment to handle the rapidly growing demand for mobile data. But poles are owned locally, and cities and counties aren't eager to give away access at below-market rates. Doing so would essentially subsidize an already wealthy industry — nationwide, as much as $2 billion a year, money that could otherwise go to expanding low-cost broadband access for people like Omar's family.

As a result, the industry is waging a war for those poles, at all levels. Big Telecom and its allies in the White House have quietly carried out a campaign to secure rapid and cheap access to those poles, at taxpayer expense. Here in California, state legislators recently advanced a bill introduced by Senator Ben Hueso that would allow wireless service providers to install their equipment on public street

poles at below-market rates — and to do so nearly wherever and whenever they choose — all in the name of "streamlining" local permit approvals.

We've seen similar efforts in Texas, Florida, Wisconsin and dozens of other states, where telecommunications industry lobbyists spent more than $24.5 million in campaign contributions last year, according to the National Institute on Money in State Politics. At the federal level, Trump administration appointees to the Federal Communications Commission have publicly cheered these proposals, while releasing their own draft regulations to carry out additional industry-friendly rules nationally.

What do our taxpayers get in return for this sweetheart deal? Wireless companies insist that these legislative proposals will reduce costs for consumers, and deliver better-quality cellular voice and data service. Yet, in truth, they do nothing to actually ensure that customers will benefit from a single dollar of the cost savings that the corporate telecoms will pocket.

Moreover, service improvements will benefit only those customers able to afford its service. Despite the windfall that wireless providers receive at taxpayer expense, these industry-backed proposals do not require, or even encourage, the companies to expand broadband access to underserved rural and low-income neighborhoods.

There's no provision in the California legislation, for example, for broader deployment for low-income neighborhoods. In San Jose alone, over 40 percent of low-income residents lack broadband access. While the industry will respond by pointing to its discounted internet service plans, they remain of such poor quality that students like Omar cannot download their teachers' video-recorded lesson plans, or a Khan Academy instruction on algebra, particularly when multiple family members are sharing the same account.

In essence, these wireless service providers seek all of the privileges of a regulated water or electric utility — taxpayer-subsidized use of public infrastructure, deployment in locations of their choosing, overrides of the local government's authority — but without the accompanying responsibility: to serve everyone.

It gets worse. The push by industry and the Trump administration to override local authority to set lease rates will undermine many cities' efforts to expand digital

access. That's because San Jose; Tacoma, Wash.; and many other progressive cities seek to use lease revenues from street poles to finance the expansion of low-cost broadband to poorer neighborhoods. Otherwise, the wealthy will receive better service, and the poor will remain shut out.

These proposed regulations also supplant local communities' authority with industry fiat to determine how to deploy telecommunications equipment over public streets, sidewalks and parks. Homeowners surprised by the sight of refrigerator-size equipment installed on poles outside of their windows will have no ability to seek redress from City Hall to change the location or to mitigate the aesthetic impact of these unsightly fixtures. And because signals from of these devices can disrupt the operations of others, they can preclude cities from installing public-serving devices — such as gunshot-spotters or traffic safety sensors — on their own street poles.

These are just a few of the reasons a growing number of local elected leaders have opposed the industry's efforts in state legislatures and at the F.C.C. Here in California, the mayors of six of our largest cities — Los Angeles, San Jose, San Francisco, Oakland, Long Beach and Santa Ana – have joined leaders of 150 other cities in opposing California's version of this industry-backed effort.

There is a better way. If the industry wants the same access to taxpayer-funded infrastructure that public utilities enjoy, it should bear the concomitant responsibility to make its services available to everyone in that jurisdiction. Alternatively, if Big Telecom doesn't want the responsibility of deploying broadband in low-income neighborhoods, then the states and the F.C.C. should continue to allow cities to charge market-rate fees and leases to generate municipal dollars needed to broaden access, as San Jose is doing in several low-income neighborhoods.

We should all embrace the opportunity of greater broadband deployment, at better speeds, with the latest technology. Yet how we deploy this technology — and whether families like Omar's' will benefit — matters. If we're going to provide the telecom industry with unfettered access to public property, then the public's interest must come first.

Sam Liccardo is the mayor of San Jose, Calif., and a member of the Federal Communications Commission's Broadband Development Advisory Committee.

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The Next Wave of Spectrum Reallocation:

The Value of Additional Mid-Band Spectrum Reallocations

PREPARED FOR

CTIA

PREPARED BY

Coleman Bazelon

November 14, 2017

THE Brattle GROUP

This report was prepared for CTIA. All results and any errors are the responsibility of the author and do not represent the opinion of The Brattle Group or its clients.

Acknowledgement: I acknowledge the valuable contributions of many individuals to this report, and to the underlying analysis, including Valerie Tate.

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Executive Summary

Skyrocketing global demand for mobile wireless service, coupled with the coming of 5G networks and growth of the Internet of Things (IoT), underscores the continuing need and demand for licensed radio spectrum, including the need for a robust pipeline of spectrum below 3 GHz for exclusive, licensed services. Even after the AWS-3 auction significantly exceeded expectations, raising more than $40 billion, and an Incentive Auction that raised almost $20 billion, mid-band spectrum will continue to be an integral and valuable component of wireless networks. Consequently, I anticipate, based on two decades of experience predicting spectrum auction outcomes, that demand will stay strong for spectrum, including the mid-band frequencies needed to support mobile broadband networks. Given the significant transition times often required, now is the time to start the reallocations that will meet future spectrum demand beyond those auctions.

The spectrum bands identified herein are complementary to the AWS-3 spectrum in many ways. The 1,780 MHz–1,830 MHz band is directly adjacent to the AWS-3 band (at 1,755 MHz–1,780 MHz), making it a logical extension for mobile broadband services. Additionally, the 1,300 MHz–1,350 MHz band is a lower frequency than the 2,155 MHz–2,180 MHz portion of the AWS-3 band, providing additional propagation benefits and offering the ability to provide more robust services to consumers with fewer base stations. Moreover, these spectrum bands are populated by federal incumbents that are similar (if not precisely the same) to those in the AWS-3 band, allowing the previous accrual of knowledge concerning sharing and relocations to be leveraged as part of the accommodation of these incumbent federal users.

To that end, the analysis below provides an overview of the gross and net auction receipts expected from reallocating specific bands at 1,300 MHz–1,350 MHz and 1,780 MHz–1,830 MHz that are currently used by federal users. Specifically, after accounting for a moderation in spectrum value compared to recent highs, pairing 1,300 MHz–1,350 MHz with 1,780 MHz–1,830 MHz to provide a 50 MHz + 50 MHz paired band would be expected to raise $62.6 billion in auction receipts. Making those frequencies available would cost up to an estimated $7.93 billion to relocate existing users, providing them with at least equivalent and in many cases improved wireless infrastructure. Consequently, this band could be expected to raise $54.7 billion in net receipts.

The Federal Communications Commission (FCC) has a very good track record, having raised over $100 billion from spectrum auctions to date. Furthermore, demand for wireless broadband capacity will continue to grow at a robust pace, and increasing industry revenues will support acquisitions of additional spectrum. The direct carrier revenues for the wireless industry are approaching $200 billion per year, generating significant cash flows over the coming years to support further spectrum acquisitions of the levels estimated here.

I. Introduction

Licensed radio spectrum is the keystone of the fabulously successful wireless industry in the United States. Before accounting for the recent Incentive Auction, the 645.5 MHz of already licensed spectrum currently available for mobile broadband (worth almost $500 billion) supports an industry with almost $200 billion in direct revenues each year and an overall $400 billion annual economic footprint.[1] To sustain this economic juggernaut and meet the fantastic growth in demand for wireless broadband capacity, additional frequencies will be needed.

Virtually all desirable spectrum bands have incumbent users. Identifying bands to reallocate therefore requires assessing the costs of either relocating or accommodating incumbent users and comparing those costs to the value created by using the available frequencies for mobile broadband networks.[2] In what follows, Section II assesses the costs of relocating and/or accommodating incumbent users in a set of spectrum bands potentially available for reallocation to mobile broadband.[3] Subsequently, Section III assesses the value of each band upon reallocation. The mid-band spectrum bands considered here share important similarities to the AWS allocations and have the potential to generate similar interest from the wireless industry.[4]

II. Assessment of Relocation and Accommodation Costs

I focus on the 1,300 MHz–1,350 MHz and 1,780 MHz–1,830 MHz bands in particular as they represent crucially needed mid-band spectrum that are already being considered for reallocation by Congress and have been identified as candidate bands for reallocation by the NTIA. Proposed legislation introduced in August 2017 – the Advancing Innovation and Reinvigorating

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1 Coleman Bazelon and Giulia McHenry, "Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy," Prepared for CTIA, 2015.

2 For a more detailed discussion of the appropriate framework for assessing when to relocate incumbents versus sharing with them, see Coleman Bazelon and Giulia McHenry, "Spectrum Sharing: Taxonomy and Economics," The Brattle Group, 2014.

3 Detailed analysis of these bands, and several additional bands, is provided in Section II and Appendix A.

4 The definition of mid-band spectrum has evolved. At one time the limits of mid-band spectrum were considered to be about 3 GHz, but now 'mid-band' typically refers to the frequencies from 1 GHz up to 6 GHz.

Widespread Access to Viable Electromagnetic Spectrum ("AIRWAVES") Act – identifies these bands for relocation from federal users.[5] Furthermore, both bands would be eligible for auction under the previously-enacted Spectrum Pipeline Act of 2015 and under the MOBILE NOW Act, passed in the Senate in August 2017. The Spectrum Pipeline Act of 2015 required the identification of 30 MHz of spectrum for reallocation from federal use to be auctioned in 2024; the MOBILE NOW Act requires the FCC and NTIA to make at least 255 MHz below 6 GHz available for mobile and fixed wireless broadband.[6] Finally, the NTIA identified both bands as candidates for reallocation in October 2010.[7]

A. 1,300 MHz–1,390 MHz

This band is part of the larger 1,300 MHz–1,390 MHz allocation. The 1,300 MHz–1,350 MHz band is used by federal agencies to operate various types of "long-range radar systems that perform missions critical to safe and reliable air traffic control (ATC) in the national airspace, border surveillance, early warning missile detection, and drug interdiction."[8]

- The Federal Aviation Administration (FAA) and Department of Defense (DoD) operate long-range aeronautical radionavigation radar systems that use a continually rotating antenna mounted on a tower to monitor aircraft and other targets. Specifically, Air Route Surveillance Radar (ARSR) systems measure targets' range, bearing, and velocity.[9]

- The Tethered Aerostat Radar system, consisting of balloon-mounted radars, also operates in this band and is used for monitoring the southern borders and Caribbean airspace for drug interdiction.[10]

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5 S.1682 – AIRWAVES Act, 2017. See https://www.congress.gov/bill/115th-congress/senate-bill/1682/text.

6 The Spectrum Pipeline Act also requires the FCC and NTIA to submit two additional reports in 2022 and 2024, each identifying an additional 50 MHz for reallocation. H.R.1314 - Bipartisan Budget Act of 2015, Title X. See https://www.congress.gov/bill/114th-congress/house-bill/1314. S.19 - MOBILE NOW Act. See https://www.congress.gov/bill/115th-congress/senate-bill/19.

7 NTIA, "Plan and Timetable to Make Available 500 Megahertz of Spectrum for Wireless Broadband," 2010. See https://www.ntia.doc.gov/files/ntia/publications/tenyearplan_11152010.pdf.

8 NTIA, "Spectrum Use Report: 1300–1350 MHz," 2015. See https://www.ntia.doc.gov/files/ntia/publications/compendium/1300.00-1350.00_01DEC15.pdf.

9 *Id.*

10 *Id.*

- The military also operates tactical radar systems in this band. These tactical radars "are designed to be more easily tuned than air traffic control radars, since they may have to operate in a battlefield environment with many other systems and they need to be able to change frequencies to reduce their exposure to hostile forces."[11]

- Finally, the FAA and DoD hold frequency assignments in this band for research and development purposes in addition to their operational radars. This includes "examining new waveforms and testing new signal processing techniques."[12]

Though one major use of the 1,300 MHz–1,350 MHz band is radar used by the FAA for air traffic control, the FAA is implementing a program known as NextGen to improve the safety and efficiency of the national airspace. In particular, this program aims to replace ground radar with a satellite-based system known as Automatic Dependent Surveillance Broadcast (ADS-B) as the primary way of tracking and managing air traffic.[13] All aircraft are mandated to be equipped with ADS-B technology by 2020.[14] The implementation of ADS-B for air traffic control and other applications will likely reduce the need for the ground-based radars that currently operate in the 1,300 MHz–1,350 MHz band and will cost an estimated $2.67 billion.[15]

In addition, the federal government is studying the feasibility of making a minimum of 30 MHz in the 50 MHz 1,300 MHz–1,350 MHz band available for non-federal use.[16] This feasibility study is a multi-agency program, called the Spectrum Efficient National Surveillance Radar Program (SENSR), created as a response to the Spectrum Pipeline Act of 2015, which stated that the Department of Commerce (DoC) must submit plans to free up 30 MHz of spectrum below 3 GHz for auction in 2024.[17] An amendment to the proposed FAA Reauthorization Act of 2017

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11 *Id.*

12 *Id.*

13 FAA, "NextGen Works," 2017. See https://www.faa.gov/nextgen/works/.

14 *Id.*

15 Audit Report, Office of Inspector General, FAA, "Total Costs, Schedules, and Benefits of FAA's NextGen Transformational Programs Remain Uncertain," 2016. See https://www.oig.dot.gov/sites/default/files/FAA%27s%20Transformational%20Programs%20Report_issued%20Nov%2010_508.pdf.

16 FAA, "Spectrum Efficient National Surveillance Radar Program (SENSR) Industry Day," 2017. See https://faaco.faa.gov/index.cfm/attachment/download/75333.

17 *Id.*

recommends that the SENSR program assess reallocating the entire 1,300 MHz–1,350 MHz band for non-federal use.[18] The SENSR program aims to study the possibility of consolidating existing radar systems in the 1,300 MHz–1,350 MHz band.[19] The 2,700 MHz–3,100 MHz band is one possibility for relocation of surveillance systems currently operating in the 1,300 MHz–1,350 MHz band.[20]

If these efforts are demonstrated to be feasible, at least 30 MHz, but as much as 50 MHz, of spectrum could be freed up for mobile broadband services. Although the ADS-B technology is expected to cost $2.67 billion to develop and implement, there are no firm costs currently associated with vacating the remainder of the Federal uses in the 1,300 MHz–1,350 MHz band for non-federal use.[21] In the current analysis, I rely on estimates of clearing costs provided by CTIA and described in detail in Appendix C. According to those estimates, clearing the band of these remaining uses will cost between $1 and $1.5 billion, resulting in a total cost to clear the band of between $3.67 and $4.17 billion.[22]

B. 1,780 MHz–1,830 MHz

More than 20 federal agencies as of March 2012 were utilizing more than 3,100 individual frequency assignments in the 1,755 MHz–1,850 MHz band.[23] Primary uses of the band included fixed point-to-point microwave, military tactical radio relay, air combat training systems,

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[18] As of this writing, Senate Committee on Commerce, Science, and Transportation has approved the FAA Reauthorization Act subject to Senate confirmation. U.S. Senate Committee on Commerce, Science, & Transportation, "Committee Approves FAA Reauthorization Through 2021," 2017, Gardner 2. See https://www.commerce.senate.gov/public/index.cfm/pressreleases?ID=8D616600-D134-4131-B7A7-CD1FC50ADA1C.

In addition, legislation proposed in the Senate has suggested clearing the entire 1,300 MHz–1,390 MHz band. S.1682 – AIRWAVES Act, 2017. See https://www.congress.gov/bill/115th-congress/senate-bill/1682/text.

[19] FAA, "Fact Sheet – Spectrum Efficient National Surveillance Radar (SENSR)," 2017. See https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=21734.

[20] NTIA, "Quantitative Assessments of Spectrum Usage," 2016. See https://www.ntia.doc.gov/files/ntia/publications/ntia_quant_assessment_report-no_appendices.pdf.

[21] See *supra*, at footnote 15.

[22] See Appendix C.

[23] DoC, "An Assessment of the Viability of Accommodating Wireless Broadband in the 1755–1850 MHz Band," 2012. See https://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf.

precision guided munitions, tracking telemetry and commanding, aeronautical mobile telemetry, video surveillance, unmanned aerial systems, and other DoD systems including electronic warfare, software defined radio, and tactical targeting networking technology.[24] In 2014, the 1,755 MHz–1,780 MHz band was auctioned for commercial use as part of the AWS-3 auction,[25] providing important experience working with these agencies on reallocating and sharing such spectrum-based systems. After the auction, it is likely that some systems operating over the entirety of the 1,755 MHz–1,850 MHz band are being re-tuned to operate solely in the 1,780 MHz–1,850 MHz portion of the band. For example, the relocation of some systems from the 1,710 MHz–1,755 MHz band to accommodate the AWS-1 allocation was apparently less expensive than originally estimated because it was possible to re-tune many federal systems to operate in the 1,755 MHz–1,850 MHz band and still meet federal mission requirements.[26]

According to estimates described in Appendix C, the costs associated with clearing the 1,780 MHz–1,830 MHz band are estimated to be between $2.26 and $3.76 billion.[27] These include remaining costs from the 1,755 MHz–1,780 MHz band transition, including costs to move fixed point-to-point microwave systems and the military tactical radio relay from the band.[28] In addition, some services currently operating in this band can be moved to the 1,830 MHz–1,850 MHz portion of the band or re-tuned to operate in other bands.[29]

Assuming that the incumbent satellite systems remain, the 1,780 MHz–1,850 MHz band will require coordination zones for these systems to protect their operations from potential interference caused by new commercial wireless broadband operations. According to the

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[24] NTIA, "Spectrum Use Report: 1755–1850 MHz," 2014. See https://www.ntia.doc.gov/files/ntia/publications/compendium/1755.00-1850.00_07NOV14.pdf.

[25] FCC, "Factsheet for Auction 97: Advanced Wireless Services (AWS-3)," 2014. See http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=97.

[26] United States Government Accountability Office, "Spectrum Management: Federal Relocation Costs and Auction Revenues," 2013. See http://www.gao.gov/assets/660/654794.pdf.

[27] See Appendix C.

[28] *Id.* The total costs associated with clearing the 1,755 MHz-1,780 MHz band were estimated to be $4.58 billion. Letter to Tom Wheeler, FCC, from Lawrence E. Strickling, NTIA, "Notice of Estimated Relocation or Sharing Costs and Timelines for the 1695-1710 MHz and 1755-1780 MHz Bands," 2014, Attachment B2. See https://www.ntia.doc.gov/files/ntia/publications/notification_to_fcc_re_est_costs_for_1695_and_1755_bands_05132014.pdf.

[29] *Id.*

Commerce Spectrum Management Advisory Committee (CSMAC), "using existing national coordination procedures . . . satellite control systems and Electronic Warfare operation can co-exist with [Long-Term Evolution (LTE)] operations in the [1,755 MHz–1,850 MHz band]."[30] Therefore, the sharing parameters developed to protect the satellite systems from operations in the 1,755 MHz–1,780 MHz segment should be able to be applied to mobile broadband operations in the 1,780 MHz–1,830 MHz segment. Thus, absent additional information on the undeveloped coordination zones for the upper portion of the band, the coordination zones from the lower portion of the band act as a reasonable proxy.[31]

III. Assessment of Spectrum Value

In this section, I apply an approach to spectrum valuation that I have developed and refined over the past two decades as a spectrum valuation expert. This approach is outlined in the peer-reviewed article, "Spectrum Value."[32] I have applied variations of this basic approach to spectrum valuation as an Analyst at the Congressional Budget Office, in numerous policy analyses, and as an advisor to bidders in spectrum auctions.[33]

A. Baseline Spectrum Valuation Model

The value of a swath of spectrum is derived from the profits that can be made by deploying it. The AWS-3 and Incentive auctions provide recent market-based estimates of the bounds of spectrum value. But additional developments that will play out in the coming years, including 5G and the IoT, will further impact spectrum values. In this section, I consider recent auction experience and future industry developments to estimate the baseline value of mid-band spectrum that will be used to value specific bands at auction.

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30 CSMAC, "Report on 1755-1850 MHz Satellite Control and Electronic Warfare," 2013.

31 For a detailed discussion of the coordination zones developed for the lower portion of the band, see: FCC and NTIA, "Coordination Procedures in the 1695-1710 MHz and 1755-1780 MHz Bands," 2014.

32 Coleman Bazelon and Giulia McHenry, "Spectrum Value," *Telecommunications Policy*, 2013.

33 I have a long track record of estimating spectrum receipts. For example, I accurately predicted the revenues from the 700 MHz auction three years prior to the auction. See Coleman Bazelon, "Analysis of an Accelerated Digital Television Transition," 2005. I have also significantly underestimated auction revenues, as was the case with my estimate of the value of AWS-3 spectrum of $12 billion, when the auction generated bids of almost $43 billion for the paired licenses. Coleman Bazelon, "The Economic Basis of Spectrum Value: Pairing AWS-3 with the 1755 MHz Band is More Valuable than Pairing it with Frequencies from the 1690 MHz Band," 2011. See *infra,* at footnote 36.

1. Upper Bound: AWS 3 Auction

The AWS-3 auction ended in early 2015 and received gross bids of $44.9 billion for 65 MHz of spectrum.[34] Approximately $2.4 billion of that total was for unpaired up-link frequencies at 1,695 MHz–1,710 MHz.[35] Putting those frequencies aside and focusing on the paired licenses, the total revenue was $42.5 billion or $2.71/MHz-pop.[36] Consequently, I start with an estimate of the upper bound of mid-band spectrum value of $2.71/MHz-pop.

2. Lower Bound: Incentive Auction

The recent Incentive Auction sold up to 70 MHz of low-band 600 MHz spectrum for mobile wireless networks. The total amount bid was $19.8 billion or $0.93/MHz-pop.[37] This price point provides a lower bound estimate of value for at least three reasons.

First, this is low-band spectrum. As described in more detail below, 5G network architecture makes use of a mix of low-, mid-, and high-band frequencies. The low-band frequencies provide

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[34] For details on the AWS-3 auction, see the FCC's "Factsheet for Auction 97" at http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=97. Total net bids in the auction were $41.3 billion. The gross amount included $3.6 billion in bidding credits—$3.3 billion of which was for DISH related entities. Those entities were denied their bidding credits and in response chose to turn in licenses of an equivalent value. Consequently, the total value of the band will be $41.3 billion plus the amount the FCC raises when those returned licenses are re-auctioned. Herein, I assume those licenses will receive bids in the same amounts they received in the original auction, implying a total value of $44.9 billion.

[35] Total bid values for the AWS-3 A1 and B1 blocks are calculated using the following FCC auction data: http://auctionresults.fcc.gov//Auction_97/Results/full/341//97_341_all_files.zip.

[36] Based on 2010 U.S. population of approximately 313 million within the Partial Economic Areas (PEAs) defined by the FCC. $2.71/MHz-pop = $42.46 billion / [(65 MHz–15 MHz) x 313 million pops]; FCC, "Incentive Auction: Forward Auction – Markets," 2017. See https://auctiondata.fcc.gov/public/projects/1000/reports/forward-markets.

[37] For details on the Incentive Auction, see the FCC's "Auction 1000" page at https://www.fcc.gov/wireless/auction-1000. Between four and seven licenses with 10 MHz were licensed in each of the 416 PEAs, resulting in a total of 21.2 billion MHz-pops auctioned. $0.93/MHz-pop = $19.8 billion / 21.2 billion MHz-pops. FCC, "Incentive Auction: Assignment Phase – Results by License," 2017. See https://auctiondata.fcc.gov/public/projects/1000/reports/assignment-results_by_license. FCC, "Incentive Auction: Forward Auction – Markets," 2017. See https://auctiondata.fcc.gov/public/projects/1000/reports/forward-markets. FCC, "Incentive Auction: Forward Auction – Band Plans," 2017. See https://auctiondata.fcc.gov/public/projects/1000/reports/forward-band_plans. FCC, "Incentive Auction: Forward Auction – Announcements," 2017. See https://auctiondata.fcc.gov/public/projects/1000/reports/forward-announcements.

a coverage layer, which are crucial for providing access to the network but are not the primary spectrum that will be used for meeting significant capacity needs. These frequencies would be most valuable to entrants and existing players that need to enhance their coverage layers. Consequently, demand for these frequencies should be lower than demand for mid-band spectrum.

Second, specific issues with this auction made it more difficult for the auction to realize the full value of the frequencies being sold. Among other factors, the iterative nature of the auction's process, which endogenously discovered the market-clearing amount of spectrum, meant that significant time lapsed from when the up-front deposits were due from bidders on July 1, 2016 to when final bidding ended on February 10, 2017.[38] This unusually long auction process created a dynamic where existing bidders could exit or reduce their demand in response to changing circumstances—such as the resolution of the FirstNet frequencies that would be commercially accessible—but no new bidders could join the bidding. This one-way ratchet of demand risks artificially depressing demand in the auction.

Third, recent transactions of similar spectrum in the 700 MHz band suggest that prices leading up to the auction were higher, albeit trending downward. See Table 1

[38] FCC, "Upfront Payment Instructions for the Forward Auction (Auction 1002) of the Broadcast Television Spectrum Incentive Auction," June 8, 2016. See https://apps.fcc.gov/edocs_public/attachmatch/DA-16-625A1.pdf. FCC, "Incentive Auction: Forward Auction – Announcements," February 10, 2017. See https://auctiondata.fcc.gov/public/projects/1000/reports/forward-announcements.

Table 1: T-Mobile 700 MHz A-Block Spectrum Purchases

	Sold By [1]	Year of Sale [2]	MHz-pops [3]	Purchase Price ($ mm) [4]	$/MHz-pop [5]	Relative Value Index [6]	Implied National Average $/MHz-pop [7]
[A]	AT&T / Leap Licenseco Inc.	2016	129,097,416	$420	$3.25	1.98	$1.64
[B]	Multiple Transactions, Nov 2015-Apr 2016	2015-2016	834,446,352	$1,300	$1.56	0.63	$2.48
[C]	Actel and I-700	2014	90,107,976	$51	$0.56	0.23	$2.48
[D]	Verizon / Cellco Partnership	2014	1,790,166,204	$3,315	$1.85	1.36	$1.36

Sources and Notes:

[1] - [3]: Includes 700 MHz A-Block spectrum transactions involving T-Mobile and with financial information available. FCC ULS License Databases. See http://wireless.fcc.gov/uls/index.htm?job=transaction&type=weekly.

[4][A]: Colin Gibbs, "T-Mobile's $420M price tag for Chicago's 700 MHz may not point to 600 MHz auction value: analysts," Fierce Wireless, 2016. See http://www.fiercewireless.com/wireless/t-mobile-s-420m-price-tag-for-chicago-s-700-mhz-may-not-point-to-600-mhz-auction-values.

[4][B]: T-Mobile reports having spent approx. $1.3 billion for licenses in the first half of 2016, with some deals potentially made in 2015, for licenses covering approx. 68 million people. It is unclear which transactions are included in this sum, so all T-Mobile transactions from November 2015 to April 2016 are included. Mike Dano, "T-Mobile's 700 MHz buildout in 2016 revealed: Over $1B spent in Utah, Southeast and elsewhere," Fierce Wireless, 2016. See http://www.fiercewireless.com/wireless/t-mobile-s-700-mhz-buildout-2016-revealed-over-1b-spent-utah-southeast-and-elsewhere.

[4][C]: It is possible that the purchase price covers additional transactions, as T-Mobile reported spending $50.5 million on licenses covering 8.7 million pops. The transactions with Actel and I-700 appear to only cover 7.6 million pops. Phil Goldstein, "T-Mobile scores more 700 MHz A-Block spectrum from CenturyLink unit," Fierce Wireless, 2014. See http://www.fiercewireless.com/wireless/t-mobile-scores-more-700-mhz-a-block-spectrum-from-centurylink-unit.

[4][D]: Phil Goldstein, "T-Mobile buys Verizon's 700 MHz A Block spectrum for $2.4B," Fierce Wireless, 2014. See http://www.fiercewireless.com/wireless/t-mobile-buys-verizon-s-700-mhz-a-block-spectrum-for-2-4b.

[5]: [4] / [3].

[6]: Composite relative value index for all licenses in each transaction. Calculated as the total price per MHz-pop for all BEAs covered in each transaction from the FCC's Auction 97 (AWS-3) divided by the national average price per MHz-pop from the same auction. The price per MHz-pop is calculated as the weighted average price across the gross winning bids for the H-, I-, and J-blocks.

[7]: [5] / [6].

3. New Demand: 5G and the Internet of Things

The most recent technological development that will impact spectrum value is the creation and deployment of 5G networks. The current mobile network, fourth-generation (4G) LTE, provides "more capacity for faster and better mobile broadband experiences."[39] A 4G wireless network

[39] Qualcomm PowerPoint Presentation, "The Evolution of Mobile Technologies," 2014. See https://www.qualcomm.com/media/documents/files/the-evolution-of-mobile-technologies-1g-to-2g-to-3g-to-4g-lte.pdf.

using LTE technology will soon be able to transmit at speeds as high as 1.2 gigabits per second (Gbps).[40] The next 5G wireless networks, however, are expected to support speeds that can reach 20 Gbps downlink and 10 Gbps uplink per base station in ideal conditions, while still well outpacing 4G networks in more typical settings.[41] In addition to faster data speeds, a 5G network is envisaged to have several other key capabilities, including: (i) ultra-low latency (as low as one millisecond); (ii) increased capacity; and (iii) increased connection density (as high as one million devices per square kilometer).[42]

The development of new 5G technology is also predicted to speed the growth of two budding data-intensive applications: the IoT and mission critical control. The IoT refers to the linking and communication between physical objects, such as roadways and buildings, using wired and wireless networks.[43] By 2020, there could be over 26 billion connected devices, with some estimates ranging as high as 100 billion - "anything that can be connected, will be connected."[44] Mission critical communications are envisioned to allow for the real-time control and

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40 Aaron Pressman, "Qualcomm Is Trying To Speed Up Current Mobile Networks Ahead of 5G," *Fortune*, 2017. See http://fortune.com/2017/02/21/qualcomm-speeds-4g-lte-modem/.

41 User experienced data rates are often not as high as the peak data rate in a given network. The International Telecommunications Union (ITU) envisions 5G to have peak down-link data rates of 20 Gbps and user experienced rates as high as 100 Mbps. ITU, "IMT Vision – Framework and Overall Objectives of the Future Development of IMT for 2020 and Beyond," 2015. See https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf ("ITU, IMT Vision"); and ITU, "Draft new Report ITU-R M.[IMT-2020.TECH PERF REQ] - Minimum requirements related to technical performance for IMT-2020 radio interface(s)," 2017. See https://www.itu.int/md/R15-SG05-C-0040/en ("ITU, Draft IMT-2020 Minimum Requirements").

42 The other key capabilities listed by the ITU include: increased spectrum efficiency, increased mobility, and increased network energy efficiency. See ITU, IMT Vision; and ITU, Draft IMT-2020 Minimum Requirements.

43 Michael Chui, Markus Löffler, and Roger Roberts, "The Internet of Things," *McKinsey Quarterly*, 2010. See http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things. The ITU refers to these two usage scenarios as "ultra-reliable and low latency communication" and "massive machine type communications." See ITU, IMT Vision; and ITU, Draft IMT-2020 Minimum Requirements.

44 Jacob Morgan, "A Simple Explanation of 'The Internet of Things,'" *Forbes*, 2014. See http://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/#1c732b186828.

automation of dynamic processes, such as autonomous vehicles and robotics.[45] Some estimates suggest that by 2025, there could be as many as 3 million autonomous vehicles alone.[46]

Future wireless networks must satisfy both a rise in demand for mobile data and a rise in demand for faster mobile data speeds; satisfying both of these needs will require more spectrum and different types of spectrum. That is, the architecture of a robust 5G network will require spectrum in a variety of bands: "low-band" spectrum below 1 GHz for wide-area and long-range communications; "mid-band" spectrum between 1 GHz and 6 GHz for applications that would benefit from a combination of coverage and capacity support in mobile broadband networks and mission critical communications; and "high-band" spectrum for short range communications requiring fast data rates and low latency.[47] A 5G network will be based on a dense heterogeneous network structure that includes the dense deployment of small cells in connection with the growing number of macro cells to increase network efficiency and to make connectivity more uniform across users.[48] All three pieces of this "spectrum trifecta" will be crucial for the successful deployment of a 5G network, as stated by Ericsson:

> It is important to understand that high frequencies, especially those above 10GHz, can only serve as a complement to lower frequency bands, and will mainly

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[45] Qualcomm PowerPoint Presentation, "Building a unified 5G platform: For the next decade and beyond," 2015; and Osman Yilmaz, "5G Radio Access for Ultra-Reliable Low-Latency Communications," Ericsson Research Blog, 2015. See https://www.ericsson.com/research-blog/5g/5g-radio-access-for-ultra-reliable-and-low-latency-communications/.

[46] ABI Research, "5G to be Unifying Connectivity Technology for Future Cars; To Enable V2X Communication," 2016. See https://www.abiresearch.com/press/5g-be-unifying-connectivity-technology-future-cars/.

[47] Letter to Marlene H. Dortch, FCC from Reed Hundt, "Use of Spectrum Bands Above 24 GHz for Mobile Radio Services, GN Docket No. 14-177; IB Docket Nos. 15-256, 97-95; WT Docket No. 10-112; RM-11664," 2016. See https://ecfsapi.fcc.gov/file/1070164539932/Hundt%20Letter%20on%205G%20(7-1-2016).pdf. Tom Wheeler, "The Future of Wireless: A Vision for U.S. Leadership in a 5G World," prepared remarks at the National Press Club, Washington, D.C., 2016. See http://transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0620/DOC-339920A1.pdf. GSMA Public Policy Position, "5G Spectrum," 2016. See http://www.gsma.com/spectrum/wp-content/uploads/2015/04/5G-Spectrum-Policy-Position-FINAL-2016-update-.pdf.

[48] Boyd Bangerter, Shilpa Talwar, Reza Arefi, and Ken Stewart, "Networks and Devices for the 5G Era," *IEEE Communications Magazine*, February 2014 ("Bangerter, Talwar, et al., "Networks and Devices for the 5G Era"). GSMA Public Policy Position, "5G Spectrum," 2016. See http://www.gsma.com/spectrum/wp-content/uploads/2015/04/5G-Spectrum-Policy-Position-FINAL-2016-update-.pdf.

> provide additional system capacity and very wide transmission bandwidths for extreme data rates in dense deployments.[49]

Until last year, all spectrum currently allocated to mobile wireless networks was concentrated in the low-and mid-bands below 6 GHz.[50] Until recently, spectrum above about 3 GHz was not seen as viable to deploy in mobile networks. This was primarily because the propagation characteristics of high frequencies would require cell sites that would be too limited in coverage to be economical. However, developments in 5G technology are making it possible to economically deploy high-band spectrum, specifically spectrum above 24 GHz, for mobile wireless.[51] In its Spectrum Frontiers proceeding, the FCC opened almost 11 GHz of licensed and unlicensed spectrum in the 28 GHz, 37 GHz, 39 GHz, and 64-71 GHz bands for wireless broadband.[52]

High-band spectrum is expected to be deployed for 5G first in dense areas and spaces like stadiums and public transportation stops where the wireless data demands are greatest.[53] Such dense areas make it economical to deploy high-band spectrum since there will still be many users

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[49] Ericsson White Paper, "5G Radio Access," 2016. See http://www.ericsson.com/res/docs/whitepapers/wp-5g.pdf. The term "spectrum trifecta" was coined by FCC Chairman Tom Wheeler in his June 20th, 2016 remarks at the National Press Club. Tom Wheeler, "The Future of Wireless: A Vision for U.S. Leadership in a 5G World," prepared remarks at the National Press Club, Washington, D.C., 2016. See http://transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0620/DOC-339920A1.pdf.

[50] Bangerter, Talwar, et al., "Networks and Devices for the 5G Era"; and FCC, "Fact Sheet: Spectrum Frontiers Proposal to Identify, Open Up Vast Amounts of New High-Band Spectrum for Next Generation (5G) Wireless Broadband," 2016. See https://apps.fcc.gov/edocs_public/attachmatch/DOC-339990A1.pdf.

[51] See, for example, Thomas K. Sawanobori and Paul V. Anuszkiewicz, "High Band Spectrum, The Key to Unlocking the Next Generation of Wireless," CTIA, 2016. See https://www.ctia.org/docs/default-source/default-document-library/5g-high-band-white-paper.pdf.

[52] FCC, "Fact Sheet: Spectrum Frontiers Proposal to Identify, Open Up Vast Amounts of New High-Band Spectrum for Next Generation (5G) Wireless Broadband," 2016. See https://apps.fcc.gov/edocs_public/attachmatch/DOC-339990A1.pdf.

[53] See, for example, Thomas K. Sawanobori and Paul V. Anuszkiewicz, "High Band Spectrum, The Key to Unlocking the Next Generation of Wireless," CTIA, 2016. See https://www.ctia.org/docs/default-source/default-document-library/5g-high-band-white-paper.pdf.

in the smaller coverage areas necessary for higher frequencies.[54] However, not all 5G and IoT deployments will be concentrated in dense urban areas. Mobile operators like Verizon are conducting 5G trials in cities with a range of population densities.[55] Many of the anticipated hallmarks of the IoT, such as connected devices, integrated road networks, and driverless cars, will be deployed in less dense urban and suburban areas in addition to urban cores.[56] Thus, although the ultimate economic boundaries of where the highest frequencies will be deployed for 5G are still uncertain, less dense urban and suburban areas are likely to be included in 5G deployments as they prove commercially successful.[57] The question of where 5G is deployed may ultimately be one of timing, with urban areas seeing earlier deployments and applications for suburban and rural areas evolving later.

These new 5G and IoT deployments will have profound implications for spectrum value. On the one hand, being able to integrate massive amounts of high-band spectrum into commercial mobile networks will flood the market with spectrum capacity, at least in denser, urban areas, and for applications that can utilize the higher frequency spectrum. On the other hand, these new networks will enable new uses of wireless networks and increase consumer expectations about throughput and reliability. The net effect of these two implications is uncertain, and overall spectrum values, especially for mid-band capacity spectrum, could go up or down.

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[54] See, for example, Thomas K. Sawanobori and Paul V. Anuszkiewicz, "High Band Spectrum, The Key to Unlocking the Next Generation of Wireless," CTIA, 2016. See https://www.ctia.org/docs/default-source/default-document-library/5g-high-band-white-paper.pdf.

[55] See, for example, Diana Goovaerts, "Verizon Announces 5G Customer Trials in 11 Cities with 5G Forum Partners," *Wireless Week*, 2017. See https://www.wirelessweek.com/news/2017/02/verizon-announces-5g-customer-trials-11-cities-5g-forum-partners.

[56] For example, it has been argued that the shift toward driverless cars may even encourage urban sprawl as it becomes easier to live far from city centers. Noah Smith, "Like the Suburbs? You'll Love Driverless Cars," Bloomberg View, 2015. See https://www.bloomberg.com/view/articles/2015-11-04/like-the-suburbs-you-ll-love-driverless-cars-.

[57] For example, an analysis by Plum Consulting finds that C-band spectrum would be deployed in all non-rural areas of the UK, and although C-band is considered mid-band in the 5G rubric, I take the analysis here as indicative of where new, higher frequencies will generally be economical to deploy. Plum Consulting classifies these non-rural areas as any area with a population density of at least 202 people per square kilometer. Tony Lavender, Paul Hansell, Iain Inglis, and Sarongrat Wongsaroj, "Use of C-Band (3400/3600-4200 MHz) for mobile broadband in Hungary, Italy, Sweden and the UK," Plum Consulting, 2015. See http://www.plumconsulting.co.uk/pdfs/Plum_Jun2015_Use_of_C-Band_for_mobile_broadband_in_Hungary_Italy_Sweden_and_UK.pdf. GSMA Public Policy Position, "5G Spectrum," 2016. See http://www.gsma.com/spectrum/wp-content/uploads/2015/04/5G-Spectrum-Policy-Position-FINAL-2016-update-.pdf.

But within the overall net impact on spectrum values, there are clear implications from increased user expectations for throughput, mobility, and latency for different types of spectrum. The value of mid-band spectrum used for capacity outside of the urban areas served by 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. Consequently, the flood of high-band frequencies that may enter service will not substitute for the mid-band frequencies analyzed here.

4. Conclusion: The New Spectrum Value Baseline

Expectations about overall spectrum values are somewhere between $0.93/MHz-pop seen in the Incentive Auction and $2.71/MHz-pop seen in the AWS-3 auction. There are several reasons to believe spectrum values for mid-band spectrum are at the higher end of this range. First of all, the high end of the range was set by a mid-band spectrum auction. Also, as noted above, the lower end of the range likely understates the real value of low-band spectrum. Furthermore, developments with 5G and the IoT suggest a tilting of demand toward mid-band spectrum relative to low-band spectrum. Taking this all together, and using a bit of judgment based on more than two decades of estimating spectrum values, I will use $2.00/MHz-pop to value the mid-band spectrum analyzed here. Given the larger overall base of spectrum that will be used in mobile markets in 5G deployments, the increases in the quantity of spectrum available for mobile broadband is relatively small, so I make no adjustments to price for any quantity effects of new spectrum and use the $2.00/MHz-pop estimate of mid-band spectrum value throughout the analysis.

As noted above, there is some degree of uncertainty about the future development of spectrum prices. My estimate of $2.00/MHz-pop represents my expectation about spectrum values after weighing factors that could lead to higher or lower values. That is, $2.00/MHz-pop is my expected value for the frequencies considered here. But there is some uncertainty around that expectation. If prices are higher than expected, as was the case with the AWS-3 auction,[58] then realized auction receipts would contain a windfall—a happy occurrence from a budgetary standpoint. But prices could be lower than expected, leading to less revenue than originally planned. To illustrate the downside risk, I also present a downside scenario. This would be realized if the impact of 5G developments were less dramatic in increasing both relative and

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[58] For instance, see *supra*, at footnote 33.

absolute levels of demand for mid-band spectrum, leading to lower prices. In this case, the value of mid-band spectrum would be closer to the low end of the range discussed above, and I use $1.00/MHz-pop to illustrate this downside scenario.

Other typical considerations when comparing the relative value of different spectrum bands includes the size of the allocation, whether it is paired, and potential international harmonization. None of the allocations considered are unusually small or large; the evolution of Time Division Duplex (TDD) (including in 5G standards[59]) suggests changing dynamics of TDD versus Frequency Division Duplex (FDD); and one of the two bands analyzed is harmonized, suggesting additional benefits in equipment development from international uses of the band.[60] Consequently, in the case of the bands evaluated here, I make no further adjustment for these issues to the baseline.

Finally, impairments in a band may cause a diminution in band value. For the bands considered below, the exact areas of impairment are not yet known. However, analysis of the AWS-3 auction suggests a somewhat surprising result: the levels of impairment in the AWS-3 band do not appear to have caused any reduction in prices paid. As detailed in Appendix B, I analyze the relative prices of licenses in the AWS-3 auction compared to the relative prices of similar licenses in the AWS-1 auction and find no evidence that impairments impacted relative prices. Given the differences in impairments and that there is no evidence of a difference in relative prices, I conclude that the level of impairments seen in the AWS-3 auction did not impact prices. In a complimentary analysis, I utilize econometric techniques to test whether or not the presence or level of impairment has a statistically significant negative impact on the prediction of prices in the AWS-3 auction. Similarly, I find no evidence that impairments impact the realized value of licenses in the auction. Therefore, to the extent that the impairments in the bands examined below are not significantly worse than expected, I do not expect impairments to negatively impact auction prices for these bands. Should impairments of bands be significantly worse, some adjustment to the estimated value may be warranted.

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[59] Qualcomm, "Making 5G NR a reality," 2016. See https://www.qualcomm.com/media/documents/files/whitepaper-making-5g-nr-a-reality.pdf.

[60] The 1,780 MHz-1,830 MHz band is harmonized. FCC, "FCC Online Table Of Frequency Allocations," 2017. See https://transition.fcc.gov/oet/spectrum/table/fcctable.pdf.

B. VALUATION OF 1,300 MHz–1,350 MHz PAIRED WITH 1,780 MHz–1,830 MHz

This section will value the pairing of the 1,300 MHz–1,350 MHz and the 1,780 MHz–1,830 MHz bands. I apply the estimated price of mid-band spectrum of $2.00/MHz-pop to the quantity of spectrum available and subtract the costs of making the spectrum available. I also present a downside scenario based on a value of $1.00/MHz-pop.

This pairing, which uses mid-band spectrum that is adjacent to the AWS allocation with lower down-link frequencies at 1,300 MHz–1,350 MHz, would have more favorable propagation characteristics for coverage than the AWS allocations. Somewhat offsetting this advantage, this new allocation does not have a current ecosystem developed. The Spectrum Pipeline Act of 2015 directed federal agencies to examine clearing at least 30 MHz of spectrum for mobile use; to that end, four agencies – FAA, DoD, Department of Homeland Security (DHS), and National Oceanic and Atmospheric Association (NOAA) – are studying the feasibility of clearing a minimum of 30 MHz of the 1,300 MHz-1,350 MHz band.[61] Consequently, any amount between 30 MHz and 50 MHz of that band may be made available, but because Congress is recommending that the SENSR program examine clearing all 50 MHz in the 1,300 MHz–1,350 MHz band, I will focus on the case where 50 MHz is made available.[62] In doing so, I will assume that the frequencies from the 1,300 MHz–1,350 MHz band are evenly paired with frequencies from the 1,780 MHz–1,830 MHz band, creating a total allocation of 100 MHz. It is worth noting that even though I am assuming these frequencies are "paired," they could be sold as TDD bands—doing so would not likely change the analysis significantly.

With 313 million people covered, this allocation represents 31.3 billion MHz-pops.[63] Consequently, the value before accounting for impairments or incumbent reallocation costs is $62.6 billion.[64]

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[61] FAA, "Spectrum Efficient National Surveillance Radar Program (SENSR) Industry Day," January 5, 2017. See https://faaco.faa.gov/index.cfm/attachment/download/75333; and H.R.1314 - Bipartisan Budget Act of 2015, Title X. See https://www.congress.gov/bill/114th-congress/house-bill/1314.

[62] See *supra*, at 18.

[63] 31.3 billion MHz-pops = 100 MHz x 313 million people. For total US population, see FCC, "Incentive Auction: Forward Auction – Markets," 2017. See https://auctiondata.fcc.gov/public/projects/1000/reports/forward-markets.

[64] $62.60 billion = $2.00/MHz-pop x 100 MHz x 313 million people.

I make no further adjustment for impairments. I do not have any evidence that the coordination zones will be significantly worse than for AWS-3, so I make no further adjustments for them. If coordination zones are significantly larger than for AWS-3, then some further adjustment would be warranted.

As noted in Section II, the costs of clearing the 1,300 MHz–1,350 MHz band and 1,780 MHz–1,830 MHz band would be between $3.67 and $4.17 billion and between $2.26 and $3.76 billion, respectively—amounting to a total expected cost of between $5.93 and $7.93 billion. On net, this band would therefore be expected to raise between $54.7 and $56.7 billion for 100 MHz.[65] For a downside scenario, the auction receipts would be estimated to be $31.3 billion, with net receipts between $23.4 and $25.4 billion for 100 MHz.[66]

C. Realizing Value

Whether or not any given auction will realize the value of the spectrum licenses being sold depends on a number of specifics that cannot be known ahead of time. The auction rules matter, including set-asides or reserved spectrum (which will likely decrease revenues) and bidding credits (which may raise revenues). Macroeconomic and industry conditions at the time of the auction can also impact auction outcomes. And of course auction participation, and the budgets that participants bring, is also important. Consequently, it would be inappropriate to try to forecast such auction-specific details years in the future.

Nevertheless, at a high level, there is cause for optimism for future FCC auctions realizing value. The FCC has a very good track record with auctions, having raised over $100 billion to date.[67] Furthermore, their sophistication with auction design and implementation grows with time—and was taken to a new level with the Incentive Auction. The macroeconomic and industry expectations in coming years also support high revenues. Demand for wireless broadband capacity, especially for the relatively scarce mid-band frequencies, will continue to grow at a robust pace and increasing industry revenues will support acquisitions of additional spectrum. The direct carrier revenues for the cellular industry are approaching $200 billion per year,

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[65] $54.67 billion = $62.60 billion – $7.93 billion. $56.67 billion = $62.60 billion – $5.93 billion.

[66] $31.30 billion = $1.00/MHz-pop x 100 MHz x 313 million people. $23.37 billion = $31.30 billion – $7.93 billion. $25.37 billion = $31.30 billion – $5.93 billion.

[67] FCC, "Auctions Summary," 2015. See http://wireless.fcc.gov/auctions/default.htm?job=auctions_all#completed.

generating significant cash flows over the coming years to support further spectrum acquisitions of the levels estimated here.[68]

[68] CTIA, "Annual Year-End 2016 Top-Line Survey Results," 2017. See https://www.ctia.org/docs/default-source/default-document-library/annual-year-end-2016-top-line-survey-results-final.pdf?sfvrsn=2.

Appendix A: Additional Details by Band

In what follows, for each type of operation or system (*e.g.*, long range radar systems or polar-orbiting weather satellites) within a particular band of spectrum, I provide additional detail on what is known about the incumbent users and the possible restrictions or coordination zones for each such user.[69] Specifically, in cases where incumbent users are expected to remain upon reallocation of a particular band of spectrum, I describe the coordination zones that are likely to result.

A. 1,300 MHz–1,350 MHz

Long Range Radar Systems

Spectrum contours for all radar systems operating in the 1,300 MHz–1,390 MHz band have been computed by the NTIA for a generic ground-based receiver (see Figure 1).[70] These contours represent the locations where the signal level of the radar system will cause the receiver to exceed an interference threshold of 1 dB—they do not, however, represent the physical coverage area of the radar.[71] Therefore, if any incumbent radar systems were to remain in the band upon reallocation, these contours would serve as a reasonable proxy for the terrestrial coordination zones associated with each radar system.

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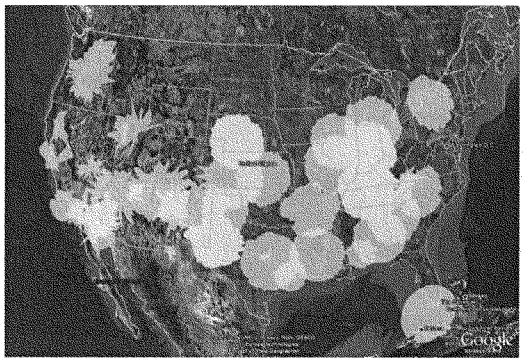
[69] The only exception is in the 1,780 MHz – 1,850 MHz band, where I lump all such operations together due to the vast quantity and variety of incumbent systems in the band.

[70] NTIA, "Spectrum Use Report: 1300-1350 MHz," 2014; NTIA, "Spectrum Use Report: 1350-1390 MHz," 2014.

[71] *Id.* Actual receiver tolerance may be higher or lower, depending on the specific wireless broadband system deployed.

Figure 1. Spectrum Contours for Radars Operating in the 1,300 MHz–1,390 MHz Band Segment



Source: NTIA, 2014.

B. 1,780 MHz–1,850 MHz

All Users

The CSMAC conducted several studies to evaluate sharing compatibility between commercial LTE systems and federal systems operating in the 1,755 MHz–1,850 MHz band, in addition to considering effective transition and/or relocation strategies. In summary the studies found:

- Video surveillance systems would need to be relocated to facilitate sharing.[72]
- Satellite control systems and electronic warfare operations could co-exist with LTE operations, as i) LTE devices were shown to produce only "negligible interference to all satellite programs except possibly a few experimental spacecraft," ii) several technologies were identified to mitigate harmful interference from LTE base stations, and iii) electronic warfare operations could continue on a non-interference basis using existing national coordination procedures.[73]

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[72] CSMAC, "Working Group 2: 1755–1850 MHz Law Enforcement Surveillance, Explosive Ordinance Disposal, and other short distance links," 2013. These systems would likely first be consolidated into the 1,839-1,850 MHz band and may ultimate be moved to other bands, such as the 2,025-2,1100 MHz band, the 2,200-2,290 MHz band, or the 2,360-2,390 MHz band. See Appendix C.

[73] CSMAC, "Report on 1755–1850 MHz Satellite Control and Electronic Warfare," 2013.

- Fixed point-to-point microwave operations would need to be relocated to facilitate sharing, but tactical radio relay and joint tactical radio systems could not share spectrum with commercial LTE systems without requiring separation distances of hundreds of kilometers.[74]

- Certain federal airborne systems may need to be relocated to facilitate sharing—however the identification and consideration of such alternate spectrum was not directly addressed.[75] Further, sharing of frequencies between commercial LTE and airborne systems (*e.g.*, air combat training systems, small unmanned aircraft systems, precision-guided munitions, and aeronautical mobile telemetry) would not be feasible without requiring separation distances of hundreds of kilometers.[76]

Thus, it is reasonable to assume that the entirety of the band will be cleared other than the incumbent federal satellite systems—which will entail the establishment of coordination zones. Prior to the AWS-3 auction, coordination zones were established for the incumbent federal satellite systems in the 1,755 MHz–1,780 MHz portion of the band.[77] Given the conclusions of the CSMAC, and pending further study, these coordination zones appear to be reasonable proxies for the coordination zones that are likely to be established in the upper portion of the band upon reallocation.

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[74] CSMAC, "1755–1850 MHz Point-to-Point Microwave Tactical Radio Relay (TRR) Joint Tactical Radio System / Software Defined Radio (JTRS/SDR)," 2013. Fixed point-to-point microwave operates will be relocated to the 4,400-4,490 MHz or 7,125-8,500 MHz bands, and tactical radio relay will be relocated to the 2,025-2,110 MHz or 2,200-2,290 MHz bands. DoC, "An Assessment of the Viability of Accommodating Wireless Broadband in the 1755–1850 MHz Band," 2012. See https://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf.

[75] CSMAC, "1755–1850 MHz Airborne Operations," 2013.

[76] *Id.*

[77] FCC and NTIA, "Coordination Procedures in the 1695–1710 MHz and 1755–1780 MHz Bands," 2014.

Appendix B: Effect of Impairments on Spectrum Value

The AWS-3 auction provides a unique opportunity to empirically investigate the impact of impairments on the value of spectrum. In the AWS-3 band, certain licenses are shared between license winners and the incumbent federal operations that currently operate in these areas.[78] Sharing between auction winners and the federal operations occurs via a coordination process that takes place over a specified "transition timeline."[79] Licenses are potentially impaired by the DoD in two ways: via interference from AWS-3 up-link transmissions that may create noise for DoD receivers and from DoD transmitters to AWS-3 receivers.

Because the level of impairment generated by interference from AWS-3 transmitters to DoD systems is used to define federally regulated protection zones where successful coordination is required among users during the transition time period, I focus my attention on this measurement of impairment in my analysis.[80] Information on potential interference, and transition time (*i.e.,* the time it takes a DoD operation to migrate to another frequency or medium), is available on a census tract level provided by the NTIA.[81] Transition times vary by operation, ranging from zero to 120 months.[82]

Virtually all of the licenses offered in the AWS-3 band are impaired for at least a period of time. Approximately 309 million people in 172 license areas (out of 176 total licenses offered for each block) are estimated to be potentially impaired to some degree.[83] However, the population impaired over the longer term is significantly less. The total population potentially impaired for

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78 NTIA, "DoD Workbook Information File In Support of AWS-3 Transition Planning for 1755-1780 MHz Band," 2014. See http://www.ntia.doc.gov/files/ntia/publications/dod_workbook_info_file_update_exp_093014-clean.pdf.

79 *Id.*

80 *Id.*

81 NTIA, "DoD Workbook Tab 1," 2014. See http://www.ntia.doc.gov/other-publication/2014/transition-plans-and-transition-data-1755-1780-mhz-band.

82 The reported maximum transition time ("Max TT") in the NTIA data ranges from 0 to 120 months. Analysis based on NTIA, "DoD Workbook Tab 1," 2014. See http://www.ntia.doc.gov/other-publication/2014/transition-plans-and-transition-data-1755-1780-mhz-band.

83 *Id.*

at least 10 years ranges from approximately 8.5 million to 16.7 million, depending on license block.[84]

It is possible to build a picture of an Economic Area (EA) license by examining its component census tracts' populations and transition times. As a result, it is possible to estimate the population that is "impaired" for a given license over given transition times.

I examined the patterns of prices in the AWS-3 auction and can find no evidence of impairments having any impact on license values. I performed two distinct analyses: First, I assessed the patterns of relative prices within the auction and compared them to the patterns of relative prices in previous auctions of similar spectrum licenses; Second, I used econometric techniques to test whether or not the presence or level of impairment resulted in a meaningful decline in license prices in the AWS-3 auction.

A. Relative Price Analysis

Each FCC license covers defined geographies and a specified bandwidth. As a consequence, differences in value of different licenses depends on factors such as the number of people covered, the demographics and distribution of the population, as well as the bandwidth of the license. Because many of the drivers of the value of a specific license do not change from auction to auction, the *relative* prices of spectrum licenses follow regular patterns across auctions. For example, historically a license covering New York City would sell for a relatively predictable amount more than a license covering Atlanta, GA, which in turn will go for a predictable amount more than a license covering Des Moines, IA.[85] This regularity of relative prices persists even after license prices are adjusted for the amount of population in the license area. Here I exploit this regularity in relative prices to look for evidence of impairments on license prices.

I compared licenses in like bands across the AWS-1 and AWS-3 auctions. Specifically, I compared the AWS-3 J Block to the AWS-1 B Block (both licensed as 20 MHz Economic Areas) and the AWS-3 H & I Blocks to the AWS-1 C Block (all three licensed as 10 MHz Economic Areas). I then calculated the $/MHz-pop value for each license and divide that by the specific

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[84] *Id.*

[85] As note earlier, this historical relationship between relative spectrum prices will change with the advent of 5G. At the time of the AWS-3 auction 5G was not well developed, so I can rely on the historical relationships for the analysis in this Appendix.

band average $/MHz-pop value to create an index of relative license values.[86] If impairments have an impact on license prices, I would expect the licenses in the AWS-3 auction with the greatest impairments to have relatively lower index values than for the similar licenses (without impairments) in the AWS-1 auction.

As shown in Table 2, 14.8% of licenses will still have impairments after 10 years. I segregated the licenses where the AWS-1 index value was greater than 120% of the AWS-3 index value.[87] A 20% price difference covers potential differences in bid increments for the licenses sold in the different auctions.[88] If there was no impact from impairments, I would expect the prevalence of impaired licenses in this subset to be the same as for the licenses overall—which is in fact what I find. The actual number of impaired licenses with more than a 20% higher relative price in the AWS-1 auction compared with the AWS-3 auction is 1 or 2 more or less than expected if impairments have no impact.

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[86] I use an index of license values instead of actual license values to extrapolate from any overall or sea level changes in spectrum value.

[87] In other words, I isolated the licenses where (AWS-1 index price / AWS-3 index price) ≥ 1.20.

[88] In FCC auctions, the prices of licenses rise by increments determined by the FCC. Such price increments vary, but can be up to 20% of the previous license price. As a consequence, variation in license prices of up to 20% can be an artifact of the auction rules and not necessarily reflecting underlying value differences. See, for example, the AWS-3 and AWS-1 auction procedures: https://www.federalregister.gov/articles/2014/08/12/2014-19080/auction-of-advanced-wireless-services-aws-3-licenses-scheduled-for-november-13-2014-notice-and; https://www.federalregister.gov/articles/2006/04/21/06-3819/auction-of-advanced-wireless-services-licenses-scheduled-for-june-29-2006-notice-of-filing#h-71.

Table 2. Impairment Analysis: Indexed Value Differences

	AWS-3 I Block	AWS-3 H Block	AWS-3 J Block
[1] Total Licenses in AWS-3 Auction	176	176	176
Count Impaired - Total	26	26	26
[2] % of Total Licenses Impaired After 10 Years	14.8%	14.8%	14.8%
[3] Total Licenses where AWS-1 License Index Value > 120% of AWS-3 License Index Value	61	67	59
[4] Expected Impaired	9	10	9
[5] Count Impaired in Sample	8	11	11
[6] Difference	1	-1	-2

Sources & Notes:
[1]: Total licenses for each BEA block in auction.
[2]: Based on impairment analysis and data provided by NTIA.
[3]: Based on comparison of AWS-3 J Block with AWS-1 B Block, and AWS-3 I and H Blocks with AWS-1 C Block.
[4]: [2] x [3], rounded to nearest whole number
[5]: Based on impairment analysis and data provided by NTIA.
[6]: [4] - [5].

B. STATISTICAL ANALYSIS

A second approach to finding evidence of impairments on spectrum licenses uses statistical techniques. The approach here is to predict specific license prices in the AWS-3 auction using standard explanatory variables and then to test if the inclusion of information on impairment levels result in a meaningful decline in the prediction of license price. If the impairment of a license does not reduce the price of that license, all else equal, then I must conclude that such impairments were not a significant consideration in bidders' behavior in the auction. In practice, this is exactly what I find.

There have been a number of studies that use econometric techniques to predict spectrum license prices.[89] Based on a review of those studies, I specified the following linear regression model of spectrum license prices:

[89] J. Pierre de Vries and Cheng-Yu Chan, "Edge License Discounts in Cellular Auctions," Presented at Telecommunications Policy Research Conference, 2010; Peter Cramton and Jesse A. Schwartz, "Collusive Bidding in the FCC Spectrum Auctions," *Contributions in Economic Analysis & Policy*, 2002; and Scott Wallsten, "Is There Really a Spectrum Crisis? Quantifying the Factors Affecting Spectrum License Value," Technology Policy Institute, 2013.

$$Price = \alpha + \beta_1 * TotalPops + \beta_2 * TotalPops^2 + \beta_3 * PerCapIncome$$
$$+\beta_4 * AWS1Block + \beta_5 * Impairment + \epsilon$$

where

$Price$	=	AWS-3 Spectrum License Price, measured in $\$/(MHz\ Pop)$
$\alpha, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5$	=	Parameters to be estimated
$TotalPops$	=	Total Population in Licensed Area
$TotalPops^2$	=	(Total Population in Licensed Area)^2
$PerCapIncome$	=	Average per Capita Income in Licensed Area
$AWS1Block$	=	Price of AWS-1 B Block when estimating AWS-3 J Block, measured in $\$/(MHz\ Pop)$; Price of AWS-1 C Block when estimating AWS-3 H and I Blocks, measured in $\$/(MHz\ Pop)$.
$Impairment$	=	Percent of Licensed Area Population Impaired for more than 5 or 10 years
ϵ	=	Residual or Error Term

This model was tested for the AWS-3 H, I, and J Blocks and for the percentage of population impaired after 5 and 10 years, respectively.[90] Regression results for each of the six model specifications are reported below. In each specification, the coefficient estimating the impact of the level of impairment on license prices was statistically indistinguishable from zero (see bolded rows in the following tables).[91] Consequently, I find no evidence of license impairments impacting the value of AWS-3 spectrum.

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[90] I ran the model using the impairment variable that captures the level of interference from AWS-3 transmitters to DoD receivers. However, model results remain the same when I use the other impairment variable that captures the level of interference from DoD transmitters to AWS-3 receivers.

[91] I also ran alternative specifications analyzing whether the presence of impairments above specified thresholds (as opposed to the percentage of license area impaired) would generate observable impacts on license prices. Each of these models returned insignificant parameter estimates, further strengthening my finding that impairments have no statistical impact on license prices.

Continued on next page

Table 3. AWS-3 J Block, 10 Year Impairment

Parameter	Units	Estimate	Std. Error	t-stat	p-value
Intercept		-0.50	0.41	-1.23	0.22
Total Population	*billions*	436.63	53.35	8.18	0.00**
Total Population^2	*trillions*	-0.01	0.00	-5.69	0.00**
Per Capita Income	*$, millions*	26.08	10.28	2.54	0.01*
Dollar_MHZpop_AWS1_B	*$ / MHz Pop*	1.33	0.48	2.77	0.01**
Impaired_10yr	**%**	**0.00**	**0.31**	**-0.01**	**0.50†**

No. of Observations: 171
Residual Std. Error: .737
Adjusted R-squared: 0.638
F-statistic: 60.807 on 5 and 165 DF, p-value: < 2.22e-16

Statistically significant at the 1% (*) or 5% (**) level
† One-tailed p-value (p < t)

Table 4. AWS-3 J Block, 5 Year Impairment

Parameter	Units	Estimate	Std. Error	t-stat	p-value
Intercept		-0.48	0.44	-1.10	0.27
Total Population	*billions*	437.27	53.29	8.21	0.00**
Total Population^2	*trillions*	-0.01	0.00	-5.69	0.00**
Per Capita Income	*$, millions*	25.72	10.59	2.43	0.02*
Dollar_MHZpop_AWS1_B	*$ / MHz Pop*	1.34	0.48	2.79	0.01**
Impaired_5yr	**%**	**-0.02**	**0.13**	**-0.13**	**0.45†**

No. of Observations: 171
Residual Std. Error: .737
Adjusted R-squared: 0.638
F-statistic: 60.817 on 5 and 165 DF, p-value: < 2.22e-16

Statistically significant at the 1% (*) or 5% (**) level
† One-tailed p-value (p < t)

Continued from previous page

Conceptually, if impairments were to impact prices it would be in a negative manner. Therefore, I conducted one-sided (as opposed to two-sided) statistical tests for the impairment variable, whereby my alternative hypothesis was that the parameter estimate was < 0 (as opposed to ≠ 0).

Table 5. AWS-3 H Block, 10 Year Impairment

Parameter	Units	Estimate	Std. Error	t-stat	p-value
Intercept		-0.47	0.41	-1.14	0.25
Total Population	*billions*	431.68	52.33	8.25	0.00**
Total Population^2	*trillions*	-0.01	0.00	-6.05	0.00**
Per Capita Income	*$, millions*	24.16	10.42	2.32	0.02*
Dollar_MHZpop_AWS1_C	*$ / MHz Pop*	0.96	0.38	2.51	0.01*
Impaired_10yr	**%**	**0.02**	**0.31**	**0.08**	**0.53†**

No. of Observations: 171
Residual Std. Error: .741
Adjusted R-squared: 0.606
F-statistic: 53.241 on 5 and 165 DF, p-value: < 2.22e-16

Statistically significant at the 1% (*) or 5% (**) level
† One-tailed p-value (p < t)

Table 6. AWS-3 H Block, 5 Year Impairment

Parameter	Units	Estimate	Std. Error	t-stat	p-value
Intercept		-0.79	0.44	-1.81	0.07
Total Population	*billions*	432.13	51.58	8.38	0.00**
Total Population^2	*trillions*	-0.01	0.00	-6.12	0.00**
Per Capita Income	*$, millions*	27.24	10.35	2.63	0.01**
Dollar_MHZpop_AWS1_C	*$ / MHz Pop*	0.84	0.38	2.23	0.03*
Impaired_5yr	**%**	**0.29**	**0.15**	**1.94**	**0.97†**

No. of Observations: 171
Residual Std. Error: .733
Adjusted R-squared: 0.615
F-statistic: 55.206 on 5 and 165 DF, p-value: < 2.22e-16

Statistically significant at the 1% (*) or 5% (**) level
† One-tailed p-value (p < t)

Table 7. AWS-3 I Block, 10 Year Impairment

Parameter	Units	Estimate	Std. Error	t-stat	p-value
Intercept		-0.25	0.36	-0.68	0.50
Total Population	*billions*	414.12	45.96	9.01	0.00**
Total Population^2	*trillions*	-0.01	0.00	-6.67	0.00**
Per Capita Income	*$, millions*	17.43	9.15	1.91	0.06
Dollar_MHZpop_AWS1_C	*$ / MHz Pop*	1.24	0.33	3.71	0.00**
Impaired_10yr	**%**	**0.30**	**0.27**	**1.10**	**0.86†**

No. of Observations: 171
Residual Std. Error: .651
Adjusted R-squared: 0.665
F-statistic: 68.510 on 5 and 165 DF, p-value: < 2.22e-16

Statistically significant at the 1% (*) or 5% (**) level
† One-tailed p-value (p < t)

Table 8. AWS-3 I Block, 5 Year Impairment

Parameter	Units	Estimate	Std. Error	t-stat	p-value
Intercept		-0.17	0.37	-0.47	0.64
Total Population	*billions*	410.40	46.10	8.90	0.00**
Total Population^2	*trillions*	-0.01	0.00	-6.60	0.00**
Per Capita Income	*$, millions*	16.13	9.13	1.77	0.08
Dollar_MHZpop_AWS1_C	*$ / MHz Pop*	1.28	0.33	3.83	0.00**
Impaired_5yr	**%**	**-0.01**	**0.12**	**-0.10**	**0.46†**

No. of Observations: 171
Residual Std. Error: .653
Adjusted R-squared: 0.663
F-statistic: 67.780 on 5 and 165 DF, p-value: < 2.22e-16

Statistically significant at the 1% (*) or 5% (**) level
† One-tailed p-value (p < t)

Appendix C: Cost Estimates for Relocation of the 1,780 MHz–1,830 MHz Band and 1,300 MHz–1,350 MHz Band[92]

This appendix seeks to provide detailed estimates for relocation costs associated with the Federal government use of the 1,780 MHz–1,830 MHz and 1,300 MHz–1,350 MHz spectrum bands. As these estimates will require further refinement based upon actual relocation requirements for the Federal agencies, the values provided are ranges rather than specific costs. Specifically:

- Anticipated relocation clearing costs for the 1,780 MHz–1,830 MHz band of $2.26 to $3.76 billion; and
- Anticipated relocation clearing costs for the 1,300 MHz–1,350 MHz band of $3.67 to $4.17 billion.

The estimated cost ranges provided above are based on conservative assumptions due to the lack of information about the number of Federal systems remaining in the 1,780 MHz–1,850 MHz band, the amount of operations that can be shifted to the 1,830 MHz–1,850 MHz band, the number of Federal incumbent users who are only in the 1,830 MHz–1,850 MHz band (and that will not require relocation), and due to a lack of certainty on costs associated with accommodating the Defense Department's incumbent use of the 1,300 MHz–1,350 MHz band. Providing an approximation of Federal relocation costs within a conservative range should allow future detailed estimates to be reduced as more precision is provided on incumbent usage and relocation requirements.

A. 1,780 MHz–1,830 MHz Band

Cost estimates for the 1,780 MHz–1,830 MHz band have been derived based on information gathered by NTIA in the 2011 timeframe. At that time, Federal agencies estimated it would require $18 billion to allow full relocation from the entire 1,755 MHz–1,850 MHz band. NTIA and the Federal agencies subsequently created more refined estimates for relocation of the lower 25 MHz of that band, from 1,755 MHz–1,780 MHz, which was then auctioned as part of the

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[92] CTIA has provided the analysis and estimates in this Appendix. I have reviewed the analysis, and it seems reasonable, but I am unable to independently verify the accuracy of these estimates. Consequently, I use them as provided.

AWS-3 auction. The resulting process for relocating Federal systems out of the lower 25 MHz officially began in October of 2015 and is now well underway.[93] Therefore, the portion of the initial $18 billion estimate that was dedicated to the 1,755 MHz–1,780 MHz band, as adjusted for the intervening developments, can be removed for purposes of making the current estimate.[94]

There are a variety of Federal incumbent operations within the 1,780 MHz–1,830 MHz band. The table below identifies each of these operations and, for each such operation, quantifies; the number of corresponding assignments prior to the AWS-3 auction; the number of those assignments relocated pursuant to the AWS-3 auction; the initial 2012 cost estimates for relocation of Federal systems out of the entire 95 MHz band, and updated cost estimates for relocation out of the lower 25 MHz (1,755 MHz–1,780 MHz); and, finally, the estimated relocation costs for the 1,780 MHz–1,830 MHz band:

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[93] NTIA, "AWS-3 Transition." See https://www.ntia.doc.gov/category/aws-3-transition.

[94] The cost estimate for the 1,755 MHz–1,780 MHz band was approximately $4.5 billion which is covered by revenues from the Commission's AWS-3 auction. NTIA, "Initial Estimated Costs and Timelines for the 1755-1780 MHz Band," 2014. See https://www.ntia.doc.gov/files/ntia/publications/initial_estimated_costs_and_timelines_1755-1780_mhz_band_05-12-2014.pdf. Letter to Tom Wheeler, FCC, from Lawrence E. Strickling, NTIA, "Notice of Estimated Relocation or Sharing Costs and Timelines for the 1695-1710 MHz and 1,755 MHz-1,780 MHz Bands," 2014, Attachments B1 and B2. See https://www.ntia.doc.gov/files/ntia/publications/notification_to_fcc_re_est_costs_for_1695_and_1755_bands_05132014.pdf.

Table C 1: Estimated Relocation Cost for the 1,780 MHz-1,830 MHz Band

Operation [1]	Federal Assignments (2012) [2]	Federal Assignments Relocated from 1,755 MHz-1,780 MHz [3]	2012 Relocation Costs for 1,755 MHz-1,850 MHz Band ($ mm) [4]	1,755 MHz-1,780 MHz Relocation Costs ($ mm) [5]	Estimated Relocation Cost for 1,780 MHz-1,830 MHz Band ($mm) [6]
Fixed Point-to-Point Microwave	360	68	$186	$95	None
Military Tactical Radio Relay	579	310	$160	$175	None
Air Combat Training Systems	707	147	$4,500	$81	$1,000-$1,500
Precision Guided Munitions	21	16	$518	$42	$5-$10
Tracking, Telemetry, and Commanding	269	57	$2,350	$26	None (Sharing)
Aeronautical Mobile Telemetry	514	187	$3,140	$485	$500-$1,000
Video Surveillance	178	179	$5,097	$1,604	$500-$750
Unmanned Aerial Systems	475	248	$1,511	$810	None (Sharing)
Other DoD Systems	80	195	$364	$773+$485 other costs	$250-$500
Total	3,183	1,407	$17,826	$4,576	$2,255-$3,760

Sources and Notes:

[2]: DoC, "An Assessment of the Viability of Accommodating Wireless Broadband in the 1,755 -1,850 MHz Band," 2012, at Table 2-1. See https://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf ("NTIA, 1,755 MHz-1,850 MHz Report").

[3]: NTIA, "Initial Estimated Costs and Timelines for the 1755-1780 MHz Band," 2014. See https://www.ntia.doc.gov/files/ntia/publications/initial_estimated_costs_and_timelines_1755-1780_mhz_band_05-12-2014.pdf ("NTIA, AWS-3 Cost Estimates").

[4]: NTIA, 1,755 MHz-1,850 MHz Report, at xi.

[5]: NTIA, AWS-3 Cost Estimates, at 1. The costs for Robotics were added to the costs of Other DoD Systems.

Discussion of Cost Estimates

As can be determined from the table above, NTIA and the Federal agencies have provided a great deal of historical data and relocation costs for the 1,755 MHz–1,850 MHz band. For each particular Federal incumbent use, below is a discussion of how the cost ranges provided in the table above were derived and what assumptions were used.

- **Fixed Microwave.** A variety of Federal incumbents have utilized the 1,755 MHz–1,850 MHz band for point-to-point fixed microwave services. As part of the AWS-3 process, the 1,755 MHz–1,780 MHz band was repurposed and all the Federal operations were relocated at a cost of $95 million. Therefore, there should be no additional relocation costs for these systems.

- **Tactical Radio Relay (TRR).** TRR systems have the capability to tune to other spectrum and were relocated almost entirely out of the 1,755 MHz–1,850 MHz band during the AWS-3 transition by means of an arrangement that was brokered with broadcasters to

share the 2025-2210 MHz band. The costs expended for the AWS-3 transition exceeded the costs associated with the 2012 estimates for relocating all Federal assignments out of the entirety of the 1,755 MHz–1,850 MHz band. As such, the expectation is that there should not be additional costs to complete the relocation process for these systems as they simply have the capability to tune to new channels.

- **Air Combat Training Systems (ACTS).** Unlike other systems, Air Combat Training Systems were not extensively relocated during the AWS-3 process. Only about 20% of systems were moved/relocated at a cost of approximately $80 million. Since the 2012 estimate for complete relocation was approximately $4.5 billion, significant additional relocation costs are likely for this Federal usage. Based on expectation that ACTS will need to be redesigned to operate in the 4,400 MHz–4940 MHz or other aeronautical bands, an approximate cost for relocation would be from $1 to $1.5 billion.

- **Precision Guided Munitions (PGM).** These systems, similar to TRR, were almost completely relocated during the AWS-3 transition. This fact is borne out by the fact that nearly 80% of Federal assignments were relocated at a cost of about $42 million. The expectation is that there may be a few remaining operations to be relocated to the 1,435 MHz–1,525 MHz band at a cost of $5 to $10 million.

- **Tracking, Telemetry, and Commanding (TT&C).** TT&C is used to manage and control Federal satellite systems. During the AWS-3 process, the commercial industry and Federal incumbents worked to create a detailed methodology to protect existing TT&C facilities while still permitting the use of the 1,755 MHz–1,780 MHz band for commercial wireless services without a need for relocation of satellite systems. For the 1,780 MHz–1,830 MHz band, this same sharing framework should negate the need for any additional Federal relocation.

- **Aeronautical Mobile Telemetry (AMT).** Approximately a third of the Federal assignments for AMT were relocated during the AWS-3 transition at a cost of approximately $484 million. The majority of the remaining AMT systems will need to retune to the 4,400 MHz–4,940 MHz band (or other aeronautical bands) at an estimated cost range from $500 million to $1 billion (or one to two times the cost of the initial relocation).

- **Video Surveillance.** While video surveillance systems had the highest cost of any system in the 2012 cost estimates, based on technical feasibility issues, it is expected that many of these systems will remain in the 1,830 MHz–1,850 MHz band rather than face relocation to another band. As a number of these systems were replaced/updated due to the AWS-3 transition (as well as the AWS-1 transition, for the 1,710 MHz–1,755 MHz band), the expectation is that a large portion of this equipment already has the capability to retune to just the 1,830 MHz–1,850 MHz band. However, some systems will require relocation (would expect to use the 2,200 MHz–2,290 MHz band) and/or costs to retune to the 1,830 MHz–1,850 MHz band. Based on the AWS-3 transition costs, would expect these costs in the range of $500 to $750 million (or roughly one-half to one-third of the previous costs).

- **Unmanned Aerial Systems (UAS).** The majority of these systems were transitioned during the AWS-3 process to the 2,025 MHz–2,110 MHz band. Those that remain have the ability to retune to the 1,830 MHz–1,850 MHz band as well as continuing to utilize the 2,025 MHz–2,110 MHz band. Therefore, there should be no estimated relocation costs for this equipment.

- **Other Systems (and Transition Costs).** During past transitions (AWS-1 and AWS-3), there have been additional systems or transition costs that have arisen. There is therefore an estimate of $250 to $500 million to accommodate such unexpected systems or additional transition costs.

B. 1,300 MHz–1,350 MHz Band

To allow for the use of this spectrum by commercial systems, existing high-powered radar systems must relocated.[95] The primary entities utilizing radar systems in the 1,300 MHz–1,350 MHz band are the FAA, and the Departments of Defense, Homeland Security, and Commerce. There is an ongoing feasibility study for a Spectrum Efficient National Surveillance Radar (SENSR) that could be part of a potential reallocation opportunity for the band.[96] Should this

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[95] The U.S. Department of Commerce has found that the 1,300 MHz-1,350 MHz offered no opportunities for frequency/geographic/time sharing. DoC, "Quantitative Assessments of Spectrum Usage," 2016, at 7. See https://www.ntia.doc.gov/files/ntia/publications/ntia_quant_assessment_report-no_appendices.pdf.

[96] *Id.* at 7-8. FAA, "SENSR Team Gets Green Light for Spectrum Analysis," 2017. See https://www.faa.gov/news/updates/?newsId=88187.

effort be successful, much of the radar operations in the 1,300 MHz–1,350 MHz could be relocated into other comparable spectrum, freeing up this 50 MHz for commercial operations. Office of the Inspector General of the Department of Transportation has conducted a recent study on the FAA's Next Generation Air Transportation System and has determined that it would require approximately $2.67 billion to develop and implement the new radar system known as the Automatic Dependent Surveillance – Broadcast (ADS-B) system.[97] The ADS-B system would obviate the need for current ground-based radar system of Air Traffic Control (using the 1,300 MHz–1,350 MHz band) with a satellite-based system for Air-Traffic Management (using other spectrum). However, in addition to radar for normal tracking, DoD will have an ongoing mission requirement to track non-cooperative targets that will require enhancements to the ADS-B system as well as relocation of systems in the 1,300 MHz–1,350 MHz band that provide other non-radar uses. There is no publicly available discussion of the costs to enhance ADS-B nor for the costs to relocate other DoD use of the 1,300 MHz–1,350 MHz band. However, consultation with DoD personnel indicates that an estimated cost range of $1 to $1.5 billion would be an acceptable approximation of potential relocation and transition costs.

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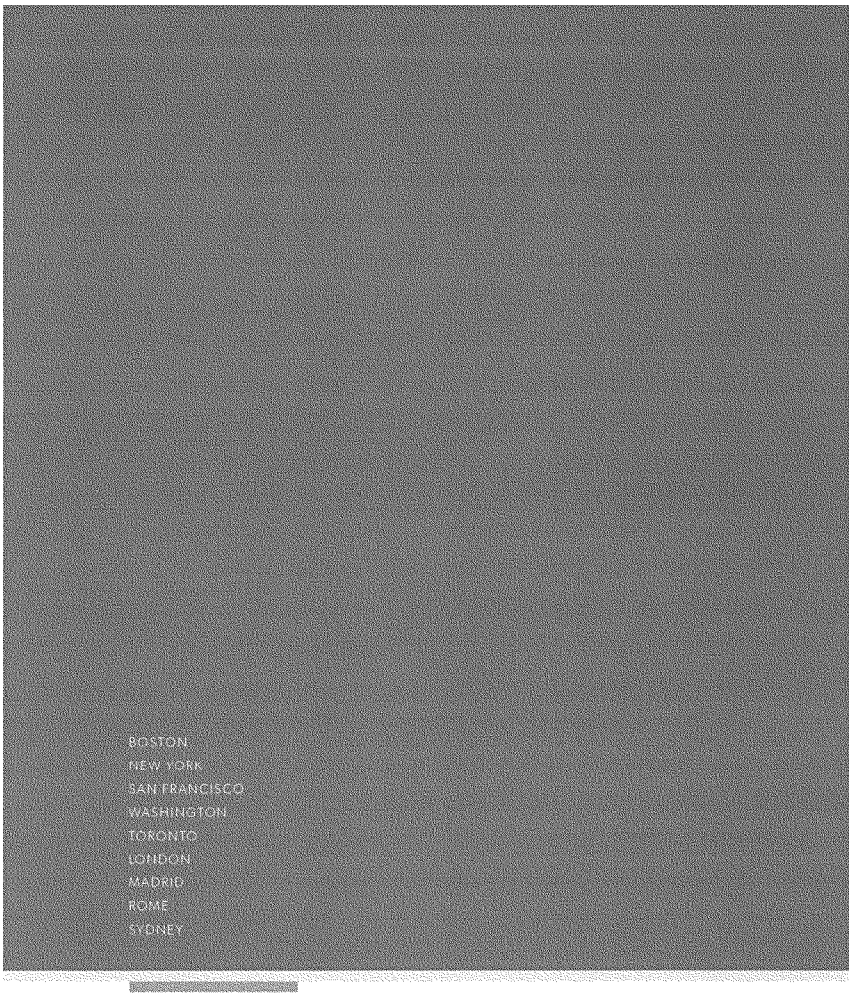
[97] Office of Inspector General, FAA, Audit Report, "Total Costs, Schedules, and Benefits of FAA's NextGen Transformational Programs Remain Uncertain," at 5. See https://www.oig.dot.gov/sites/default/files/FAA%27s%20Transformational%20Programs%20Report_issued%20Nov%2010_508.pdf.



THE Brattle GROUP

November 15, 2017

The Honorable Marsha Blackburn
Chairman, Subcommittee on Communications
and Technology
2266 Rayburn House Office Building
Washington, DC 20515

Dear Representative Blackburn:

For economic development, 5G technology is the way of our future. Hardin County is a regional draw for surrounding counties because of our robust commercial and healthcare industries.

As mayor of a rural county in Western Tennessee, we face challenges every day; one of which is accessibility to the internet. Broadband is not readily available to all of our citizens. We have a K-8 school in Pickwith with limited download and upload capabilities, and we have a technology company that moved from Pickwith to Savannah to increase its internet capabilities.

HMC, a county owned hospital, is the only hospital between Savannah and Memphis. 5G is paramount to be able to share medical test results and information with other providers in larger hospitals.

Access to broadband and 5G is crucial for our continued growth. Thank you for your support of these technologies and your concern for rural Tennesseans.

Regards,

____/S/____

Kevin Davis
Mayor
Hardin County, Tennessee

Congress of the United States
Washington, DC 20515

November 7, 2017

The Honorable Ajit Pai, Chairman
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Dear Chairman Pai,

We write to express serious concerns with the Federal Communications Commission's lack of coordination with local governments relating to the Commission's efforts to improve deployment of broadband internet service. We are concerned about local representation on the Broadband Deployment Advisory Committee (BDAC), particularly in the context of the Commission's ongoing wireless and wireline infrastructure proceedings.[1]

We believe the BDAC, as it is currently designed, lacks sufficient input from local governments and could result in recommendations that unduly preempt local authority. We therefore urge you to implement reforms to the BDAC to provide local governments with adequate opportunity to offer their perspectives regarding this important matter. We also urge you to enhance transparency by reforming the BDAC's internal procedures and ensure the public has ample opportunity to comment on any BDAC proposals before they are used as the basis or justification for Commission actions.

Broadband internet access is an essential service that American consumers and communities need to compete and fully participate in the 21st century. As Members of Congress who are committed to enacting policies that enhance broadband internet access across the U.S., we were encouraged by your decision in January to form the BDAC to advise the Commission on current regulatory barriers impeding the deployment of broadband.

However, we are concerned that the composition of the 30-member BDAC relies too heavily on the input of industry voices and less on public officials who are responsible for protecting the public interest and who understand the issues and perspectives of local communities nationwide. Speaking directly to these concerns, a recent report by the Center for Public Integrity noted that:

> "More than three out of four seats on the BDAC are filled by business-friendly representatives from the biggest wireless and cable companies such as AT&T Inc., Comcast Corp., Sprint Corp., and TDS Telecom. Crown Castle International Corp., the nation's largest wireless

[1] *In the Matter of Accelerating Wireless Broadband Deployment By Removing Barriers to Infrastructure Investment*, WT Docket No. 17-79; *In the Matter of Accelerating Wireline Broadband Deployment by Removing Barriers to Infrastructure Development*, WC Docket No. 17-84.

> infrastructure company, and Southern Co., the nation's second-largest utility firm, have representatives on the panel."[2]

The same report found that of numerous local government representatives that applied to join the BDAC, only one was originally selected to serve on the 30-member committee. While two more local officials were later appointed to the BDAC, this constitutes only ten percent of the voting membership. This imbalanced roster does not adequately represent the broad array of voices whose input is necessary to conduct a reasoned and comprehensive analysis and develop inclusive solutions which can earn acceptance from a broader array of stakeholders.

There is also the problem of the BDAC's lack of transparency and restrictions on public access to the BDAC's working documents. We're concerned that the BDAC will serve as a vehicle to advance laws and policies that serve the needs of industry at the expense of the public interest. This is reflected in the language of the BDAC overview itself, which states the purpose of the Committee is to "eliminate regulatory barriers," - presuming that regulatory protections are an inherent obstruction - other than to examine or address regulatory policy through a more holistic approach. This premise happens to adhere closely to the longtime anti-regulatory efforts of the very interests who make up the overwhelming majority of the BDAC. Taken together, those facts underscore the need for a more transparent process to reassure stakeholders that the final proposals will have resulted from a fair and measured debate.

In order to allow for a fair and balanced perspective of all stakeholders both on and off the BDAC who are committed to accelerating broadband deployment, we call on you to do the following:

- Immediately expand representation of state and local government officials on the BDAC and all five of its working groups;
- Make all meetings, submissions, and drafts of working documents relied upon by the BDAC and its working groups publicly available and accessible to allow for input from a broader group of stakeholders;
- Provide the public with ample time to comment on recommendations and reports adopted by the BDAC before using those materials to inform, justify, or guide Commission action; and
- Refocus the work of the BDAC to create more industry accountability for increasing quality network coverage and lowering costs to all Americans, including in rural and low-income areas, instead of solely focusing on tying the hands of state and local governments.

We believe these reforms are critical to ensuring the BDAC incorporates diverse and balanced input that will ultimately lead to policies that promote the increased deployment of broadband Internet service in a manner that is consistent with the Commission's statutory obligation to serve the public interest. We're concerned that the current composition and operation of the BDAC and aggressive timeline pursued by your office will undermine the legitimacy of any eventual recommendations if the concerns we have raised here are not promptly addressed.

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[2] Blake Dodge, FCC packs broadband advisory group with big telecom firms, trade groups, The Center for Public Integrity (Aug. 11, 2017), https://www.publicintegrity.org/2017/08/11/21057/fcc-packs-broadband-advisory-group-big-telecom-firms-trade-groups.

Thank you for your attention to this important request, and we look forward to your timely response.

Sincerely,

Anna G. Eshoo
Member of Congress

Michael F. Doyle
Member of Congress

Ro Khanna
Member of Congress

Keith Ellison
Member of Congress

Louise M. Slaughter
Member of Congress

Peter A. DeFazio
Member of Congress

Zoe Lofgren
Member of Congress

Peter J. Visclosky
Member of Congress

Jacky Rosen
Member of Congress

Tony Cárdenas
Member of Congress

Peter Welch
Member of Congress

Jerry McNerney
Member of Congress

John P. Sarbanes
Member of Congress

Joseph Crowley
Member of Congress

cc: The Honorable Mignon Clyburn, Commissioner, Federal Communications Commission
The Honorable Michael O'Rielly, Commissioner, Federal Communications Commission
The Honorable Jessica Rosenworcel, Commissioner, Federal Communications Commission
The Honorable Brendan Carr, Commissioner, Federal Communications Commission

GREG WALDEN, OREGON
CHAIRMAN

FRANK PALLONE, JR., NEW JERSEY
RANKING MEMBER

ONE HUNDRED FIFTEENTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON ENERGY AND COMMERCE

2125 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6115
Majority (202) 225-2927
Minority (202) 225-3641

December 13, 2017

Mr. Chris Pearson
President
5G Americas
1750 112th Avenue, N.E.; Suite B220
Bellevue, WA 98004

Dear Mr. Pearson:

Thank you for appearing before the Subcommittee on Communications and Technology on Thursday, November 16, 2017, to testify at the hearing entitled "The Race to 5G and its Potential to Revolutionize American Competitiveness."

Pursuant to the Rules of the Committee on Energy and Commerce, the hearing record remains open for ten business days to permit Members to submit additional questions for the record, which are attached. The format of your responses to these questions should be as follows: (1) the name of the Member whose question you are addressing, (2) the complete text of the question you are addressing in bold, and (3) your answer to that question in plain text.

To facilitate the printing of the hearing record, please respond to these questions with a transmittal letter by the close of business on Friday, January 5, 2018. Your responses should be mailed to Evan Viau, Legislative Clerk, Committee on Energy and Commerce, 2125 Rayburn House Office Building, Washington, DC 20515 and e-mailed to Evan.Viau@mail.house.gov.

Thank you again for your time and effort preparing and delivering testimony before the Subcommittee.

Sincerely,

Marsha Blackburn
Chairman
Subcommittee on Communications and Technology

cc: The Honorable Michael F. Doyle, Ranking Member, Subcommittee on Communications and Technology

Attachment

1750 112th Avenue, N.E.
Suite B220
Bellevue, WA 98004

January 5, 2018

The Honorable Marsha Blackburn
Chairman
Subcommittee on Communications and Technology
2125 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Blackburn:

Thank you for the opportunity to testify before the Subcommittee on Communications and Technology at the hearing, "The Race to 5G and its Potential to Revolutionize American Competitiveness." Please find enclosed my response to the additional question from Representative Bilirakis for the record, formatted pursuant to your request.

Thank you again for the chance to give the Subcommittee my perspective on the importance of making globally-harmonized spectrum available for 5G, so the U.S. is positioned to lead on this impactful, revolutionizing technology.

Sincerely,

Chris Pearson

Chris Pearson
President
5G Americas

Enclosure

Answers to Additional Questions for the Record

The Honorable Gus Bilirakis

1. **As discussed, the FCC has opened an inquiry for the possible use of mid-band spectrum, particularly the 3.7 to 4.2 GHz band. Satellite companies currently make use of these frequencies. Do you have any thoughts on how to quickly and efficiently proceed with 5G in this band in light of these incumbent users?**

Answer: The 3.7-4.2 GHz band (called the C-Band by satellite companies) includes spectrum that is being reviewed in Asian and European markets for 5G. Accordingly, 5G Americas has noted its interest to the Federal Communications Commission (FCC) in 3.7-4.2 GHz being repurposed for licensed mobile broadband. However, because there are satellite incumbents in the band (receive earth stations), sharing mechanisms that protect satellite incumbents and uses while still permitting some terrestrial mobile use in the band should be explored. The FCC's rules should be revised to promote efficiency.

5G Americas believes there is the potential for some dynamic sharing of the band, given the coordinated nature of the earth stations in the bands. The FCC should take further steps to investigate flexible use, starting with conducting a rigorous audit of C-Band use, and the interference susceptibility of such uses, and working with industry to develop protocols for interference tests in the lab and in real world environments. Once the range of uses is fully understood and characterized, workable sharing mechanisms should be explored that would allow for terrestrial use of the band.

5G Americas would support rule changes designed to de-authorize satellite facilities that are no longer in use. Further understanding the extent of actual C-Band use may ultimately allow the FCC to adopt measures that would permit more efficient shared use of the band among existing services.

With respect to other incumbents, the FCC stated in its Mid-Band Notice of Inquiry that there is limited incumbent use of the 3.7-4.2 GHz for fixed services like microwave, and that use has been declining steeply over the last two decades as operators migrate to fiber or other spectrum bands. Incumbents' relocation could be paid for through winning bidders' auction proceeds for access to the band. As a globally harmonized band for 5G, 3.7 GHz could be very valuable at auction as it will offer coverage, capacity, roaming and economies of scale. For fixed services with current stations in the band, relocation to another band entirely, such as 7.1 – 8.4 GHz, may be an appropriate solution, paid for out of auctions proceeds.

Because the 3.7–4.2 GHz band is adjacent to the 3550- 3700 MHz band, already identified by the FCC and a number of other countries' regulators for mobile broadband, the 3.7 – 4.2 GHz band is particularly of interest to 5G Americas for licensed broadband service to efficiently serve the connectivity needs of American citizens.

GREG WALDEN, OREGON
CHAIRMAN

FRANK PALLONE, JR., NEW JERSEY
RANKING MEMBER

ONE HUNDRED FIFTEENTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON ENERGY AND COMMERCE

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December 13, 2017

Dr. Coleman Bazelon
Principal
The Brattle Group
1800 M Street, N.W.; Suite 700 North
Washington, DC 20036

Dear Dr. Bazelon:

Thank you for appearing before the Subcommittee on Communications and Technology on Thursday, November 16, 2017, to testify at the hearing entitled "The Race to 5G and its Potential to Revolutionize American Competitiveness."

Pursuant to the Rules of the Committee on Energy and Commerce, the hearing record remains open for ten business days to permit Members to submit additional questions for the record, which are attached. The format of your responses to these questions should be as follows: (1) the name of the Member whose question you are addressing, (2) the complete text of the question you are addressing in bold, and (3) your answer to that question in plain text.

To facilitate the printing of the hearing record, please respond to these questions with a transmittal letter by the close of business on Friday, January 5, 2018. Your responses should be mailed to Evan Viau, Legislative Clerk, Committee on Energy and Commerce, 2125 Rayburn House Office Building, Washington, DC 20515 and e-mailed to Evan.Viau@mail.house.gov.

Thank you again for your time and effort preparing and delivering testimony before the Subcommittee.

Sincerely,

Marsha Blackburn
Chairman
Subcommittee on Communications and Technology

cc: The Honorable Michael F. Doyle, Ranking Member, Subcommittee on Communications and Technology

Attachment

THE Brattle GROUP

January 5, 2018

Evan Viau
Legislative Clerk
Committee on Energy & Commerce
2125 Rayburn House Office Building
Washington, D.C. 20515

USPS and email to: Evan.Viau@mail.house.gov

Re: Communications and Technology Subcommittee hearing

Dear Mr. Viau:

Please see my response provided herein to the requested questions for the record from the November 16, 2017, Communications and Technology Subcommittee hearing entitled, "The Race to 5G and its Potential to Revolutionize American Competitiveness."

The Honorable Greg Walden

Does blanket extension of FCC auction authority derive the most value from spectrum auctions and incentivize additional auctions that unlock commercial spectrum? Or is it preferable for Congress to authorize specific auctions of specific spectrum bands?

Answer to Mr. Walden

The FCC requires authority to hold spectrum auctions. Historically, the estimated revenues associated with such authorizations have provided an impetus for Congress to direct that specific frequencies are made available for auction. Once blanket authority is authorized, the incentives for Congress to authorize specific reallocations can be blunted. Consequently, more spectrum is ultimately likely to be reallocated, and more value generated, by authorizing specific auctions of specific bands, as opposed to granting blanket auction authority.

The FCC effectively uses its blanket auction authority to assign licenses in many bands, not all of them large high-dollar auctions. It would be overly burdensome for Congress to specifically authorize each of these smaller auctions. Consequently, authorizing blanket authority for auctions expected to raise revenues under some threshold would preserve the FCC's ability to effectively manage spectrum, but without diminishing the incentives to facilitate larger spectrum reallocations.

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The Honorable Gus Bilirakis

As discussed, the FCC has opened an inquiry for the possible use of mid-band spectrum, particularly the 3.7 to 4.2 GHz band. Satellite companies currently make use of these frequencies. Do you have any thoughts on how to quickly and efficiently proceed with 5G in this band in light of these incumbent users?

Answer to Mr. Bilirakis

I have investigated this band on behalf of some of the interested parties and my research found that reallocating some or all of the 3.7 GHz to 4.2 GHz band to support 5G services is expected to create significant value. Incumbent users have made investments and planned business operations based on legitimate rights and expectations about the availability of the 3.7 GHz to 4.2 GHz band. Any transition of the frequencies in this band that does not include the incumbent users as active partners is likely to get bogged down in legal and regulatory proceedings. Consequently, a framework that includes incumbent and new users of the C band as partners is more likely to efficiently and quickly reallocate these frequencies.

The Honorable Billy Long

1. **Unlike the U.S., many other countries competing in the race to 5G don't auction their spectrum – it is simply allocated to commercial users by their government. How does the U.S. method of competition affect our ability to lead in 5G?**
    a. **What are the long-term gains by auctioning spectrum?**

2. **As a former analyst at the Congressional Budget Office, how can we maximize the value of limited spectrum for bidders at auction?**

3. **As we identify more spectrum to develop a solid formation for 5G deployment, how should the FCC think about pending proposals to bring mid-band spectrum to market quickly? Specifically, I'm interested in your view about the potential of L-band spectrum to support an advanced satellite-terrestrial network providing mission-critical connectivity for 5G and IoT applications.**

Answer to Mr. Long

Auctions are an effective and efficient way to assign frequencies to specific users because when properly implemented they get frequencies to those who can most productively use them as quickly as possible. To the extent auctions also raise revenue they can be helpful in facilitating allocations to new

uses, including making additional frequencies available for 5G. The use of auctions in the U.S. has facilitated our historic leadership in wireless by making frequencies available to entities determined to develop valuable wireless networks. The same benefits should be expected in auctioning frequencies for 5G.

As with any scarce resource, maximizing its value requires putting it to its highest valued uses and with the least delay possible. In the case of spectrum needed for 5G services, private and public interests are largely aligned, suggesting putting the frequencies into private hands quickly through an auction would be expected to maximize value. As with other bands sought after for 5G, this is also true of L-band spectrum. As I noted in my Testimony, the central innovation of 5G is one of architecture, integrating different spectrum bands to meet different needs. In that context, any action to facilitate an advanced satellite-terrestrial network in the mid-band would be expected to add desirable complementary spectrum and services that would make a 5G and IoT network more robust and valuable.

Sincerely,

Coleman Bazelon

CB/cmm

GREG WALDEN, OREGON
CHAIRMAN

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December 13, 2017

The Honorable Jonathan Adelstein
President and CEO
Wireless Infrastructure Association
500 Montgomery Street; Suite 500
Alexandria, VA 22314

Dear Mr. Adelstein:

Thank you for appearing before the Subcommittee on Communications and Technology on Thursday, November 16, 2017, to testify at the hearing entitled "The Race to 5G and its Potential to Revolutionize American Competitiveness."

Pursuant to the Rules of the Committee on Energy and Commerce, the hearing record remains open for ten business days to permit Members to submit additional questions for the record, which are attached. The format of your responses to these questions should be as follows: (1) the name of the Member whose question you are addressing, (2) the complete text of the question you are addressing in bold, and (3) your answer to that question in plain text.

To facilitate the printing of the hearing record, please respond to these questions with a transmittal letter by the close of business on Friday, January 5, 2018. Your responses should be mailed to Evan Viau, Legislative Clerk, Committee on Energy and Commerce, 2125 Rayburn House Office Building, Washington, DC 20515 and e-mailed to Evan.Viau@mail.house.gov.

Thank you again for your time and effort preparing and delivering testimony before the Subcommittee.

Sincerely,

Marsha Blackburn
Chairman
Subcommittee on Communications and Technology

cc: The Honorable Michael F. Doyle, Ranking Member, Subcommittee on Communications and Technology

Attachment

Wireless
Infrastructure
Association

Additional Questions for the Record

The Honorable Gus Bilirakis

1. **An Accenture report concluded that municipalities con attract investment across industries by facilitation 5G infrastructure. As you mention in your testimony, a handful of states, including Florida, have taken action to quicken 5G deployment. Have these states begun to see that benefits of their actions in telecom operator investments?**
    a. **Is that any state action that specifically stand out as a model that we should consider for federal action?**

In 2017, nearly two dozen bills were either enacted or introduced in state legislatures that would remove regulatory barriers, reduce delays, and rationalize fees for wireless broadband deployment. As more states enact sound, pro-investment legislation, the pace of 5G deployment will continue to speed up. WIA members report that states with streamlined and expedited siting policies will be at or near the top of the list for the rollout of 5G networks.

For example, AT&T plans to launch 5G Evolution in parts of Minneapolis in the coming months, including areas near the host stadium for the Super Bowl. Minnesota recently enacted a 5G bill that was supported by the wireless industry. As is evident in states across the country, pro-investment policies will attract greater, and faster, investment.

These bills enacted by states promote responsible deployment, creating height limits and other policies incentivizing deployment in specifics areas, including the right-of-way and on existing infrastructure. Specifically, helpful state laws would provide timelines and deadlines for local review of wireless facility application. It would also prohibit municipalities from instituting a moratorium on new wireless facilities and charging review fees not required for other types of commercial development. These provisions promote responsible deployment and will help unleash the potential of 5G in communities across the country. WIA fully expects that states that enact supportive legislation will see greater investment in wireless broadband networks that will benefits their citizens and enhance economic growth.

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GREG WALDEN, OREGON
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December 13, 2017

Mr. David Broecker
CEO
Indiana Biosciences Research Institute
6827 West 96th Street
Zionsville, IN 46077

Dear Mr. Broecker:

Thank you for appearing before the Subcommittee on Communications and Technology on Thursday, November 16, 2017, to testify at the hearing entitled "The Race to 5G and its Potential to Revolutionize American Competitiveness."

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Thank you again for your time and effort preparing and delivering testimony before the Subcommittee.

Sincerely,

Marsha Blackburn
Chairman
Subcommittee on Communications and Technology

cc: The Honorable Michael F. Doyle, Ranking Member, Subcommittee on Communications and Technology

Attachment

The Honorable Gus Bilirakis

Your testimony focuses on how 5G improves quality of care. Healthcare affordability continues to be a major concern for my constituents. A Deloitte study suggests that telehealth programs can have a 50% reduction in medical costs associated with chronic heart failure. A separate poll states that most healthcare executives believe 5G will reduce patient costs. Can you tease out how 5G will equate to better health outcomes at lower cost?

This is very good question. Unlike previous improvements to wireless technology, 5G represents a transformational change that will enable significant gains (i.e.; orders of magnitude) for the transmission of data and information. Because healthcare is extremely data- and information-rich, 5G technology will create new opportunities to deliver care remotely. This means a patient doesn't need to go to their doctor or to the hospital every time they need care.

You reference the Deloitte study regarding chronic heart failure (CHF) as an example of how telehealth programs have reduced medical costs. This is a great example of what is possible. Patients with CHF need to be monitored frequently to ensure that they do not develop complications to their disease or to treatment. Rather than having a patient come back to the doctor's office to be monitored, telehealth enables the patient to be monitored at home. Every morning, a patient can have their blood pressure, heart rate, oxygen levels, and overall body weight measured through at-home devices and this information is automatically sent to the doctor or nurse for their review. If they see a problem, then they will ask the patient to come to the hospital or office. This is only possible if the infrastructure exists to send this amount of information safely, securely, and effectively. 5G technology enables this to be possible.

Other diseases where telemedicine is showing promise include diabetes, obesity, stroke, cancer, asthma and COPD, and addiction treatment. All these examples present opportunities to deliver better health outcomes at lower costs and improved quality of life for patients and their care givers, including family members.

Thank you for your interest in this important topic.

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