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THE RACE TO 5G: EXPLORING SPECTRUM NEEDS TO MAINTAIN U.S. GLOBAL LEADERSHIP

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

JULY 25, 2018

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

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THE RACE TO 5G: EXPLORING SPECTRUM NEEDS TO MAINTAIN U.S. GLOBAL LEADERSHIP

WEDNESDAY, JULY 25, 2018

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 10 a.m., in room SR–253, Russell Senate Office Building, Hon. John Thune, Chairman of the Committee, presiding.

Present: Senators Thune [presiding], Wicker, Blunt, Cruz, Fischer, Moran, Heller, Inhofe, Lee, Capito, Johnson, Gardner, Nelson, Cantwell, Klobuchar, Blumenthal, Schatz, Markey, Udall, Peters, Baldwin, Hassan, Cortez Masto, and Tester.

OPENING STATEMENT OF HON. JOHN THUNE, U.S. SENATOR FROM SOUTH DAKOTA

The CHAIRMAN. Good morning. This morning, our Committee meets again to examine the issue of spectrum needed to maintain U.S. global leadership in next-generation wireless services.

5G, with gigabit speeds, extremely low latency, and the ability to connect tremendous numbers of devices, sounds like a wireless service from the future. But make no mistake, the 5G evolution is upon us. The race to lead the world in 5G has begun. It's a race we must win, but, by many accounts we are already behind China and other nations in key areas. Here is what's at stake: 5G is expected to contribute $275 billion in new investment, $500 billion in economic growth, and 3 million new jobs. It is estimated that American leadership in 4G contributed more than $100 billion to our Nation's economy. We have the technology. The technology created by American industries, including those represented here today, leads the world in next-generation mobile communications. But, that is only part of the equation. Spectrum and deployment are critical. We must ensure that wireless providers have spectrum on which their systems can operate, and they must be able to deploy those networks in a reasonable and timely manner.

The MOBILE NOW Act, legislation that I introduced with the Ranking Member that was enacted earlier this year, addressed both of these critical components. But, as we noted at the time, it was just a down payment. There is much more to do. We will address ways to reduce barriers to deployment in the near future. Senator Schatz and I introduced the STREAMLINE Small Cell Deployment Act a few weeks ago. It reflects many months of hard

work, of meetings with stakeholders from across the country, and of negotiation, and it is still a work in progress as we try to bring the benefits of 5G to American consumers, reap the benefits of 5G leadership for America, and respect the important role that State and local governments play in deployment decisions. It has been a pleasure working with Senator Schatz and his team, and I look forward to continuing our work.

But, today our focus is on spectrum. It is the lifeblood of wireless communications. If we do not have enough of the right kinds of spectrum available, we simply cannot have the speed and the connections that we need. This is particularly important for those of us in more rural parts of the country. The business cases for delivering 5G to New York and Chicago are much different than for Sioux Falls and Spearfish. If inadequacy of spectrum resources makes 5G less viable, it will be the rural areas that no longer make business sense.

The Federal Communications Commission has concluded that next-generation wireless networks will require efficient use of the low, mid, and high bands of spectrum. The FCC, acting in a bipartisan manner, has moved forward with bold proposals to make thousands of megahertz of high-band spectrum available for licensed and unlicensed, fixed and mobile use, and it has taken—I should say, and it has proceedings underway to make even more high-band spectrum available. And the broadband incentive auction completed last year was an important contribution to much-needed low-band spectrum, although we must identify additional low-band spectrum for auction in the near future.

With regard to mid-band spectrum, however, the United States is falling significantly behind. This is particularly troubling because mid-band spectrum is crucial to the initial deployment of 5G. Both the National Telecommunications and Information Administration and the FCC have taken important steps in the last several months to make mid-band spectrum available. But the fact remains that only 150 megahertz of mid-band spectrum has been specifically identified for likely 5G use, and that is on a shared basis under a creative, but novel, licensing scheme. This puts us far behind both China and South Korea in this regard, and represents a serious threat to American leadership of next-generation technology.

The FCC's current proceeding on the 3.7 to 4.2 gigahertz band is considering new approaches to get mid-band spectrum to market quickly while protecting key satellite and related broadcast and cable operations in that band, including providers like Midco, in South Dakota. I look forward to hearing from our witnesses today on that matter.

While we pursue licensed spectrum for 5G, we also must be mindful of the critical role that unlicensed spectrum plays throughout the communications landscape. Wi-Fi operating on unlicensed spectrum is responsible for a tremendous and growing amount of the data transmitted in our homes and offices, and is expected to play an increasing role in the handoff of traffic originating or terminating on licensed spectrum, as well, as in the Internet of Things. It was in recognition of these facts that MOBILE NOW required identifying 100 megahertz of spectrum below 8 gigahertz be-

fore 2023. I recently wrote to the FCC, noting that the 6 gigahertz band had particular promise for unlicensed use, and noting that much more unlicensed spectrum would be needed soon.

As we consider specific spectrum bands that can be made available for licensed and unlicensed use, we must also ensure that our policies and procedures keep spectrum in the pipeline. In that regard, I want to commend the bipartisan work of Senators Wicker and Schatz on SPECTRUM NOW, and Senators Gardner and Hassan on the AIRWAVES Act. I also appreciate that Senators Cruz, Markey, and several other members of our committee are actively exploring new ideas for making additional spectrum available.

Making the Spectrum Relocation Fund a better resource for studying spectrum and relocating Federal incumbents is essential if we are to efficiently make Federal spectrum available for commercial use. Identifying spectrum resources, not just for the next 3 years, but for the next 10 years and beyond, is essential if we're to retain American leadership.

We have a distinguished panel before us today, and I look forward to hearing your thoughts on how we can deliver the benefits of 5G to the American people and secure continuing American leadership in next-generation telecommunications. Thank you all for being here.

I turn now to Senator Nelson, our Ranking Member, for his opening remarks.

STATEMENT OF HON. BILL NELSON,
U.S. SENATOR FROM FLORIDA

Senator NELSON. Mr. Chairman, I will short-circuit my remarks, because you've laid it out quite well.

I just want to say that I'm pleased that the Committee is going to hear from the satellite industry, which is essential for the Nation's communication networks. And there's a lot of promise in the future of these communications systems that are satellite-based. Many of these worldwide constellations are in the testing phase, and even Facebook has confirmed its interest in developing a satellite broadband platform. And, of course, that's going to bring additional activity to the Space Coast, which has already come alive with the exceptional number of rocket launches. We're seeing the rocket launches come back into this country with a launch industry that we had only hoped for, years ago.

Also, I want us to remember that we need to maintain a balanced spectrum policy to support various types of wireless technologies as the engine of innovation, Senator Markey. Innovation. That means that we need additional licensed spectrum for 5G and other services. And we can't forget the need to make sure that the Federal Government—in particular, our national security and Homeland Security agencies—have enough spectrum today and into the future for the mission-critical operations. So, it remains essential for us to make sure adequate spectrum is available for the next-generation wireless services.

We were able to pass the MOBILE NOW bill earlier this year to help foster this 5G revolution. It was bipartisan, as the Chairman said. We're going to work together to address the additional spectrum issues.

And, although the purposes of this hearing is spectrum, I want to say something about infrastructure. It's true that 5G networks are designed around denser wireless infrastructure made up of many small cell facilities. The Chairman has a bill on this siting process. We have all received passionate feedback on this. And I want us to have a robust conversation about the bill at a future hearing that we must include participation by local government and all the interested stakeholders.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Nelson.

As I said, we've got a great and distinguished panel with us today. We have the Honorable Meredith Baker, who's President and Chief Executive Officer of CTIA—The Wireless Association. We have Mr. Dean Brenner, Senior Vice President, Spectrum Strategy and Technology at Qualcomm; Mr. Craig Cowden, who's Senior Vice President, Wireless Technology for Charter Communications, Inc.; and Mr. Tom Stroup, who's President, Satellite Industry Association.

Thank you all for being here. We look forward to hearing from you. And if you could confine your oral remarks to about 5 minutes, we'll make sure that your entire statements are included as part of the permanent record, and it'll give us time to get to questions from our members.

So, Ms. Baker, I look forward to hearing from you. Please proceed.

Thanks.

STATEMENT OF HON. MEREDITH ATTWELL BAKER, PRESIDENT AND CHIEF EXECUTIVE OFFICER, CTIA

Ms. BAKER. Terrific. Thank you, Chairman Thune. We really appreciate you and Ranking Member Nelson and all of the members of the panel for holding this very important hearing.

I'm Meredith Baker. And, on behalf of the wireless industry, we are grateful. We are also grateful for the way that you have phrased this hearing as "The 5G Challenge," because you are right, we are in a global race. And I'm happy to report that, with your leadership, we can win this technological race, if we act fast.

Before we talk about the race, what is 5G? Well, 5G is the next generation of wireless service. Over the last 10 years, we have spent our time working on connecting everyone. Over the next few years, with 5G, we will connect everything. 5G networks will be 100 times faster and five times more responsive. This will power our economy: 3 million new jobs and $500 billion to GDP. But, those numbers just scratch the surface, because the key, to me, is what 5G enables. Pick an industry in your state, from South Dakota to Florida. Pick a constituency that needs something. 5G will help enable innovative new solutions, from telehealth to precision agriculture. That is why the 5G race matters the most. We can't allow tomorrow's advancements in healthcare, in transportation, in energy to be exported overseas. After all, we don't want "Uber for healthcare" to start in China. And make no mistake, other nations see what our wireless leadership has done for our economy, and winning the 5G race is their opportunity to seize those benefits.

So, where does the United States stand internationally? A year ago, candidly, I was worried. It came as no surprise to me that the experts found that the United States was behind China and Korea—South Korea—in 5G readiness. While we led the race to 4G, we found ourselves behind in 5G. Most significantly, we lacked concrete plans to address our Nation's spectrum needs and our outdated siting rules. The good news—we have responded, like I knew our industry would, with decisive action. 5G standards have been finalized. All the national carriers will launch 5G this year, years ahead of the original schedule.

We are ready to build tomorrow's infrastructure. In fact, the U.S. wireless industry is projected to invest $275 billion of our own money to deploy 5G. But, we need some policy help from you to make it happen. That's why I'm heartened by this Committee's swift response to address the exact reforms we need to win the race. The Committee is well positioned to ensure that we, one, have enough spectrum for our 5G future, and, two, have new siting rules for our new networks.

Today's hearing focuses on the first. Spectrum is the critical input for wireless services. MOBILE NOW, enacted earlier this year, was a key bipartisan downpayment. Thank you. Looking ahead, Senator Gardner and Hassan's AIRWAVES Act provides the schedule of new spectrum auctions we need to win. And on siting, tomorrow's networks will be built on small cells, the size of backpacks. The challenge? They can take an hour to install, but up to a year to get approved, because the current rules treat everything like a 200-foot tower. Here again, I commend Senators Thune and Schatz for their STREAMLINE Act that provides a commonsense and balanced framework to modernize our rules while preserving local authority. I urge swift action on AIRWAVES and STREAMLINE to help us win the 5G race.

I want to leave you with three closing points:

First, I want to commend FCC Chairman Pai and the entire FCC for committing to win the 5G race. The progress that they have made on our core priorities this year is laudable.

Second, in taking steps to win the 5G race, we should also redouble our efforts to shrink the digital divide. I think the rural dividend in the AIRWAVES Act is an innovative solution that could really make a difference.

Last, rapid execution on the key legislation that you've identified is critical. 5G is a race, after all. While we have made great progress, other nations are not standing still. China is making available millions of sites for new networks, and South Korea just had a huge spectrum auction last month. To help quantify the stakes of moving fast, Accenture concluded that if we can speed up deployment by just one year, 365 days, we can add an extra $100 billion to the U.S. economy. Let's do that.

I look forward to working with you so the U.S. leads the world in wireless once again. Thank you. And I look forward to your questions.

[The prepared statement of Ms. Baker follows:]

PREPARED STATEMNT OF MEREDITH ATTWELL BAKER, PRESIDENT AND CHIEF EXECUTIVE OFFICER, CTIA

Chairman Thune, Ranking Member Nelson, and members of the Committee, on behalf of CTIA and the U.S. wireless industry, thank you for the opportunity to testify today.

CTIA applauds this Committee's commitment to advancing U.S. spectrum policy, and securing U.S. global leadership in the mobile marketplace. Today's hearing on the race to 5G comes at a critical time. The wireless industry needs your help to realize 5G's tremendous potential to create jobs, grow the economy, and ensure future innovation happens first here in the United States. With your leadership and the important legislative agenda you have before you, I'm confident the U.S. can win the 5G race.

Winning the Race to 5G

5G is the next generation of wireless, and our new networks will offer speeds up to 100 times faster than today's services, enable 100 times the number of devices, and be five times more responsive than today's. I'm excited by 5G's promise to drive transformational improvements in health care, education, transportation, and nearly every other industry. 5G will help create the smart industries and opportunities of the future, including smart communities, precision agriculture, and the Internet of Things.

The United States is not alone in identifying the global competiveness at stake in the potential of 5G services. Other countries, from Asia to Europe, are moving aggressively to lead the world. The United States currently ranks third in overall 5G readiness, behind China and South Korea, according to an Analysys Mason report released earlier this year.[1]

China's position is due primarily to its government's aggressive steps to provide access to significant new spectrum bands for 5G. That commitment includes the Chinese regulatory authority's decision to release at least 100 megahertz of mid-band spectrum (with a focus on 3.4–3.6 GHz) and two gigahertz of high-band spectrum (above 24 GHz) to each wireless provider. In South Korea, the government just completed an auction for 3.5 GHz and 28 GHz band spectrum. And the siting of wireless facilities in China and South Korea is dramatically easier, faster, and less costly than in the U.S.

It's clear: the global race to 5G is on, and the stakes are high. The nation that leads on 5G will capture millions of new jobs and billions in economic growth.

Under your leadership, the United States has led the world in 4G services. According to a study by Recon Analytics, the launch of 4G nearly doubled the number of U.S. wireless-related jobs in just three years, and 4G leadership helped drive nearly $100 billion GDP growth.[2] 4G also helped create the world-leading app and sharing economies in America. Conversely, losing wireless leadership in the transition from 2G to 3G and 3G to 4G had significant, long-term, negative effects on the European and Japanese telecommunications sectors. The rest of the world has seen what 4G wireless leadership has meant to our economy and now seeks to leverage 5G and seize those benefits for themselves.

The good news is that while there's work to do to catch up to China and South Korea and fend off other countries on 5G, the United States is well positioned to win the race if we act fast and put the right policies in place.

For our part, U.S. wireless providers will invest some $275 billion in 5G-related networks—creating three million new jobs and adding $500 billion to our economy according to Accenture. All the national providers have announced aggressive deployment schedules with the launch of services as early as this Fall, years ahead of schedule. American network and technology companies are investing aggressively to ensure that equipment, handsets, and devices are ready for American innovators and consumers to leverage the power of the new 5G platform.

But our industry cannot win the race to 5G alone. We need your help to capture global leadership. Today's hearing is focused on spectrum, one of the two critical areas where we need your help to modernize our Nation's approach. The second is modernizing siting rules for tomorrow's networks.

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[1] Analysys Mason, *Global Race to 5G—Spectrum and Infrastructure Plans and Priorities,* (Apr. 2018), *https://api.ctia.org/wp-content/uploads/2018/04/Analysys-Mason-Global-Race-To-5G_2018.pdf.*

[2] Roger Entner, *How America's 4G Leadership Propelled the U.S. Economy,* Recon Analytics (Apr. 16, 2018), *http://reconanalytics.com/2018/04/how-americas-4g-leadership-propelled-the-u-s-economy/.*

Defining A 5G Spectrum Policy

Other countries are releasing hundreds of megahertz of new spectrum to promote 5G because they recognize sufficient spectrum is key to winning the 5G race and unlocking the corresponding economic and societal benefits. To fully realize the connected life and Internet of Things breakthroughs we are talking about this morning, we need more spectrum, and we need it now.

CTIA commends this Committee, the Federal Communications Commission (FCC), and the Administration for the ongoing work in identifying and repurposing spectrum for 5G. With your support, the wireless industry has invested hundreds of billions of dollars in private capital in acquiring and building out spectrum. But the need for additional spectrum remains pressing. A predictable pipeline of spectrum will do much to advance U.S. 5G interests, and help us match the aggressive efforts foreign governments are taking to allocate spectrum for 5G services. Encouragingly, the Committee has identified all the right bands. Now it is only a matter of us finishing the job fast.

MOBILE NOW. Congress has already made an important "down payment" with the MOBILE NOW Act, bipartisan legislation championed by Chairman Thune and Ranking Member Nelson. CTIA thanks this Committee for its leadership in enacting this legislation earlier this year. Among other things, the MOBILE NOW Act directs the FCC and the National Telecommunications and Information Administration (NTIA) to identify at least 255 megahertz of Federal and non-federal spectrum for licensed and unlicensed wireless broadband use by December 31, 2022. With this direction from Congress, the FCC and NTIA are working to advance 5G here in the United States. MOBILE NOW also helped jump-start our Nation's focus on mid-and high-band spectrum, leading to important steps taken by the FCC to make available new spectrum. The Bipartisan Budget Act of 2015 also directed the Administration to provide access to important low-band spectrum, which is a key component of our Nation's future spectrum planning as well.

AIRWAVES. From that foundation, CTIA strongly supports the Advancing Innovation and Reinvigorating Widespread Access to Viable Electromagnetic Spectrum ("AIRWAVES") Act, which establishes a much-needed schedule of future spectrum auctions critical to U.S. global leadership in 5G.

CTIA thanks Senators Gardner and Hassan for introducing the AIRWAVES Act, and Committee cosponsors Tester, Young, Cortez Masto, and Johnson for their support. This bill enjoys broad bipartisan backing in both the Senate and the House. It also boasts bipartisan support from Chairman Pai and the FCC Commissioners, and has attracted widespread praise from a broad and diverse array of organizations, including the Consumer Technology Association, Connected Nation, the African American Mayors Association, and Public Knowledge (as represented in a letter attached hereto).[3]

The AIRWAVES Act sets a timeline for auctioning a series of key low-, mid-, and high-band frequencies over the next five years. By recognizing that we need different types of spectrum to unlock the full complement of 5G services, Senators Gardner and Hassan have identified a core challenge we face in the U.S., the lack of access to sufficient mid-band spectrum. To achieve our 5G goals, we are going to need different types of spectrum, and mid-band is key as it can offer both capacity and coverage. Unfortunately, the U.S. ranks sixth globally in terms of mid-band spectrum availability. AIRWAVES remedies that by providing access to the same spectrum bands being made available throughout Asia and Europe.

Congressional deadlines, like those in AIRWAVES, have always been an essential tool to enable U.S. spectrum leadership by ensuring timely access to new spectrum. This auction schedule will allow wireless providers to plan and build their 5G networks to maximize efficiency and robustness. And knowing when and what spectrum will be auctioned creates a 5G pathway for industry "verticals" such as telemedicine, smart agricultural systems, and connected vehicles.

CTIA urges the Committee, and the Congress, to move this legislation forward expeditiously. Passage of the AIRWAVES Act is the most important step the Committee can take to ensure that our Nation has the spectrum resources it needs to compete and win the 5G race.

Other Key Initiatives. We also support the Supplementing the Pipeline for Efficient Control of The Resources for Users Making New Opportunities for Wireless ("SPECTRUM NOW") Act, introduced by Senators Wicker, Schatz, Udall, and Moran. This bipartisan legislation would help government agencies more efficiently and effectively manage spectrum resources. The Act allows use of approximately $8

[3] Letter from CTIA *et al.* to Senators Cory Gardner and Maggie Hassan (June 11, 2018), available at *https://api.ctia.org/wp-content/uploads/2018/06/AIRWAVES-Senate-Support-Letter-004.pdf.*

billion in existing Spectrum Relocation Fund monies to support research into the feasibility of Federal spectrum users either relocating or sharing spectrum with non-federal users.

Key Administration and FCC Roles. In addition to legislative action, Congress should continue to encourage work at the FCC and NTIA to promote the development of a 5G spectrum agenda. CTIA commends Chairman Pai and the FCC for their commitment to winning the 5G race and the significant steps taken this year to address our Nation's lack of access to mid-and high-band spectrum.

High-band spectrum will be critical to high-capacity future wireless services and applications. Yet at the start of 2018, there were no planned auctions for these spectrum bands. To the FCC's credit, and as envisioned by MOBILE NOW and AIRWAVES, Chairman Pai has announced the auctioning of five separate bands of high-band spectrum by the end of next year, starting this Fall. The FCC's decisiveness here should be commended.

Similarly, the FCC also has seized on the need for additional mid-band spectrum and is working to optimize rules for the 3.5 GHz band for mobile broadband, and the FCC launched a new proceeding to evaluate repurposing up to 500 MHz of mid-band spectrum between 3.7 and 4.2 GHz just this month. At the same time, the Administration has initiated its important review of the 3.45 GHz band under Administrator Redl's leadership at NTIA. These are important steps, and we urge the FCC and the Administration to commit to a clear auction schedule as soon as practicable for these three critical mid-band spectrum opportunities. Congressional support and encouragement for these initiatives would be beneficial, and would be strongly bolstered by timely passage of the AIRWAVES Act.

Promoting Small Cell Deployment

While not the focus of today's hearing, the other key set of reforms needed to secure 5G leadership is modernizing siting rules to allow the accelerated deployment of new wireless networks and small cells. Small cells are about the size of a backpack and are typically installed on utility poles, streetlights, and the sides of buildings. They complement existing cell towers by densifying wireless infrastructure and provide the capabilities needed for next-generation networks.

Building Tomorrow's Networks. To handle growing mobile data demands and unlock new 5G applications, wireless providers will need to install hundreds of thousands of small cells in the next few years. Recent estimates have projected we will need over 800,000 small cells by 2026. To put that into perspective, our industry has a little over 150,000 cell towers in operation today, built over 30 years. If we do not update our approach and greatly accelerate the approval and deployment process, we will not be able to construct the networks we need fast enough to win the 5G race.

The good news is that a small cell often can be installed in about an hour. The challenge we face is that governmental approval processes can take more than a year, and the application and fee structures are often mismatched with the smaller footprint of tomorrow's networks. Indeed, many rules, regulations, and fees for wireless infrastructure applications are outdated, designed for a world in which 200-foot cell towers were the norm and the necessity. Globally, the process for siting small cells and other wireless infrastructure is often simpler and more streamlined, while our 20-plus-year-old approach hampers the ability of U.S. operators to compete. Our new networks need new rules to keep pace, and we need to start our 5G buildout this year.

While we applaud the efforts of many cities and 20 states to update their approaches to facilitate small cell deployment, we risk falling further behind in the 5G race absent a clearly articulated national framework. As Congress has done before, America needs a modernized, national policy framework for small cell deployment that accommodates state and local interests while advancing our national interest in 5G leadership.

A Bipartisan National Framework. Congress should expeditiously adopt the bipartisan Streamlining The Rapid Evolution And Modernization of Leading-edge Infrastructure Necessary to Enhance Small Cell Deployment Act ("STREAMLINE Small Cell Deployment Act"). We applaud and thank Chairman Thune and Senator Schatz for proposing such a common sense framework.

The STREAMLINE Small Cell Deployment Act addresses the central barriers to deployment of 5G infrastructure, while maintaining localities' prerogatives with regard to safety and neighborhood aesthetics. CTIA strongly supports the STREAMLINE Small Cell Deployment Act and urges it passage.

Other Key Reforms. Additional measures that would make great strides toward modernizing siting processes include Senators Wicker and Cortez Masto's SPEED Act and Senator Moran's RAPID Act, which modernizes the Federal siting approval

process, and Senators Heller and Manchin's work on the Rural Broadband Deployment Streamlining Act, which builds on Federal reforms in MOBILE NOW and injects much-needed deadlines and reforms for siting requests on Federal lands.

The FCC's Important Role. Here again, under this Committee's watch, the FCC has similarly focused its attention on the need for infrastructure reform to promote small cell deployment. Led by Chairman Pai and Commissioner Carr, the FCC has taken a holistic approach to modernizing its rules with a clear focus on winning the 5G race. Earlier this year, the FCC updated historic preservation and environmental rules to reflect the differences between 200-foot towers and small cells. The Commission is now focused on equally important reforms updating the FCC's national guidelines and guardrails for local communities' small cell approval procedures. We urge Congress to encourage the FCC's excellent work in this area.

Need for Urgent Action. Just as with spectrum policy, we have bipartisan support for critical 5G infrastructure initiatives that will help us close the gap with China and South Korea. A report prepared by Accenture last week found that accelerating infrastructure deployment by just one year would also result in an additional $100 billion to our economy.[4] These benefits are within reach—but only if we act swiftly.

Delivering Mobile Broadband to More Americans

I'm proud of our industry's commitment to building mobile service across America, driven by over $226 billion investment in our networks since 2010 alone, and over $25 billion just last year. In the past five years, we were able to connect for the first time 1.5 million additional rural consumers. Nevertheless, there are communities across the country that still do not have access to the benefits of wireless, and we need Congress's and the FCC's help to ensure these under-and unserved areas get connected. The AIRWAVES Act would provide key new low-band spectrum that offers great coverage and propagation characteristics that can help reach hard-to-serve areas. Further, the recently auctioned 600 MHz spectrum is rapidly being deployed as broadcasters vacate that spectrum. Both steps will help extend mobile coverage. Similarly, the STREAMLINE Small Cell Deployment Act and other siting reforms can help reduce the cost and complexity of deploying in rural America and on adjacent Federal lands, particularly in the West. And lower siting fees will free capital for more deployment.

One of the most promising proposals for reaching more Americans is in Senators Gardner and Hassan's AIRWAVES Act. AIRWAVES not only provides us a roadmap to win the 5G race but will also help us shrink the digital divide through its "rural dividend" provision. That provision sets aside 10 percent of the proceeds from new spectrum auctions for deployment of wireless networks in rural America. If this provision had been in place during the last two spectrum auctions, the rural dividend would have made available an additional $6 billion to build out wireless in rural America and unserved communities. CTIA urges Congress to expeditiously pass this legislation and implement this program, which would drive greater rural investment without the need for taxpayer funding.

This Committee has also placed renewed focus on the key role the FCC and Administration can play in expanding access to broadband services. The FCC's Mobility Fund will provide nearly $500 million in annual support, which will provide much-needed universal service funding dedicated to wireless coverage. And ensuring that broadband mapping is accurate will help better inform broadband infrastructure planning.

Thank you for the opportunity to testify today. Just as winning the race to 4G required smart government policies, winning the race to 5G will require swift action on repurposing spectrum as well as modernizing small cell siting rules. CTIA looks forward to working with you to win the 5G race and urges swift adoption of the core 5G legislative proposals discussed this morning to make that a reality.

The CHAIRMAN. Thank you, Ms. Baker.

Mr. Brenner.

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[4] Accenture Strategy, *Accelerating Future Economic Value from the Wireless Industry,* available at *https://api.ctia.org/wp-content/uploads/2018/07/Accenture-Strategy-Wireless-5G-Accelerating-Economic-Value-POV-July-2018.pdf.*

STATEMENT OF DEAN R. BRENNER, SENIOR VICE PRESIDENT, SPECTRUM STRATEGY AND TECHNOLOGY POLICY, QUALCOMM INCORPORATED

Mr. BRENNER. Chairman Thune, Ranking Member Nelson, and members of the Committee, my name is Dean Brenner, and I'm here today on behalf of Qualcomm, a company that's an American success story.

Qualcomm was founded in a San Diego living room. It grew rapidly as cell phones began to take off. And today, working out of our larger headquarters, still in San Diego, Qualcomm is the world's leading supplier of chips for smartphones and other wireless devices, and the world's leading inventor and licensor of new wireless technologies. The technologies we develop, most especially 5G, and the chips we design all depend upon one key input controlled by the government: spectrum. As this committee has recognized most recently in the MOBILE NOW Act, enabling a steady stream of new spectrum across the board—low, mid, and high band, and licensed, unlicensed, and shared—is essential for the rapid broad rollout of 5G. We're working on 5G at a feverish pace to use each and every sliver of spectrum to deliver the kind of wireless connectivity you can only dream about today, speeds that are more than 100 times faster, latency as low as a millisecond, but it all comes back to that steady stream of new spectrum. So, let me thank this committee for leading the way to enact the MOBILE NOW Act and for taking spectrum policy a step further, in the AIRWAVES Act.

Let me give all of you a status report on 5G, but I'll start with an update on 4G LTE.

Our latest 4G chips deliver peak speeds of 2 gigabits per second. We achieve that speed not just because we support over 1,000 different spectrum combinations and we use other LTE enhancements; in addition, we now use both licensed and unlicensed spectrum for 4G. In 2016, the FCC approved the first small cells with our chips, which use a new technology called License Assisted Access, or LAA. LAA uses 5 gigahertz unlicensed spectrum, when and where it's available, in addition to licensed spectrum. LAA enabled gigabit LTE and, later this year, will enable LTE to reach the 2 gigabit mark. Operators around the world and in the United States are all racing to deploy this great new technology. We see gigabit-plus LTE as the foundation for 5G.

Likewise, 4G-based small cell deployments are occurring today around the country, even in advance of 5G. 4G and 5G small cell deployments will be broader and less expensive if regulations keep pace with technology. That's why we support the STREAMLINE Small Cell Deployment Act, introduced by Chairman Thune and Senator Schatz.

Turning to 5G, we're on track to deliver chips that support 5G in both sub-6 gigahertz and millimeter wave spectrum in time to enable 5G data-only devices to launch before the end of 2018 and for the first 5G smartphones to launch in the first half of 2019. That's a tremendous undertaking for Qualcomm and our partners working with these new technologies. Different operators in the United States and around the world will begin providing 5G using different spectrum bands, so it's very important that our chips and

related components support as many bands as possible. In sub–6 gigahertz bands, 5G will have relatively wide coverage. In millimeter wave bands, 5G will cover smaller dense areas, but, using a larger amount of spectrum in our advanced antenna technologies, millimeter wave-based 5G will deliver much faster connectivity than is possible in lower bands.

We're excited by the recent FCC announcements establishing a schedule for this year and next for spectrum auctions in millimeter wave bands. We applaud the recent FCC and NTIA initiatives to free up more mid-band spectrum and bands that other countries and regions have targeted. We also hope the FCC will soon finish up its rules for the CBRS 3.5 gigahertz band. Enabling a steady stream of new spectrum for 5G requires progress on all of these fronts in parallel.

Finally, we're developing versions of 5G built from the ground up for unlicensed and shared spectrum. One version will be a 5G-based LAA. Another version will use new spectrum-sharing techniques to deliver a user experience that will be much better than is possible today in any unlicensed band, and will not require any licensed spectrum at all, enabling 5G for factories, warehouses, and many other industrial uses. These technologies are well suited for the 6 gigahertz band, which Chairman Thune urged FCC Chairman Pai to allocate, in a June 29 letter.

Executing on this 5G spectrum roadmap, working in conjunction with so many industry partners and with Congress, the administration, and the FCC, is crucial for American leadership. It requires close collaboration between all parts of the government and the wireless industry. 5G has the potential to transform every industry, driving productivity gains, jobs, and economic growth, and enabling 5G to be used for all the things that today require wired broadband. By 2035, we estimate that 5G could produce over $12 trillion worth of goods and services. With the stakes so high, spectrum policy has never been so important, which is why I'm so pleased to be here today and to work with all of you.

Thank you. I look forward to your questions.

[The prepared statement of Mr. Brenner follows:]

PREPARED STATEMENT OF DEAN R. BRENNER, SENIOR VICE PRESIDENT, SPECTRUM STRATEGY AND TECHNOLOGY POLICY, QUALCOMM INCORPORATED

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Thank you. I look forward to answering your questions.

The CHAIRMAN. Thank you, Mr. Brenner.

Mr. Cowden.

STATEMENT OF CRAIG T. COWDEN, SENIOR VICE PRESIDENT, WIRELESS TECHNOLOGY, CHARTER COMMUNICATIONS

Mr. COWDEN. Good morning, Chairman Thune, Ranking Member Nelson, and members of the Committee. I am Craig Cowden, Senior Vice President of Wireless Technology at Charter Communications, which markets its products under the Spectrum brand. It's an honor to testify before you today.

At Charter, I lead the team responsible for network architecture and engineering for all of our wireless initiatives. This includes Wi-

Fi, mobility, and innovative fixed and mobile wireless technologies, including 5G.

Charter is investing in a high-capacity, high-compute, low-latency broadband infrastructure with the goal of providing ubiquitous wired and wireless connectivity to our customers, anywhere, on any device. We have invested more than $27 billion in technology and infrastructure since 2014, building out our network in communities across the country, in big cities, in small towns and rural areas that may never have had broadband before.

Charter has invested billions of dollars in our network, in part, to offer the fastest broadband speeds in the market, but also, in part, to prepare for the bandwidth needs of 5G. With 5G, wireless connectivity is transforming from a traditional macro network based on large towers and broad coverage to a network of at least hundreds of thousands of small cells required to achieve higher bandwidth and lower latency. Charter's pervasive network makes us well suited to meet small cell architecture requirements because it enables us to integrate Wi-Fi, 4G LTE, and 5G to provide consumers with wireless connectivity at great efficiency.

Our Wi-Fi network currently serves more than 280 million wireless devices, many of which are smartphones provided by cellular companies. In fact, 80 percent of the data used on these devices in the home and office goes through our Wi-Fi network. Charter is currently deploying Wi-Fi devices that enable speeds approaching 1 gigabit, and we are now the first U.S.-based broadband provider to introduce routers featuring the next-generation Wi-Fi standard, called the 802.11ax.

Technology has evolved to enable the combination of Wi-Fi with licensed cellular spectrum. Last month, we began offering spectrum mobile, a Wi-Fi first, MVNO, that incorporates our robust indoor and outdoor Wi-Fi infrastructure with Verizon's cellular network. The result is a high-quality mobile experience at great value.

In addition, we are conducting tests using millimeter wave 5G spectrum, the 28 gigahertz band, to explore how we can use this high-band 5G spectrum in conjunction with our broadband network to cost-effectively deliver 5G services to homes and businesses. We have also been testing fixed wireless technologies in the 3.5 gigahertz CBRS band across the country. Results have been truly promising. We believe this lower-frequency spectrum could be used to extend the reach of our network and provide robust broadband to more rural areas.

Given the focus of this hearing, I want to address a few specific spectrum issues that could positively impact our ability to deliver next generation of wireless broadband across the country, including in rural areas. Our experience in the wireless market have made clear that the success of 5G requires a full range of wired and wireless technologies and a complete toolkit of spectrum. We urge Congress and the FCC to ensure policies are neutral across wireline and wireless technologies, and to search for ways to make both unlicensed and licensed spectrum available for wireless broadband.

First, opening the 5.9 gigahertz band for unlicensed use is one of the most immediately impactful steps policymakers can take to help the growing demand for Wi-Fi and other unlicensed technologies. This band has been unused for more than 20 years and

lies right next to the most-used Wi-Fi band. Service providers could bring advanced Wi-Fi services to the market immediately without needing time to develop costly new equipment.

Second, we appreciate the FCC's focus on the 3.5 gigahertz CBRS band. Quickly enabling the use of this spectrum will facilitate a significant increase in wireless broadband capacity and greatly improve mobile service for consumers. Perhaps more importantly, it holds tremendous potential for cost-effective rural broadband.

Finally, the lower C-band should be considered for wireless broadband, as it provides the proper balance of capacity and coverage for 5G mobility. However, this band is currently used to deliver video services to millions of consumers. It's essential that they are protected in any potential reallocation.

I'd like to end where I started. We are investing in high-capacity, high-compute, low-latency broadband infrastructure. Whether that is expanding the reach of our wired network, enhancing Wi-Fi, or testing 5G technologies, Charter is working to deliver a leading wired and wireless connectivity experience.

I thank the Committee for its time, and look forward to answering your questions.

Thank you.

[The prepared statement of Mr. Cowden follows:]

PREPARED STATEMENT OF CRAIG COWDEN, SENIOR VICE PRESIDENT OF WIRELESS TECHNOLOGY, CHARTER COMMUNICATIONS

Introduction

Good morning, Chairman Thune, Ranking Member Nelson and distinguished members of the Senate Committee on Commerce, Science and Transportation.

Thank you for inviting me this morning to discuss topics that are critical to our country's future: how we can harness the power of wireless technologies, why U.S. leadership is important, and what we need to do to keep driving innovations that will spur continued economic growth and help millions of people across the Nation connect to each other and to the world.

I am Craig Cowden, Senior Vice President of Wireless Technology at Charter Communications, which markets its products throughout the country under the Spectrum brand. I lead the team responsible for the network architecture and engineering for all of our wireless initiatives. This includes WiFi, mobility, and innovative fixed and mobile technologies including 5G. Charter is investing in all of these elements along with innovating its advanced fiber and coax based network infrastructure, with the goal of providing customers access to any content, anywhere, on any supported device with a leading wired-wireless connectivity experience.

The future of connectivity is at hand, but can be hard to grasp. To put it simply, a variety of innovative wireless access technologies which includes 5G, 4G LTE, and enhanced WiFi will increase today's broadband speeds by as much as 1,000 times while reducing network latencies down to less than a millisecond. This connectivity will transform our daily lives; allowing us to connect billions of devices, communicate with the Internet of Things (IoT), make communities and government services "smarter" and more efficient, enable patients to receive real-time, comprehensive medical care, and create new forms of entertainment using augmented and virtual reality.

This distinguished Committee is at the center of policy discussions that are critical not only to the future of communications but to the future of our country as a whole. Policies that ensure continued innovation and investment in our networks, while expanding broadband access to more communities, are essential to our country's continued economic growth and global competitiveness.

We thank the Committee for its efforts to date, and look forward to continuing to work together to increase the availability of licensed and unlicensed spectrum and create forward-looking policies that promote competition and provide regulatory certainty, all of which will help ensure the United States retains its leadership in the 5G era.

Charter's Advanced Network

Our goal at Charter is to deliver ubiquitous connectivity to all of our customers—those living in urban, suburban *and* rural communities. With more than 97,000 employees serving 41 states, Charter is making the investments needed to meet the connectivity needs of our customers today, tomorrow, and every day after that.

Since 2014, we have invested more than $27 *billion* in technology and infrastructure. These investments have enabled us to significantly extend the reach of our network and enhance our service offerings. We are building out our broadband network in communities across the country; in big cities and small towns, in places that are underserved and in some cases unserved altogether. We now have 840,000 miles of fiber and coax-based network infrastructure passing 50 million homes and businesses. Last year alone, we expanded the reach of our network to an additional one million homes and small businesses.

Charter's Emerging Wireless Leadership

Charter has invested these billions of dollars in fiber and densifying our networks in part to offer the fastest broadband speeds in the market, and in part to prepare for the bandwidth needs of 5G. The IoT and the advanced video and virtual reality applications that individuals and communities want depend on combining ultra-fast WiFi with innovative wireless technologies like 5G—all powered by a robust high capacity, high compute, low latency broadband infrastructure.

While the term "5G" is used to describe a wide variety of technologies, 5G architecture is fundamentally different than all of the previous generations of wireless infrastructure (2G, 3G, 4G,) that have come before it. With 5G, wireless connectivity is transforming from a traditional macro network based on large towers with broad coverage to a network of at least hundreds of thousands of small cells strung closely together which, because of spectral re-use, produces significantly higher bandwidth at much lower latency. Cable companies like Charter, with fiber-based wireline networks covering all kinds of neighborhoods in cities and towns, suburban communities and rural areas, are well suited to meet future 5G small cell architecture requirements. With our pervasive networks, we can integrate multiple access technologies such as WiFi, 4G/LTE and 5G millimeter wave radios with great efficiency, enabling us to provide consumers with wireless connectivity at a good value.

1. Enhanced WiFi

Charter has long been a "wireless company" by virtue of our robust WiFi network. Our WiFi network currently serves more than *280 million* wireless devices. Many of those wireless devices are smart phones provided by cellular companies yet *80 percent* of the data used on those phones goes through our WiFi network.

With the vast majority of our customers' wireless traffic running on our WiFi network, we need it to be the most robust it can be to ensure the best experience for them. We are currently deploying WiFi devices that enable speeds approaching 1 Gigabit, among the fastest in the country.

We are also excited to announce this week that we are now the first WiFi provider to use the latest WiFi technology, called 802.11ax. Compared to previous WiFi standards, this is a game changer. It increases speeds, improves coverage, furthers the ability of many devices to run at the same time, further improves our already robust video streaming and provides better battery life.

Our pervasive WiFi network therefore is the starting point for our mobile strategy. Charter's is an "Inside-Out" strategy, focusing first on wireless solutions inside the home and office, and then providing connectivity outside the home to meet growing customer demand for connectivity when they are on-the-go.

2. Mobile

Technology has evolved to enable the combination of WiFi with licensed cellular spectrum. Last month we began offering Spectrum Mobile, bringing more competition to the wireless marketplace in the 41 states we serve.

Spectrum Mobile customers enjoy the same ubiquitous mobile coverage they get from traditional wireless companies, but their connections are through a WiFi-first MVNO that incorporates our robust indoor and outdoor WiFi network with Verizon's cellular network. The result is a high quality mobile experience at a great value. The data switchover from our WiFi to Verizon's network is seamless and not noticeable to customers, yet it can save them money.

The next step in our mobile evolution will be to deploy LTE licensed small cells and then 4G LTE and 5G wireless access technologies and integrate them with our existing infrastructure. We are conducting extensive trials using small cells in Tampa, Florida and Charlotte, North Carolina, and will expand this testing to Los

Angeles and New York City within the next few months. These trials will inform how we will leverage these innovative technologies to improve our wireless products.

3. Fixed Wireless

We also have been exploring how 5G and other new wireless technologies can be used to deliver significantly improved broadband services to homes and businesses small and large.

For over a year, Charter has been conducting tests around the country using millimeter-wave 5G spectrum, the 28 GHz band, in Orlando, Florida; Bakersfield and Los Angeles, California; Reno, Nevada; Clarksville, Tennessee; Columbus, Ohio; and Grand Rapids, Michigan. The results to date have been promising and we are continuing to test how we can use this high-band 5G spectrum in conjunction with our fiber network to cost-effectively deliver 5G services to homes and businesses for things like multiplayer AR/VR interactive gaming, multiple simultaneous 4K-quality video streaming, and "Desktop-as-a-Service" models that push compute functions to the network cloud but require large bandwidth and low latency.

We have also been testing fixed wireless technologies in the 3.5 GHz bands in locations near Lexington, Kentucky; Bakersfield, California; Tampa, Florida; Denver, Colorado and Coldwater, Michigan. We believe this lower-frequency spectrum could be used to extend the reach of our network and provide cost-effective, wireline-like connectivity to less densely populated areas. Results of these trials have been promising; we're seeing speeds that significantly exceed the FCC's definition of high speed broadband in most circumstances, allowing for video streaming and the use of multiple apps simultaneously. Charter plans to continue its investigation of fixed wireless solutions using 3.5 GHz to expand rural broadband.

The Wireless Future

The success of 5G requires a full range of wired and wireless technologies and a full toolkit of spectrum that includes licensed and unlicensed, high-band, mid-band and low-band spectrum.

We appreciate the attention of the Committee and the Federal Communications Commission to identify policies that promote the deployment of 5G and the continued expansion of broadband infrastructure. Adopting technology-neutral policies that promote competition and innovation is critical, as are efforts to make available additional unlicensed and licensed spectrum, both of which are necessary to support 5G.

1. 5.9 GHz

Opening the 5.9 GHz band, which has been unused for more than 20 years, for unlicensed use is one of the most immediately impactful steps policymakers can take to help meet the growing demand for WiFi and other unlicensed technologies. WiFi already securely powers home security systems, medical devices and services in and out of hospitals, hundreds of billions of dollars of financial transactions, essential education and workforce services, and critical machine communications. It also generates billions of dollars for the U.S. economy each year.

The 5.9 GHz band lies right next to the most-used WiFi band in the country, making it the gateway to revolutionized WiFi speeds and innovation in Gigabit WiFi. Opening up this band for unlicensed use will unleash continued innovation and economic growth. Additionally, WiFi providers could bring advanced WiFi services to the market immediately, without needing time consuming and costly new equipment.

2. 3.5 GHz

3.5 GHz is another spectrum band that offers tremendous potential for unlicensed use or General Authorized Access. We have encouraged the FCC to make the unlicensed part of the band available quickly and to adopt licensing rules that preserve an innovative approach to spectrum sharing in the band. This will encourage efficient use of that spectrum, lower barriers to entry for new competitors, and promote rural broadband deployment.

3. 3.7GHz–4.2GHz

The lower C-band spectrum (3.7GHz—4.2GHz) also holds promise as it provides both meaningful bandwidth and RF propagation that could enable ubiquitous 5G mobility. At the same time, it is currently relied upon by C-Band satellite video providers to deliver video services to millions of consumers. Therefore it is essential that those customers and consumers they serve are protected and compensated for any costs associated with a reallocation to mobile.

Conclusion

Whether it's testing 5G technologies, investing in broadband infrastructure or expanding the reach of our wired network, Charter is working to deliver the next generation of broadband. We appreciate this Committee's commitment to developing smart policies that will advance these efforts, and we look forward to continuing to work with you.

I thank the Committee for its time and look forward to answering your questions. Thank You.

The CHAIRMAN. Thank you, Mr. Cowden.

Mr. Stroup.

STATEMENT OF TOM STROUP, PRESIDENT, SATELLITE INDUSTRY ASSOCIATION

Mr. STROUP. Chairman Thune, Ranking Member Nelson, and distinguished members of the Committee, thank you for inviting me to testify before you today. I'm Tom Stroup, President of the Satellite Industry Association.

Today, I would like to discuss the benefits, innovations, and related spectrum policies for enabling satellite broadband as part of the race for 5G and next-generation services under U.S. global spectrum leadership.

The satellite industry has invested tens of billions of dollars to innovate and increase connectivity in the United States and across the globe. Today, users across the U.S. receive 25.3 megabits-per-second speeds, meeting the FCC's definition of broadband service. And this year, the industry has reached a new milestone, providing up to 100 megabits-per-second download speeds. With satellites that are currently under construction, operators will have the ability to reach speeds of up to a gigabit per second and simultaneously process a terabit of data per second. These high-throughput geostationary satellites will provide orders-of-magnitude increases, ensuring they remain competitive with terrestrial offerings.

At the same time, tens of thousands of new non-geostationary satellites from multiple providers will soon be launching into low-Earth and medium-Earth orbit to provide low-latency, high-speed broadband across the globe. These satellites not only have expanded capabilities, but are also designed to utilize spectrum efficiently. For example, high-throughput satellites rely on frequency reuse and spot-beam technology to produce increased output factors upward of 100 times that of traditional satellites. These satellite services deliver key attributes that are important to the innovation ecosystem. In addition to competition where service already exists, spectrum-enabled satellite services are extending the powerful benefits of broadband to the 24 million Americans who today lack broadband Internet access. The nature of satellites' wide coverage ensures that all communities within a satellite network footprint receive the same quality of service whether they are remote communities or big cities.

When you fly, satellite mobility services are delivering high-speed Wi-Fi at 25 megabits-per-second speeds capable of streaming your favorite Netflix show right to your seat. And, unfortunately, when natural and manmade disasters can interrupt terrestrial broadband services that must rely on towers and ground systems, satellite broadband, however, can quickly restore communications

in a disaster aftermath, or prevent the outage in the first place, due to the very limited amount of terrestrial infrastructure necessary to connect.

Of course, all of the breakthroughs we've seen because of satellite broadband technologies should not be taken for granted. Satellite innovation depends on our industry's ability to reliably access spectrum. In order for our industry to continue to innovate and meet the need—the continuous demand for more and faster satellite broadband speeds, we need more spectrum. Therefore, the spectrum pipeline must include satellite spectrum. Satellite broadband networks need spectrum just as terrestrial wireless systems do. This can be done in a way that ensures the U.S. will benefit from the broadest range of technological opportunities. This means that satellites must also be able to depend on having certainty of access to existing spectrum resources.

In addition, technology neutrality in spectrum policy is critical. The U.S. cannot win the race for broadband deployment with just one technology having exclusive spectrum access. In some cases, this may require exclusive spectrum allocations, and, in other cases, when needed and technically demonstrated, it involves adoption of coexistence and sharing arrangements.

Finally, spectrum policy does not stop at national borders. It requires coordination with the rest of the world. While terrestrial 5G spectrum access is an important agenda item for the upcoming World Radio Conference, including proposals to add 5G in longstanding satellite bands, there are also important satellite spectrum proposals to expand mobile satellite broadband and adjust spectrum coexistence and sharing environments for new non-geostationary satellite systems.

Policymakers have within their reach an opportunity to ensure U.S. leadership in the 5G ecosystem by driving cooperation from all spectrum users to develop and enable technical solutions to meet future demands. For spectrum policy to work for satellites, however, because of their global reach, we need leadership at home and abroad. The FCC must continue to ensure satellite and 5G can advance their spectrum needs by providing leadership at the upcoming World Radio Conference that recognizes the global dimensions of satellite spectrum requirements.

I appreciate the opportunity to appear before you today, and I look forward to your questions.

[The prepared statement of Mr. Stroup follows:]

PREPARED STATEMENT OF TOM STROUP, PRESIDENT,
SATELLITE INDUSTRY ASSOCIATION

Chairman Thune, Ranking Member Nelson, and distinguished Members of the Committee, thank you for inviting me to testify before you today. I am Tom Stroup, President of the Satellite Industry Association (SIA). SIA is a U.S.-based trade association providing representation of the leading satellite operators, service providers, manufacturers, launch services providers, and ground equipment suppliers. Before joining SIA in late 2014, I served as CEO of Shared Spectrum Company (SSC), a leading developer of spectrum intelligence technologies. For a little more than ten years, I also served as the President of the Personal Communications Industry Association (PCIA). I have also founded and run several companies in the technology industry, including Columbia Spectrum Management, P-Com Network Services, CSM Wireless, and SquareLoop.

In an age when high speed broadband is quickly becoming the most transformative technology of our time, enabling pervasive reliable high-speed access everywhere has not only become an opportunity equalizer, learning enabler, and innovation accelerator, but an economic imperative. U.S. policymakers recognize the transformative satellite broadband opportunities on the horizon and the critically important role that informed spectrum policy plays in enabling it. FCC Chairman Ajit Pai recently explained: *"I've often said that in order to bring digital opportunity to all Americans, we need to use all of the tools in the toolbox. Satellite broadband service is one of those tools. Next-generation satellites are bringing new competition to the broadband marketplace and new opportunities for rural Americans who have had no access to high-speed Internet access for far too long."* Whether it's NTIA Administrator Redl, Commerce Secretary Wilbur Ross, or White House Space Council Executive Secretary Scott Pace, there is a growing recognition (as shown in Appendix A) that satellite technologies are driving transformative new benefits. To take advantage of future opportunities, we need to be thinking proactively about the vitality and availability of satellite spectrum resources.

Today, I would like to discuss the benefits, innovations, digital inclusion, and related spectrum policies for enabling satellite broadband as part of the race for 5G and next generation services under U.S. global spectrum leadership.

I. Benefits of Satellite Broadband

We can already see the enormous benefits that satellite broadband is delivering.

Investment in Technology. The satellite industry has invested tens of billions of dollars to innovate and increase connectivity in the United States and across the globe and is continuing to make significant investments. As early as 2012, satellite downloads speeds reached 12 Mbps, above the national average at the time. But the industry did not stop there. New services are launching every year, and in the last several years began broadly providing users across the United States with lightning fast 25/3 Mbps service. This year the industry reached a new milestone, providing up to 100 Mbps download speeds. Across the country today, about 2 million fixed broadband customers and millions more flying on aircraft are already taking advantage of reliable satellite broadband services at reasonable rates and speeds that meet and surpass the FCC's definition of broadband service, with faster speeds and greater capacity on the horizon. The investments that enable satellite broadband speeds and services include U.S. manufacturers of spacecraft, antennas, and other satellite communications components, reflecting U.S. global leadership in the sector.

Expanding Capabilities. Spectrum enabled satellite capabilities are continuously expanding and improving. Soon satellite broadband operators will be delivering fiber-like speeds using satellites that are under construction today, with the ability to reach speeds of up to a gigabit per second and simultaneously process a terabit of data per second. These high throughput geostationary satellites will provide orders of magnitude capacity increases and resulting consumer broadband benefits, remaining competitive with terrestrial offerings. At the same time tens of thousands of new non-geostationary satellites from multiple providers will soon be launching into Low-Earth and Medium-Earth orbits to provide low-latency, high-speed broadband across the globe.

Spectrum Efficiency. Satellite services are designed to utilize spectrum efficiently. Satellite service providers have shared the use of spectrum bands amongst themselves and other communications services for decades. Frequency re-use and spot beam technology are examples of efficiency innovations that increased output using the same amount of spectrum. For example, high throughput satellites rely on frequency re-use and spot beam technology to produce increased output factors upward of 100 times that of traditional satellites. And these existing high throughput satellites currently support the delivery of 3G and 4G services, as well as enable global machine-to-machine communications. As we move into the future, satellite fleets will continue to be a part of a system architecture that delivers new 5G, IoT, and intelligent, connected transportation services to consumers everywhere.

Ubiquity. The capabilities of satellite include extending digital opportunity to people wherever they may live, work or play, and helping transform businesses, which is one of the reasons that demand for satellite service is at an all-time high.

II. Satellite Broadband Innovation

These satellite services deliver key attributes that are important to the innovation ecosystem:

Competition. Just as the satellite industry already has with radio and television services, satellite broadband services are providing market-based competition to terrestrial broadband services. Satellite broadband brings additional package options, greater capacity for video downloads and streaming, competitive pricing per gigabit,

and innovative services to consumers in the United States, often in areas with only a single or low number of terrestrial providers. Satellite broadband is also used by business and government enterprises, for both fixed and mobile purposes, using a range of spectral bands to deliver assured access to broadband communications. Further, satellites are providing critical backhaul Internet connectivity to local Internet Service Providers and community institutions in remote locations.

Coverage. Spectrum enabled satellite services are extending the powerful benefits of broadband to the 24 million Americans who today lack broadband Internet access. High quality and cost-effective satellite broadband is playing an increasingly important role in addressing the digital divide across the United States, including in the most rural and remote areas of the country, where it remains uneconomical for terrestrial services to build. The nature of satellite's wide coverage ensures that all communities within a satellite network's footprint receive the same quality of service, whether they are remote communities or big cities.

Cost-efficiency. Importantly, satellite is reaching rural and remote communities with a geographically-independent cost structure, in many cases taking advantage of the same technologies and similar pricing as satellite subscribers in urban America. Because satellite systems have inherently wide-area coverage there are minimal additional costs to build out to rural and remote areas, aside from opportunity costs from not serving other markets. This is one reason why incentives made to encourage capacity redirection should be technology neutral.

Mobility. Satellite broadband opportunity is literally taking off. When you fly, satellite services are delivering high speed WiFi at 25 Mbps speeds capable of streaming your favorite Netflix show right to your seat. WiFi on aircraft has become so popular that there are often more connected devices than passengers on planes. It's extending urban quality broadband services to rural America, to the seat on your plane, and even war fighters and senior government leaders.

Reliability. Natural and manmade disasters can interrupt terrestrial broadband services that must rely on towers and ground systems. Satellite broadband, however, can quickly come in and restore communications in a disaster aftermath, or prevent the outage in the first place due to the very limited amount of terrestrial infrastructure (*i.e.,* antenna or dish) necessary to connect. The role of satellite in an emergency was recently witnessed in 2017 in the aftermath of the hurricanes where satellite broadband supported FEMA, other government agencies, businesses and residents, so that they could get back to normal.

These technologies don't just have the potential to help connect the unconnected, extend new health, educational and societal opportunities throughout the country, but satellite broadband can help expand economic opportunity everywhere—on the ground, in the air, across the seas, and around the globe. As the country, and indeed the world, is blanketed with high speed broadband access, the opportunities become even more pervasive, the technologies more transformative, and the impacts even more profound.

Soon the next big thing will be billions of little things connected to sensors that are embedded into everyday devices. As we connect our electric and other grids, our thermostats, our factories, our homes, cars, and cities to broadband, ubiquitous connectivity will transform whole sectors of our economy—from transportation to healthcare, manufacturing and energy. It extends how and where emergent technologies like the Internet of Things, Artificial Intelligence, big data and the cloud, can be used to help us unlock amazing new opportunities to solve problems in ways that we simply never could before or can't even imagine today.

III. Satellite Broadband for Digital Inclusion

Satellite is a vital part of this innovation ecosystem and uniquely situated to solve the digital inclusion challenge:

Farming. Satellite broadband is helping enable a whole new generation of precision agriculture opportunities on the horizon, driven by broadband that enables remote farms especially with livestock sensors, soil monitors, and autonomous farming equipment in rural America, far beyond where cell towers can reach or make economic sense. Autonomous farm equipment, already enabled by satellite positioning technology, often needs connectivity far beyond the line of sight of a cell tower.

Education. At a time when 7 in 10 teachers assign homework that requires Internet access, 1 in 3 households across the country with school-aged children and incomes less than $50,000 still do not have broadband. Satellite is helping close this gap at home,and will soon enable school buses on long commutes to become WiFi-enabled mobile study halls.

Healthcare. With too many Americans living in areas with only sporadic and even diminishing access to quality healthcare, satellite broadband technologies that span distance are extending connected care everywhere. No one should be forced to put

their life at risk simply because they live too far from a doctor. Satellite technology is cost-effectively overcoming a rural physician shortage, extending experts to where they are needed most, and delivering services regardless of where the doctor or patient are physically located. In addition, satellite broadband can help connect the elderly when they need it most.

Mobility. The ubiquity of satellite coverage provides access to areas across the globe that are otherwise unreachable—keeping us connected in the air, on the move, and in the sea. These spectrum-enabled capabilities are enabling our warfighters to protect us by land, sea or air, providing agencies with state-of-the-art technologies to protect our national security, and connecting our embassies and government leaders with secure communication options.

IV. Satellite Broadband Spectrum Policy

Of course, all of the breakthroughs we've seen because of satellite broadband technologies should not be taken for granted. Satellite innovations depends on our industry's ability to reliably access spectrum. In order for our industry to continue to innovate and meet the continuous demand for more and faster satellite broadband speeds, and to power the mission critical solutions that require satellite technology, we need continuous access to more spectrum. The following principles are essential for good spectrum management.

Spectrum Pipeline Must Include Satellite Spectrum. Satellite broadband networks need spectrum, just as terrestrial wireless systems do. This can be done in a way that ensures the United States will benefit from the broadest range of technological opportunities. This means that satellites must also be able depend on having certainty of access to existing spectrum resources, including the millimeter wave bands. Satellites may be good sharing partners in both Federal and non-federal spectrum with compatible technologies and uses.

Technology Neutrality in Spectrum Policy is Critical. The United States cannot win the race for broadband deployment with just one technology having exclusive access through regulation. Successful and innovative broadband services result from multiple technologies and all need more spectrum access. In some cases, this may require exclusive spectrum allocations, and in other cases, when needed and technically demonstrated, adoption of co-existence and sharing arrangements.

We recognize that the Federal Communications Commission is actively seeking to identify additional bands for terrestrial 5G. As part of this process, it must carefully consider how to protect incumbent satellite operations and the critical services they provide. Space-to-earth downlink spectrum is particularly susceptible to interference as these signals are relatively weak by the time they hit the ground. Satellite operators have invested billions of dollars in dozens of satellites serving the United States and currently provide important services to American consumers, either directly or indirectly, as well as to the USG. Sound spectrum policy will account for this reality and avoid allocations that disrupt this delicate infrastructure.

ITU World Radio Conference (Fall 2019). Spectrum policy does not stop at national borders. It requires coordination with the rest of the world. While terrestrial 5G spectrum access is an important agenda item for the upcoming World Radio Conference, including proposals to add 5G in long-standing satellite bands, there are also important satellite spectrum proposals. Based on technical compatibility studies, the satellite proposals will expand mobile satellite broadband for aircraft, trains, cars, and ships. Still other technical proposals will address spectrum co-existence and sharing environments for new non-geostationary satellite systems. In addition, because satellite capacity is critical for the deployment of 5G, satellite and satellite operators will need continued access to millimeter wave bands to meet the demand for broadband services.

For satellite networks, there are two ground components—user terminals and gateways. User terminals, that connect the user to the satellite, require dedicated spectrum because they need to operate ubiquitously, either fixed or mobile. Gateways, or antennas that connect the satellite to fiber backhaul and the Internet, are fixed in place for a long time and can co-exist more easily with other spectrum services.

The satellite industry has been sharing spectrum through technical rules and coordination of individual systems for decades. The FCC and the ITU international rules require close spacing of geostationary orbit satellites to permit frequency reuse at multiple orbital locations, so the satellite industry has been an industry leader in spectrum use and reuse. The satellite industry has also worked with regulators and others industry spectrum users to study how earth stations can operate with minimal impact in bands where spectrum is shared with other services.

U.S. policymakers, including the Members of the Committee, the FCC, NTIA and others, have within their reach an opportunity to ensure the U.S. leadership in 5G

ecosystem, to include satellite broadband operators and terrestrial wireless stakeholders, by driving seeking cooperation from all spectrum users to develop and enable technical solutions to meet future demands. When necessary, enabling policymakers should get all parties to work together or seek and implement solutions that will promote spectrum efficiency and opportunities for all. The ultimate winners will be the American public and broadband consumers.

For the United States to ensure its continued global leadership in next generation satellite broadband, and to meet our national security communication needs, agency leaders are beginning the process of ensuring the protection and stewardship of spectrum to support commercial satellite activities. For spectrum policy to work for satellites, because of their global reach, we need leadership at home and abroad. The FCC must continue to ensure satellite and 5G can advance their spectrum needs by providing leadership at the upcoming World Radio Conference that recognizes the global dimensions of satellite spectrum requirements.

V. Conclusion

With enormous opportunities on the horizon, policymakers need to think broadly about the entire innovation ecosystem. It takes pragmatic policies that:

- Foster win-win solutions enabled by equitable dedicated spectrum and spectrum sharing where necessary with technical solutions.
- Continue to advance technology neutral broadband policies that let consumers and the market decide on technologies
- Ensure U.S. government agencies can take full advantage of the latest spectrum enabled communications technologies. Satellites offer resilient and ubiquitous communications that keep America safe. Policymakers have an opportunity to maximize the use of spectrum by using cutting-edge commercial satellite communications technologies to grow their capacity while giving taxpayers their greatest bang for their buck.
- And because these are global services, it's vital that our policymakers provide spectrum leadership around the globe, including for the upcoming World Radio Conference in 2019. We encourage regulators to continue to allocate sufficient spectrum for satellite use, both domestically and via United States support at the upcoming World Radiocommunications Conference.

I appreciate the opportunity to appear before you and I am happy to answer any questions.

APPENDIX A

Policy leaders are coming to recognize the vital role satellite plays and the critical role that satellite spectrum plays in enabling opportunity

NTIA Administrator David Redl

"There is no doubt that the United States needs a vibrant satellite sector. This industry creates tens of thousands of high-paying jobs and enables millions more in the larger economy. In the next few years, a new era in satellite coverage will strengthen our Nation's broadband infrastructure and power advanced services that will improve people's lives . . . As the agency that is principally responsible for advising the President on telecommunications and information policy, NTIA can help create an environment that allows for continued global leadership in the market for satellite-based services and manufacturing. This includes the important role satellites will play in delivering 5G and ensuring that the United States stays on the cutting edge of wireless technology."

FCC Chairman Ajit Pai

"I've often said that in order to bring digital opportunity to all Americans, we need to use all of the tools in the toolbox. Satellite broadband service is one of those tools. Next-generation satellites are bringing new competition to the broadband marketplace and new opportunities for rural Americans who have had no access to high-speed Internet access for far too long. . . . Breakthroughs are already happening. . . . Viasat began offering 100 Mbps broadband service in the United States with unlimited data. This was made possible by high-throughput satellites that use spot-beam technology and frequency re-use to dramatically increase capacity . . . it's so important for the Federal Government to set rules that encourage innovation in [the satellite] industry rather than regulatory roadblocks to progress.'"

White House Space Council, Executive Secretary Scott Pace

"The United States has a strong and entrepreneurial satellite communications industry, available to engage in global competition. To ensure we retain the strategic advantages afforded by space services, the United States needs to continue to open and promote competitive markets and protect spectrum allocation for space services to compete. Since radio waves, as you know, don't stop at borders, unfettered terrestrial wireless network [like 5g] use in one country could certainly preclude the use of satellite services in neighboring countries. That would harm the global economy, and a global approach is necessary to protect U.S. space commerce.". . . "it's for these reasons the National Space Council is examining how the Department of State, Commerce and FCC can better coordinate to ensure the protection and stewardship of spectrum necessary for space commerce—and, again, not just for space purposes and it's unique uses, but also to make sure that we're competitive in terrestrial areas, as new technologies like 5G come along."

Director of the Office of Policy Planning at the Department of Commerce, Earl Comstock

"[F]rom the secretary's point of view, and certainly from the fact that it's recognized in the recent Space Council documents, there is a concern within the administration that we need to make sure that, as we go forward, and we obviously want to facilitate 5G, we want to facilitate broadband, but we also want to keep an eye on the future of if we're going to have this expanding space market, we don't want to discover that we've basically stunted the growth of that market by denying the spectrum that might be needed for those transactions. So it's going to be a balancing act. It's going to be something that people have to take a hard look at. But we are very cognizant of the fact that when you're looking at the space regime, we are looking to the future. We're looking at an expansion of this. It's a very significant expansion. And so we want to move very carefully in terms of any changes that might end up shortchanging that ability to move forward in space."

The CHAIRMAN. Thank you, Mr. Stroup.

Senator NELSON. Mr. Chairman——

The CHAIRMAN. Senator Nelson.

Senator NELSON. —may I insert in the record a number of letters raising concerns on infrastructure, particularly from municipalities——

The CHAIRMAN. Yes.

Senator NELSON.—from mayors?

The CHAIRMAN. Without objection.

[The information referred to follows:]

LEAGUE OF CALIFORNIA CITIES
Sacramento, CA, July 10, 2018

Senator DIANNE FEINSTEIN,
United States Senate,
Washington, DC.

Senator KAMALA HARRIS,
United States Senate,
Washington, DC.

Dear Sen. Feinstein and Sen. Harris,

RE: Opposition to S. 3157 (Thune & Schatz)—STREAMLINE "Small Cells" Act

On behalf of the League of California Cities, we urge your opposition to S. 3157 (Thune & Schatz), the STREAMLINE Act. The bill would force local governments to lease out publicly owned infrastructure, eliminate reasonable local environmental and design review, and eliminate the ability for local governments to negotiate fair leases or public benefits for the installation of "small cell" wireless equipment on taxpayer-funded property.

Just last year, the wireless industry pursued similar failed legislation here in California that sought to achieve many of the elements present in this bill. The industry's effort here was met with overwhelming opposition from over 325 cities concerned about shifting authority away from our residents, businesses, and communities over to a for-profit industry whose shareholder returns potentially outweigh their considerations for the health, safety, aesthetic, and public benefits of the communities we serve.

To be clear, cities across California share in the goal of ensuring all our residents have access to affordable, reliable high-speed broadband and eagerly welcome instal-

lation of wireless infrastructure in collaboration with local governments. However, this bill will not help in achieving these goals.

Instead, this bill interferes with local governments' management of their own property and their ability to receive fair compensation for its use. Local governments actively manage the rights of way to protect their residents' safety, preserve the character of their communities, and maintain the availability of the rights of way for current and future uses. By stringently limiting those factors that local governments may consider in their own land use decisions, and restricting the compensation they receive to the "actual costs" they incur to process applications, this bill limits local governments' ability to adequately serve and protect residents.

Furthermore, this bill would transfer public property to private companies with no public obligation. S. 3157 restricts the rental rates cities can charge for use of public property such as the right-of-way and municipally owned poles, in direct violation of the 5th and 10th Amendments of the U.S. Constitution while also limiting rental rates to "actual and direct costs" which also violates the gift prohibition of many state constitutions. This forces taxpayers to subsidize private, commercial development, without any corresponding obligation on providers to serve communities in need or contribute to closing the digital divide in those markets.

This bill can have lasting damaging impacts on the character of each individual city, while simultaneously creating an undue burden on taxpayers to subsidize the irresponsible deployment of wireless infrastructure for private corpor at ions. S. 3157 should be rejected and wireless providers should be instead encouraged to work in collaboration with their local government partners to deploy this critical infrastructure.

For these reasons, the League of California Cities is *OPPOSED to S. 3157 (Thune & Schatz).* If you have any questions or need any additional information, please contact me or the League's Washington advocate, Leslie Pollner (*leslie.pollner @hklaw.com*) at 202.469.5149.

Sincerely,

CAROLYN COLEMAN,
Executive Director.

cc: California Congressional Delegation

LEAGUE OF MINNESOTA CITIES
St. Paul, MN, July 11, 2018

Hon. AMY KLOBUCHAR,
United States Senate,
Washington, DC.

Dear Senator Klobuchar,

The League of Minnesota Cities (LMC) respectfully requests you to oppose S. 3157 (Thune & Schatz), a bill referred to as the "Streamlining The Rapid Evolution And Modernization of Leading-edge Infrastructure Necessary to Enhance" (STREAMLINE) Small Cell Deployment Act.

Simply stated, this bill is a direct attack on local decision-making authority. S. 3157 would give the Federal Communications Commission (FCC) unfair power over local officials and Minnesota communities and would *not* grandfather in Minnesota's Right-of-Way Management (ROW) law that includes small cell wireless deployment provisions. Significant changes were enacted to Minnesota's ROW law following the 2017 legislative session. This followed intense and lengthy negotiations between LMC, other local government associations, wireless carriers, and cable providers. Dozens of cities have implemented or updated their ROW ordinances in accordance with the new law. Wireless providers and local governments are collaboratively working to deploy small cell wireless technology within the confines of statute, which has been confirmed by wireless industry representatives during a hearing this past legislative session and through informal conversations. Minnesota cities would be stifled by additional layers of preemptive legislation that would give the FCC jurisdiction over all public facilities in public rights-of-way.

The bill, like recent rulemaking by the FCC, inhibits local decision-making by changing current Federal requirements for small cell siting by carving out a new category with new requirements, separate from existing wireless siting law. While the FCC's statutory authority to take these actions is debatable and could potentially be challenged in court, congressional action to limit local authority would be permanently damaging. New parameters in the bill eliminate the flexibility for cities to deny an application based on the general health, safety, and welfare of citi-

zens. Protecting the health, safety, and welfare of the public is a core function of city government and the ability to do so must be preserved.

Attached to this letter is a table providing a comparison between the bill and Minn. Stat. § 237.162–163, Minnesota's telecommunications ROW law. We anticipate that the Senate Commerce Committee will hear this legislation this month. On behalf of our 833 member cities, we ask you to oppose S. 3157. Please contact Laura Ziegler at *lziegler@lmc.org* or 651–281–1267 with any questions you may have.

Thank you for the work that you do on behalf of all Minnesotans.

Sincerely,

HEIDI OMERZA,
President,
League of Minnesota Cities.

CC: Senator Tina Smith
Representative Timothy Walz
Representative Jason Lewis
Representative Erik Paulsen
Representative Betty McCollum
Representative Keith Ellison
Representative Tom Emmer
Representative Collin Peterson
Representative Rick Nolan

Comparison Between ''STREAMLINE'' Act and Minnesota State Right-of-Way Law

Issue	S. 3157	Effect on MN Law
Wireless siting in the public rights-of-way	It would limit local consideration of "small personal wireless facilities" to "objective and reasonable" "structural engineering standards based on generally applicable codes; safety requirements; or aesthetic or concealment requirements."	Eliminates the flexibility for cities to deny an application based on the general health, safety, and welfare of citizens.
"Shot clock"/Time for local government to issue a decision	Modification of the application shot clock to 60 days for collocations, and 90 days for new sites.	Shortens time frame for decisions on applications for collocations from 90 days to 60 days. No impact on request for new wireless support structure decision.
Notice of incomplete application	Cities are allowed ten days to notify applicants in writing if their application is incomplete.	Shortens time frame from 30 days to ten days.
Special shot clock carveouts for small cities, defined as fewer than 50,000 residents	• 90 days for collocations if the provider has filed 50 or fewer applications in a 30-day period, or 120 days if the provider has filed more than 50 applications in 30 days • 120 days for new sites if the provider has filed 50 or fewer applications in a 30-day period, or 150 days if the provider has filed more than 50 applications in 30 days	This is new and would differ from state law, as described under the "shot clock" issue.
Moratoria prohibition	Prohibits moratoria/tolling to lengthen these shot clocks.	Same as state law.
One-time local government waiver	Allows local governments to request a one-time 30-day waiver from the FCC.	This is new. No comparable language in state law.

Comparison Between ''STREAMLINE'' Act and Minnesota State Right-of-Way Law—Continued

Issue	S. 3157	Effect on MN Law
Automatic approval	Includes a deemed granted provision for applications not acted upon by the local government in the stated period.	Same as state law, but has a shorter time frame to act under Federal regulations.
Fees—application, management, rent	Limits "fees," which the bill defines as "a fee to consider an application for the placement, construction, or modification of a small personal wireless facility, or to use a right-of-way or a facility in a right-of-way owned or managed by the State or local government for the placement, construction, or modification of a small personal wireless facility." This would include not only application fees, but also recurring rents for usage of public property.	This would be a massive financial hit to cities to combine one fee for all, and could result in a subsidy for the wireless industry by cities. MN state law allows cities to require telecommunications ROW users to get a permit for use of the ROW; however, it creates a separate permitting structure for the siting of small wireless facilities. Cities can recover their ROW management costs and charge rent for attaching small cell facilities to city-owned structures in the public rights-of-way. Rent is capped for collocation of small wireless facilities.
Rent	Fees must be "competitively neutral, technology neutral, and nondiscriminatory; publicly disclosed; and based on actual and direct costs."	Conflicts with MN law as outlined above.
Definitions	The bill also defines "small personally wireless service facility," limits it to "a personal wireless service facility in which each antenna is not more than 3 cubic feet in volume; and does not include a wireline backhaul facility."	This is new. A "small wireless facility" is defined as "each antenna is located inside an enclosure of no more than six cubic feet in volume or, in the case of an antenna that has exposed elements, the antenna and all its exposed elements could fit within an enclosure of no more than six cubic feet; and all other wireless equipment associated with the small wireless facility, excluding electric meters, concealment elements, telecommunications demarcation boxes, battery backup power systems, grounding equipment, power transfer switches, cutoff switches, cable, conduit, vertical cable runs for the connection of power and other services, and any equipment concealed from public view within or behind an existing structure or concealment, is in aggregate no more than 28 cubic feet in volume."
Tribal land	Orders a GAO study on broadband deployment on tribal land	This is also new, but it was an issue tabled by the Broadband Deployment Advisory Committee, referred to as BDAC, early on.

NEW YORK STATE CONFERENCE OF MAYORS
Albany, NY, July 13, 2018

Hon. CHARLES E. SCHUMER,
U.S. Senate,
Washington, DC.

Dear Senator Schumer:

On behalf of the cities and villages comprising the membership of the New York State Conference of Mayors, I write to express our strong opposition to the Streamlining the Rapid Evolution and Modernization of Leading-edge Infrastructure Necessary to Enhance (STREAMLINE) Small Cell Deployment Act (S. 3157). This legislation would severely restrict local governments' authority to regulate wireless facilities, grant wireless service providers unfettered rights of access to the municipal right-of-way (ROW) and mandate specific application procedures for wireless facilities installed in the ROW. While NYCOM supports universal high-speed Internet access for all, the means by which this legislation mandates the installation of wireless facilities and eliminates the ability of local governments to obtain a fair return for wireless equipment installed on taxpayer property is fatally flawed and not in the public interest.

During 2018–2019 state budget negotiations, the wireless industry pursued a similar proposal here in New York that attempted to achieve many of the elements present in this bill. The industry's effort was met with overwhelming opposition from New York's municipalities dedicated to protecting the safety and welfare of New Yorkers and guarding against the misappropriation of taxpayer property. Local governments across New York State support the proliferation of broadband technology, especially in our underserved and rural communities. However, achieving meaningful Internet access throughout the state will not be advanced by this legislation.

Maintaining the public ROW is an essential function of local governments and their capacity to protect the public's health, safety, and welfare and preserve the character of communities. The standard provided in this bill would fundamentally impinge on the ability and responsibility of local governments to make well reasoned decisions in the best interest of their residents. Specifically, this bill would usurp local government authority to address particularized public safety and aesthetic concerns related to the installment of such facilities by limiting the factors that a municipality may include when reviewing a wireless application, and reducing the amount of time a local government has to consider an application. Furthermore, under this legislation, the failure to issue a determination on an application would result in the application's automatic approval.

This legislation also seeks to limit how much a municipality may charge a wireless provider when renting space on municipally owned structures. Compelling local governments to charge below-market rates for the use of public structures will foster the already inequitable deployment of broadband technologies. Additionally, limiting the fees that municipalities may charge a wireless applicant to the direct and actual costs of the installation will eliminate the ability of local governments to receive fair compensation for the use and maintenance of public property.

Again, achieving broadband ubiquity is an important and necessary goal for all municipalities in New York State and across the country. However, forcing local governments to abdicate their authority to protect and maintain public rights-of-way and preventing cities and villages from receiving a fair return for rented space on municipally owned infrastructure is simply untenable. For the aforementioned reasons, NYCOM vigorously opposes this legislation and urges you to reject this proposal.

Sincerely,

PETER A. BAYNES,
Executive Director.

FLORIDA MUNICIPAL ELECTRIC ASSOCIATION
Tallahassee, FL, July 16, 2018

Hon. BILL NELSON,
United States Senate,
Washington, DC.

Dear Senator Nelson:

Re: Concerns with S. 3157, the STREAMLINE Small Cell Deployment Act

On behalf of the 34 community-owned, public power utilities in Florida, I am writing to express our serious concerns with a new legislative proposal , S. 3157, the STREAMLINE Small Cell Deployment Act. The bill is currently under consideration in the Commerce, Science, and Transportation Committee, and we understand that the Committee may hold a hearing on this bill soon.

The bill in question, S. 3157, ostensibly is aimed at ushering in the next generation of wireless technology, including encouraging widespread broadband deployment. We support that effort, but not at the expense of state and locally owned electric utilities. The Communications Act of 1934, still the standard for today's telecommunications industry, is quite clear—Section 224 explicitly exempts public power utilities from Federal Communications Commission (FCC) pole attachment regulations. That section exempts municipally owned and rural electric cooperative utilities from pole attachment regulation because these entities are already subject to "a decision-making process based upon constituent needs and interests." Indeed, Congress has consistently upheld this long-standing tradition.

But this legislative proposal puts the municipal exemption in jeopardy. Specifically, the bill would change section 332 of the Communications Act, which currently gives the FCC jurisdiction over mobile telecommunications services and gives nondiscriminatory access to state and local rights of way. S. 3157 would revise section 332 to require mandatory access to attachments to a "facility in a right of way owned or managed by a State or local government." The bill would also allow the state or locality to charge fees for the "placement, construction, or modification" of a small wireless facility that is "in accordance with section 224."

Because utility pole attachments are the *only type* of facility covered under section 224, and because public power utility poles are the *only types* of poles "owned or managed by a State or local government" in the public right of way, this decision would give the FCC jurisdiction over all public power pole attachment decisions. All told, these provisions would effectively repeal the public power exemption from FCC regulation.

The bill would also create conflicts among several provisions of the Communications Act, may run afoul of state constitutional provisions that prohibit political subdivisions from subsidizing private enterprise, and would create a one-size-fits-all approach to pole attachment decisions. Further, we have legitimate concerns about reliability, liability, and safety—critical issues when dealing with our public infrastructure. Safety is of utmost concern to us in Florida, especially given our susceptibility to hurricanes.

As you know, Florida tackled this issue just last year. The Florida Legislature developed new law in this area (HB 687) when it passed the Advanced Wireless Infrastructure Deployment Act, which addresses broadband infrastructure in the public rights of way and provides local governments with an application timeframe. Critical to Florida's public power community, the Act exempts municipal electric utilities, *as well as ALL electric utilities,* from the new law. Perhaps this Florida model can be utilized in future Commerce Committee discussions.

We appreciate your continued support of Florida' s public power communities and look forward to working with you on this important issue. Please contact me at (850) 224–3314, ext. 1, or *azubaly@publicpower.com* if you have any questions.

Sincerely,

AMY ZUBALY,
Executive Director.

CITY OF TACOMA
Tacoma, WA, July 17, 2018

Hon. MARIA CANTWELL,
United States Senate,
Washington, DC.

Dear Senator Cantwell:

On behalf of the City of Tacoma, including the City's General Government and Tacoma Public Utilities, we write to express our concerns regarding S. 3157, the "Streamlining the Rapid Evolution and Modernization of Leading-Edge Infrastructure Necessary to Enhance Small Cell Deployment Act," and respectfully request you oppose the legislation. Based on our experience and recent effo1is undertaken across the City of Tacoma, we believe this legislation would undercut the authority and responsibility of local government to manage and protect property in the responsive way our citizens expect.

As you know, under current Federal law, municipal pole attachments and rights of way are already regulated at the state or local level. Local governments and their consumer-owned utilities charge fees and administer regulations responsive to the public interest and in accordance with state laws.

In the City of Tacoma, we have worked with telecommunications providers to provide access to publicly-owned infrastructure and rights of way in ways that make sense for our community. More recently, we collaborated with telecommunications providers on revisions to our fee structure and land use regulations to accommodate new technologies, including small cell attachments. Those new fees and municipal code revisions were enacted in 2018 following extensive stakeholder outreach and public processes.

If enacted, S. 3157 would amend that effective policy model and cede significant control of locally-owned assets to the policies of the Federal Communications Commission. There are many troubling provisions in the legislation, including:

- S. 3157 would ove1iurn the exemption for municipal utility poles, light poles, traffic signals or other state or local government facilities from FCC oversight—this exemption has been in place for decades.
- S. 3157 gives the FCC jurisdiction over the "right-of-way" or facilities "in the right-of-way owned or managed by the State or local government."
- S. 3157 sets the stage for our taxpayers and utility customers to subsidize for-profit telecommunications operations by setting all fees at a rate "calculated in accordance with section 224" for attachments to a "pole, in a right-of-way, or on any other facility that may be established under that section."
- S. 3157 restricts right-of-way and municipal pole attachment compensation under both Secs. 332 & 253 to direct costs, in direct violation of the 5th and 10th Amendments.
- Municipal governments and their consumer-owned utilities would lose their ability to allow a use or not on publicly-owned facilities or in rights of way. The legislation provides a hollow, ambiguous exemption for engineering, safety, and aesthetic issues, but it would only allow utilities to challenge the "placement, construction, and modification" of the small cell devices.
- Sets strict application timeframes and applies burdensome "deemed-granted" requirements on pole attachment applications. Namely the legislation would shorten existing FCC shot clocks (new towers, from 150 days to 90 days, and collocations: from 90 days to 60 days). Failure to meet either deadline results in a deemed granted penalty.

The City of Tacoma has worked collaboratively to bring new technologies into our community for many years. Nationally there is not a record showing that communications companies are prohibited or unduly burdened when seeking to attach their wires and devices to municipally owned poles or in the municipal right-of-way. Based on our experience, S. 3157 does not solve any problems and disenfranchises local residents from decisions about the use of community assets that have been financed through their tax dollars or utility bills. For these reasons, we urge your opposition to S. 3157.

Thank you for considering our input on this. Should you have any questions or would like to discuss these issues in greater detail, please contact Alisa O' Hanlon at 253–591–5310 or Clark Mather at 253–441–4159.

Sincerely,

VICTORIA WOODARDS,
Mayor of Tacoma.

WOODROW E. JONES,
Chair, Public Utility Board.

c: Narda Jones, Office of Senator Maria Cantwell
Megan Thompson, Office of Senator Cantwell
Rosa McLeod, Office of Senator Maria Cantwell

CITY OF RYE
Rye, NY, July 20, 2018

By U.S. Mail and E-mail
Senator CHUCK SCHUMER,
U.S. Senate,
Washington, DC.

Ms. Beatrice Pollard

beatrice_pollard@schumer.senate.gov

Dear Senator:

The City of Rye, NY ("Rye") respectfully requests that you oppose S. 3157, the so-called "Streamlining The Rapid Evolution and Modernization of . . . Small Cell Deployment Act", a bill which was to be the subject of a Senate Committee on Science, Commerce and Transportation hearing on July 25, but now awaits later action. S. 3157 (the "Bill") would virtually eliminate state and local regulatory jurisdiction over small cell siting in our rights of way and deprive local governments of the right to charge reasonable fees for access to local rights of way, something to which municipalities have been entitled for generations. The wireless industry seeks, by Federal legislative action, to convert public assets for private gain without paying reasonable compensation.

Please note at the outset, the word "small" in the term "small cell" simply refers to the area served, not the size of the equipment. A small cell may not be seen as small when installed next to a typical house or business, especially in a suburban or rural setting. This issue of scale is compounded by already existing Federal regulations (under the "Spectrum Act") that permit aggregations of small cells in a single location ("collocation") without meaningful municipal review once an initial small cell installation has been pem1itted in that location. (Under 47 PCR l.14001, a small cell site can grow beyond that originally municipally approved by an additional 10 feet in height and an additional six feet on each side without new municipal approval.)

Rye has direct experience with the wireless industry's attempts to deny municipalities even the most minimal regulatory oversight over siting of telecommunications small cell infrastructure. Rye is presently being sued by Crown Castle, infrastructure builder for Verizon Wireless. That litigation has been brought in an attempt to deny Rye any meaningful review over Crown Castle's proposed siting of almost 70 so called "DAS nodes" throughout our City. Rye, like municipalities everywhere, should be able to review proposed installations to protect aesthetic resources, community character and neighborhood quiet (from noise emitting equipment), as well as to prevent damage to property values.

The New York State Legislature this past session rejected industry-sponsored legislation similar to the Bill that would have significantly impaired municipal jurisdiction, making clear that the New York position is that municipal jurisdiction over small cell siting and franchise fees is to be protected.

The Bill would impair important state and local rights that have long been protected under the Telecommunications Act and would make the FCC, not the Federal Courts, the arbiter of disputes between wireless providers and local governments.

The Bill would federalize jurisdiction over both small cell siting and franchise fees, giving an FCC that is hostile to local control the ability to pass regulations that would make local jurisdiction irrelevant. The Bill would impose unrealistic and arbitrary Federal deadlines on any surviving municipal review authority.

The Bill's limitation on franchise fees would end an important source of local revenue. This deprivation of revenue would be especially damaging in New York

against the backdrop of the harm already caused by the SALT deductibility limitation now in the Internal Revenue Code.

The City of Rye urges your consideration of the following propositions responsive to typical wireless industry rationales for legislation of the Bill's type:

—The purpose of the present wave of small cell installations is to surround customers with sufficiently strong 4G LTE (present technology) transmitters to make wireless a more effective competitor with cable and fiber to the home providers—to encourage cord cutting and *ultimately place all data access in the hands of the wireless industry.*

—The purpose is not installation of next generation, mobile 5G equipment: 5G is in its infancy, its equipment is developmental (and may well be different in positive respects from existing small cell equipment) and 5G, in its likely long introductory years, will not be in a form suitable for mobile use.

—The purpose is not to bring broadband to underserved rural areas: small cells are efficient only where there are sufficient concentrations of customers to make short range equipment effective, in other words, in towns and cities.

—The purpose is not to bring the best communications technology forward: the potential transmission capability of fiber optic cable is far beyond the capability of wireless devices—wireless devices are a limiting factor in data transmission and wired fiber optic connections should continue to have an important role, assuming fiber optic providers survive wireless industry assault.

—The recent end of net neutrality makes it ever more important that the Federal Government not facilitate oligopolistic control of data transmission by the wireless industry.

The City of Rye is hopeful that you will strongly and effectively oppose S. 3159. We are grateful for your efforts.

Sincerely,

JOSH COHN,
Mayor.

August 6, 2018

Chairman JOHN THUNE,
Senate Commerce Committee,
Washington, DC.

Ranking Member BILL NELSON,
Senate Commerce Committee,
Washington, DC.

Dear Chairman Thune and Ranking Member Nelson:

As mayors from across the country, we write to express our deep concerns about *S. 3157, The STREAMLINE Small Cell Deployment Act,* which restricts traditionally-held local authority and will complicate, rather than simplify, national efforts to expedite infrastructure deployment. While we share Congress's goal of ensuring efficient, safe, and appropriate deployment of new broadband technology, this legislation is deeply problematic and will not achieve this goal. First, the legislation enables the Federal Government to essentially "take" broad swaths of land owned or controlled by local governments. Second, there is no one-size-fits-all solution for states and cities. Differing jurisdictions have different public safety and infrastructure interests that will be negatively impacted. Moreover, local governments should have the time and flexibility to ensure that small cell wireless infrastructure is deployed, not just quickly, but safely and correctly in our communities.

Cities across the country are working toward faster technology to improve our residents' lives. A Federal one-size-fits-all mandate will thwart efforts already underway to implement balanced regulations. By preempting local authority, S. 3157 will create inefficiency, confusion and further delays. Furthermore, cities have traditionally negotiated with providers on issues such as the location, appearance and size of wireless infrastructure. This bill severely limits the ability of cities to ensure that infrastructure suits the neighborhood around it, and that its own critical infrastructure is not compromised in any way

S. 3157 also requires mandatory access for attachments to a facility in a right-of-way owned or managed by the state or a local government. And it severely restricts the rental rates cities can charge for the wireless industry's use of public property, such as the right-of-way and municipally-owned poles. Consequently, S. 3157 forces taxpayers to subsidize private, commercial development without any corresponding obligation on providers to serve communities in need or contribute to closing the digital divide. By failing to distinguish between locations on private property (where local government responsibility is limited to land use review of deci-

sions made by private land owners) and locations on streets, sidewalks and other public property (where local governments are also the land owner), S. 3157 is unrealistic and unenforceable. Furthermore, limiting rental rates to "actual and direct costs" violates the gift prohibition of many state constitutions.

Finally, the bill imposes unreasonable "shot clocks" for small cell infrastructure, which are considerably shorter than those the Federal Government even applied to itself in the bipartisan MOBILE NOW Act. A small cell's reduced size per installation, compared to a traditional cell tower, does not translate to a reduced procedural burden on local governments. Cities must still review each site individually to ensure that it meets the jurisdiction's requirements. Further, the bill's limited extension of time for small jurisdictions and bulk applications does not address resource challenges for states and localities. These harsh timelines will limit the resources cities have for other public priorities, such as road maintenance and public safety. It also allows the Federal Government to dictate what roads and rights-of-way can be forced into construction and when the projects occur.

S. 3157 attempts to make progress on deploying faster wireless technology in urban and rural areas, but the legislation is deeply flawed. Our cities are equally interested in having faster technology to improve our communities, but Congress must work with input from states and local governments to create better solutions.

For these reasons, we oppose the bill in its current form and urge you to revise the legislation to ensure that faster wireless technology can be effectively deployed across the country.

Sincerely,

The Honorable Jenny Durkan
Mayor of Seattle, WA

The Honorable John Giles
Mayor of Mesa, AZ

The Honorable Eric Garcetti
Mayor of Los Angeles, CA

The Honorable Michael B. Hancock
Mayor of Denver, CO

The Honorable Miguel Pulido
Mayor of Santa Ana, CA

The Honorable Buddy Dyer
Mayor of Orlando, FL

The Honorable Jim Kenney
Mayor of Philadelphia, PA

The Honorable James Brainard
Mayor of Carmel, IN

The Honorable Pauline Russo Cutter
Mayor of San Leandro, CA

The Honorable Paul Soglin
Mayor of Madison, WI

The Honorable Keisha Lance Bottoms
Mayor of Atlanta, GA

The Honorable Greg Fischer
Mayor of Louisville, KY

The Honorable Victoria Woodards
Mayor of Tacoma, WA

The Honorable Bill de Blasio
Mayor of New York, NY

The Honorable Lucy Vinis
Mayor of Eugene, OR

The Honorable Lyda Krewson
City of St. Louis, MO

The Honorable Ted Wheeler
Mayor of Portland, OR

The Honorable London Breed
Mayor of San Francisco, CA

The Honorable Andrew Ginther
Mayor of Columbus, OH

The Honorable Sam Liccardo
Mayor of San Jose, CA

The Honorable Ethan Berkowitz
Mayor of Anchorage, AK

The Honorable Rahm Emanuel
Mayor of Chicago, IL

The Honorable Lily Mei
Mayor of Fremont, CA

The Honorable Tom Barrett
Mayor of Milwaukee, WI

Senator NELSON. And, Mr. Chairman, if I may, I'd like to yield my time, when you get to me, to Senator Schatz, and he'll take over.

The CHAIRMAN. OK, very good. Thank you, Senator Nelson.

Thank you all for your testimony. Let's get into a few questions here.

Ms. Baker, a number of parties have proposed a private-sector approach to clearing spectrum in the 3.7 to 4.2 gigahertz band, saying that such an approach would avoid the extensive delays that are associated with legal challenges and auction preparation. Apart

from the foregone auction revenue for the Federal Government, which is an important consideration, are we correct to see the tradeoff of such an approach as one between maximizing the amount of spectrum made available for terrestrial 5G use and the speed with which that spectrum can be put into service?

Ms. BAKER. So, thank you for your question.

The C-band, which is the 3.7 band that you're talking about, is a very important band because of its international harmonization. Mid-band is critical for 5G. And I'll reiterate that this is a race, and we're third because we are sixth in mid-band spectrum allocation. China has allocated 100 megahertz to each one of their carriers. South Korea just had a great big auction of mid-band. Mid-band, mid-band, mid-band, it's really important whether it's 3–4–5, 3–5, or 3–7. But, C-band is critical to this. You, in MOBILE NOW, told the FCC to study it. The FCC is studying it. I urge action. This is a race. We need action for it. We have a track record of being good partners when we move incumbents. There are some important incumbents there. I think—Senator Nelson mentioned government incumbents—I think some people would consider ESPN mission-critical. We need to move them, but we need to move them—we have a good track record of doing that. So, we want to be good partners. We need to come up with a plan, and execute on it rapidly.

The CHAIRMAN. OK. Do you see other bands where a private-sector-led approach to spectrum clearing could be used, essentially granting property rights to incumbents in order to avoid a more drawn-out process?

Ms. BAKER. I think there are some critical government bands, and I think there are some critical—there are probably some other civilian uses, too. I think some of the ones that you were looking at, that I think we are all looking at, in addition to the ones that I named, are also low-band spectrum. Low-band has always been critical, particularly to rural areas. If we're going to bring more broadband to rural areas, low-band spectrum travels further. I think there are some terrific win-win situations we can look at.

The CHAIRMAN. OK.

Mr. Cowden, and speaking of rural areas, you mentioned, in your opening statement, that Charter seeks to provide ubiquitous connectivity to all of your customers, including those in rural communities. What spectrum resources are most important to providing mobile wireless in rural areas?

Mr. COWDEN. Thank you for the question, Senator.

So, we have been doing extensive testing, over the last 12 months, with the 3.5 CBRS band, specific—really, two different use cases. One as a mobility small cell. That's not what I'm talking about for rural broadband. For rural broadband, a separate-use case using the same frequency spectrum in seven different markets around the country selected for their varying climate characteristics and foliage characteristics so that we can really test the consistency of using CBRS for rural broadband. We are very pleased with the results. We believe we can effectively offer cost-effective rural broadband at a minimum speed of 25-by-3 at the cell edge, meaning it would only be better within closer proximity to the cell base station. And so, we're bullish on that.

We also look at 5 gigahertz as a capacity layer for rural broadband as an effective solution. And, to the point that was just made about lower C-band, we are interested in lower C-band. We have concerns about the reallocation process. But, as the comments have been made, it is a very effective band for both coverage and capacity for 5G. And, to the extent that became available, we would certainly look to use that for rural broadband serviceability, as well.

The CHAIRMAN. Yes.

Mr. Stroup, you mentioned the role satellite broadband-compliant precision agriculture beyond the role already played by satellite positioning technology. Could you describe the industry's efforts in that regard?

Mr. STROUP. Thank you, Senator.

Precision agriculture starts with GPS. So, certainly the capabilities of the satellite industry are crucial to being able to provide precision agriculture. In addition, satellites provide weather information and Earth imaging information for precision agriculture.

In conjunction with developments in flat-screen antenna, which allows the ability to connect virtually every tractor, combine, et cetera, and the broadband capabilities that the industry is deploying, we have the ability to provide ubiquitous coverage. And ubiquitous coverage is one of the great advantages that the satellite industry provides. Certainly, having been in rural areas like yours, having participated in a wedding in Isabel, South Dakota—or just outside of Isabel, South Dakota—I know that it's highly unlikely that we're going to see the small cells deployed to be able to provide coverage for precision agriculture without utilization of satellite systems.

The CHAIRMAN. Thanks.

My time is expired.

Senator Schatz.

STATEMENT OF HON. BRIAN SCHATZ,
U.S. SENATOR FROM HAWAII

Senator SCHATZ. Thank you, Mr. Chairman.

Mr. Cowden, licensed spectrum gets a lot of attention, but unlicensed spectrum is another critical input for access to the Internet. And, as you know, demand is growing. Can you talk about the importance of unlicensed spectrum for broadband access and 5G deployment?

Mr. COWDEN. Thank you for the question, Senator.

It is—unlicensed spectrum is extremely important to us. The way we think about spectrum policy, we want it to be technology-neutral, in terms of treating both wireline and wireless policy initiatives fairly. And then, separately, we want a balance of both unlicensed and licensed spectrum. We use Wi-Fi in a significant way today. It's part of our Wi-Fi First MVNO, but we also support 280 million wireless devices on Wi-Fi today. The concern with Wi-Fi is that we are approaching exhaust. 2.4—the 2.4 band of Wi-Fi is already saturated, and the 5 gigahertz band that we currently have is approaching exhaust. It's one of the reasons——

Senator SCHATZ. So, the——

Mr. COWDEN.—we're advocating for additional spectrum right adjacent to the upper band of 5 gigahertz, the 5.9 band. And we are also interested in exploring the 6 gigahertz band for long-term increased unlicensed capacity —again, keeping in mind that we have to manage the—any potential interference in reallocation issues in that band.

Senator SCHATZ. So, the Wi-Fi Alliance is saying we need about a—1 gigahertz more of new unlicensed spectrum by 2025. I guess what you're saying is, if we open up the 5.9 gigahertz band and do a couple of other things, we can meet the demand. If we don't, we won't?

Mr. COWDEN. That's exactly correct, Senator. I would say the 5.9 bands, just to be clear, we're talking about maximum of 75 megahertz, so less than a tenth of the overall projection of the overall Wi-Fi capacity that we need, from the study that you're referencing. We certainly need to look at the 6 gigahertz band, or other bands, for additional unlicensed capacity.

Senator SCHATZ. And can you talk to me a little bit more about the CBRS band and the tests—the tests that you've done and the, I guess, encouraging information that you've gotten back? It's a little bit counterintuitive, because I think we still believe that, as it relates to 5G deployment, the economics are not going to necessarily be there for rural areas. What's different about your tech or your approach that makes this not pie in the sky?

Mr. COWDEN. I can only comment on the actual testing that we've done and the results we've concluded from those tests. Let me talk about both use cases.

We've done pervasive CBRS testing as a small cell mobility layer, so literally attaching to our cable strand in more urban areas. We've done that in Tampa, Florida, and in Charlotte, North Carolina, and then we're about to do that in New York City and Los Angeles, and then also Denver, Colorado. That's a separate use case, more for mobility handoff.

For rural broadband, though, the essence of your question, we've gone to seven different markets, and we've used 3.5 CBRS, in conjunction with 5 gigahertz unlicensed capacity, so we use 5 gigahertz more of a capacity layer, because it doesn't have the same RF propagation characteristics of 3.5.

Senator SCHATZ. I don't know what that—what is that?

Mr. COWDEN. I'm sorry.

[Laughter.]

Mr. COWDEN. So, the distance, the——

Senator SCHATZ. I may be the only one in the room that doesn't know——

Mr. BRENNER. You don't know what RF propagation is?

[Laughter.]

Mr. COWDEN. I'm sorry. Radio frequency propagation.

Senator SCHATZ. Thank you, OK.

Mr. COWDEN. The distance that a signal can reach.

So, 5 gigahertz doesn't have the same distance characteristics that 3.5 does, but it is a good capacity layer, particularly in rural broadband, where you don't have a lot of congestion of unlicensed traffic. So, it's a useful solution. And then, 3.5 gigahertz CBRS, at maximum output power and at cell towers of 200 to 250 feet, we

can get to cell edges as far as 5 miles and offer 25-by-3 megabit service, minimum speed, at that cell edge. And then, it can—if you talk about C-band, you can certainly add more capacity.

Senator SCHATZ. So, this is sort of 5 miles from an urban area, right?

Mr. COWDEN. No. So, for rural broadband—it could be that, but, in our case, Charter has pervasive broadband infrastructure——

Senator SCHATZ. I got it.

Mr. COWDEN.—all over. And so, we leverage that infrastructure——

Senator SCHATZ. I got it.

Mr. COWDEN.—to build out.

Senator SCHATZ. Thank you.

Mr. Brenner, you're doing some interesting things, in terms of spectrum sharing. Can you talk a little bit about the importance of that? Is—and is it—I know it's important. I want to understand why. And I also want to understand whether there's a role for the legislative branch to play, or is this entirely a private-sector play?

Mr. BRENNER. Thanks so much for that question, Senator.

So, from the—in 4G, as I mentioned in my testimony, we originally developed 4G for licensed spectrum, and then, as unlicensed spectrum became so important, we basically revert—you know, we jerry-rigged 4G after-the-fact to add this unlicensed component, and the results have been tremendous. There were just speed tests that were—a million tests that were done around the world using our chips. And the increased speeds were 192 percent. So, for 4G, the use of licensed and unlicensed spectrum has been tremendous. So, for 5G, what we're doing is, from the beginning, from the ground up, we're saying, "OK, we're going to have the variant for licensed spectrum. What can we do for unlicensed spectrum?" So, there's a very exciting aspect to that, which is—the way unlicensed spectrum is used today, whether it's Wi-Fi or cellular, if the four of us were unlicensed transmitters, we would each transmit one-fourth of the time, and we would each have to be quiet three-fourths of the time, when everyone in—when the one person was transmitting. What we're developing for 5G is the ability—because with 5G, we have this very, very fast new radio, and we have many, many antennas that have very thin beams. So, what we can do is, if the four of us are each going in different directions, and——

Senator SCHATZ. You can direct traffic, yes.

Mr. BRENNER.—and we can each talk to one another and sense where the other is going, we can all transmit at the same time.

Senator SCHATZ. My time is up. I'm going to take the rest through the record, because I—now I understand a little bit better the technical aspect. I do want to understand whether there's anything for the legislative branch to do, other than stay out of the way.

Thank you.

[Laughter.]

Mr. BRENNER. Thank you.

The CHAIRMAN. Thank you, Senator Schatz.

Senator Fischer.

STATEMENT OF HON. DEB FISCHER,
U.S. SENATOR FROM NEBRASKA

Senator FISCHER. Thank you, Mr. Chairman.

The DIGIT Act, which is bipartisan legislation on the Internet of Things, has passed the Senate, and I hope it's going to be enacted soon.

Ms. Baker, you noted a number of sectors impacted by the growth of IoT, and that's agriculture, manufacturing, retail, healthcare, energy, transportation. And, given the many Federal agencies to be affected by IoT, do you think that the public/private collaboration enabled by the DIGIT Act would help prevent barriers to IoT advancement, such as regulatory silos or overlap or, as Senator Schatz said, you know, keeping government out of the way?

Ms. BAKER. We appreciate your leadership on DIGIT Act, and we do think that the alphabet soup of Washington could prove to be some sort of—could prove a regulatory barrier to some of the Internet of Things. So, we think it's a good idea to bring all of the things that the Internet of Things, and all the money that it's going to save, and the conservation it's going to bring, and—I'm, personally, so excited about precision agriculture, and, you know, transportation is really big one for me, because I'm in the car all the time. I think, you know, it's 21,000 lives saved, but it's, you know, $450 billion a year. It—these numbers are huge, so—we're really going to be transformed. So, we appreciate your leadership on DIGIT.

We're also very focused on making sure we have the platform for the Internet of Things to unroll. And so, we are also very supportive, again, of AIRWAVES and STREAMLINE, so we can build the platform so that the real Internet of Things can evolve.

Senator FISCHER. Thank you for mentioning precision agriculture. About a month ago, I had the opportunity to go to a community college in northeast Nebraska. They have a program there with precision agriculture. As I'm sure you're aware, agriculture is the third-largest user of the Internet of Things, and that's only going to grow once we're able to deploy broadband, especially in rural areas.

In order for the IoT solutions to reach that full potential, though, I think we have to ensure that there is enough spectrum that's going to be available to deploy those 5G networks. And that's—is emphasized in the DIGIT Act. We have Senator Gardner, Senator Schatz, here, who are also involved with that. What further policies can we promote to make sure that there is enough spectrum to meet the growing demand that we see with the Internet of Things? If you would——

Ms. BAKER. OK, I'll go first, and everybody can—after.

Certainly, we appreciate the leadership of AIRWAVES. We think that's critically important. We need to have a schedule so that our $275 billion that our carriers are going to invest, that they know when and what that spectrum is going to be, and when it's going to be auctioned. That's really critical.

It's also—it's—there are two things. The other is streamlining. You know, as China rolls forward with millions of sites, we're going to need to do the same thing. We've had 150,000 sites that we've put up in the last 30 years of this industry. In the next few years,

we're going to have to roll out 800,000. That's a lot. So, we think that the Federal Government needs to put some guardrails, like they did in 1993, as to, kind of, where and how we site these. We think that STREAMLINE has stricken a very good balance—stricken?—has struck a very good balanced act on the localities and giving the operators some opportunity to site really small cells faster.

Senator FISCHER. OK, thank you.

Mr. Stroup, what can Congress do to ensure that conditions exist that encourage rural 5G networks so that our farmers and ranchers can benefit from that advanced technology?

Mr. STROUP. Thank you for the question, Senator.

I think that the most important thing is ensuring that there is sufficient spectrum from growth in the satellite industry. As I noted before, in rural areas, it's hard to envision that there are going to be the small cells without connecting via satellite. And the other is to ensure that there is technology neutrality in policies that are adopted so that one industry is not advantaged over the other. So, I think that those are the two primary areas I would recommend.

Senator FISCHER. Thank you.

Mr. Cowden, healthcare innovations such as remote monitoring and virtual access to specialists present, I think, exciting benefits, in rural areas especially. And 5G is needed to support it. What are the most important policy changes that we can make so that we can encourage those telehealth solutions for our seniors and for those who are living in rural areas?

Mr. COWDEN. So, I'm more of the engineer than the regulatory policy expert. However, I would say——

Senator FISCHER. Mr. Brenner's going to whisper in your ear.

Mr. BRENNER. I'm going to help, yes.

[Laughter.]

Mr. BRENNER. This is one of my favorite areas.

Senator FISCHER. You can answer, as well.

Mr. BRENNER. Great.

Mr. COWDEN. But, I would say that we are focused on technology-neutral solutions, particularly between wireless and wireline, so that one doesn't get advantaged over the other—we have somewhat of a concern there—and that we continue to focus on a balance of both unlicensed and licensed spectrum to promote competition and innovation. We feel like, if those policy frameworks, in general, are followed, a lot of innovation will occur. And, in general, that will support rural broadband and 5G in rural broadband.

One point I want to make about 5G. I think it's understood. 5G is a technology standard. It's not millimeter wave. I know 5G first rolled out in the millimeter wave space, and that's where the equipment currently exists. But, it's not exclusive to millimeter wave. And so, when we talk about 5G for rural broadband, it probably won't occur in millimeter wave, and not in a significant way, but it will likely occur in mid-band. Right? And so, that's where you can get the broadband speeds and the lower latencies that 5G can enable.

Senator FISCHER. Mr. Chairman, can the other witness answer?

Thank you.

Mr. BRENNER. Thank you so much, Senator, for the question.

The potential for—to both improve healthcare and dramatically reduce costs is gigantic with—happening today in 4G, and it's going to happen even more in 5G. The number-one policy issue to spur these technologies forward is actually not a spectrum issue all. It relates to CMS and reimbursement. So, what Qualcomm is doing is, we've worked with the AMA to create codes. I've learned a lot. I thought I was spectrum person, but I've learned a lot about healthcare reimbursement. So, we need CMS to fund codes that the AMA has created, which will allow doctors and hospitals and healthcare providers to get reimbursed when they use connected devices to engage in remote monitoring. That's step one. And that's happening today with 4G with things like glucometers and many different devices that have the 3G or even 4G connectivity.

But, for 5G, we have the potential to take this much, much further, with the ability to do everything wirelessly that we would do with a wire. So, that means we can have, actually, with ultra-low-latency, remote surgery, we can do monitoring of children with cerebral palsy for hip dislocation, remotely. So, there are many, many applications for 5G that we're very excited about in the healthcare area, but they really—it goes to dramatic change in the way the healthcare reimbursement system works.

So, thank you.

Senator FISCHER. Thank you. I'm excited to work with you on that with our rural hospitals so we can keep rural America vibrant and growing.

Thank you, sir.

Mr. BRENNER. You could see how eager I was to discuss it.

The CHAIRMAN. Yes. That affects many of us on this panel.

Thank you, Senator Fischer.

Senator Gardner.

STATEMENT OF HON. CORY GARDNER,
U.S. SENATOR FROM COLORADO

Senator GARDNER. Thank you, Mr. Chairman.

And thanks, to all the witnesses, for your time and testimony today.

Mr. Cowden, a special welcome to you to the Committee from the great state of Colorado.

I would just ask, Mr. Chairman—Mr. Cowden is probably going to have to leave in an hour and 10 minutes, as I am. Single-ticket Broncos tickets go on sale.

[Laughter.]

Senator GARDNER. Please excuse both of us as we do our Colorado duty.

The CHAIRMAN. That special dispensation will be allowed——

Senator GARDNER. Thank you.

The CHAIRMAN.—for that.

Senator GARDNER. Ms. Baker, thank you very much for your organization's strong support of the AIRWAVES Act. Senator Hassan and I introduced this bill last year. It's very crucial that we continue to have this life—this—the lifeline of spectrum, so to speak, this pipeline, in the future. And our work—our bill works to achieve just that, creating also an opportunity for investing billions

of dollars in rural broadband buildout. So, thank you very much for your support. Thanks to Senator Hassan's partnership and the support of my colleagues, including Senator Johnson, Senator Cortez Masto, Senator Young, and Senator Tester. Thanks for being on the bill.

Ms. Baker, the spectrum pipeline's going to be critical, as you laid out, to our competition in the future. Countries like China, preparing for frequencies, its help derail—to try to derail American leadership in wireless technology. Can you talk about opportunity costs if we were to fail in the 5G race, if we were to fall behind, lessons of the past—we talked a little bit about Japan—and what we learned from the 3G-to-5G race?

Ms. BAKER. Yes. Well, again, thank you, to all of you, for cosponsoring. This is very important, AIRWAVES Act. It's critical for our national policy, because it's not just wireless, it's everything else. It's the platform of which all the other exciting things in transportation and energy and education, healthcare. It's—platform of all that's going to happen.

If you look at what happened in Europe and Japan, who led in 2G and 3G, they lost their lead to us in 4G, and they really haven't recovered. And our 4G lead has meant, you know, billions of dollars to our economy, millions of jobs, but it's also meant that our companies—United States companies are the ones that are leading the world. Take Qualcomm. Because of 4G lead of the United States, Qualcomm is leader. China wants to steal that lead, and they want Chinese companies to be the leader, and Chinese companies to be selling to us. I think that we want that to be United States companies. And that's why your lead in your bill is so important.

Senator GARDNER. Just to give the Committee an idea. You know, roughly speaking, and define it how you will, what could the rural dividend mean?

Ms. BAKER. OK. So, the rural dividend is—I just want to shout from the mountaintops—it's a great idea as to how we're going to bring broadband to rural areas. It's 10 percent of any of the future auctions, which, if we had had it in place for the last two auctions, would have been $6 billion to build out rural. That means the future low-band auctions, that would be another $6 billion that we could build out rural broadband. The Mobility Fund is important, but we all know, for these rural areas, to really build them out is going to take money, and the rural broadband is a really significant, thoughtful way to go about solving that.

Senator GARDNER. Thank you, Ms. Baker.

Mr. Brenner, we've talked about U.S. participation in a number of world telecommunications forums, we've talked about ITU, World Radio Conferences, 3GPP standard make—— standard-making meetings. How important is it for the U.S. that we remain engaged in these forums, global harmonization? What does that mean for the success of wireless connectivity?

Mr. BRENNER. Oh, it's absolutely crucial that the Americans—that America lead in all—and participate heavily in all these bodies that you mentioned. Qualcomm is —devotes substantial resources to this 3GPP, which is the worldwide global standards body, which creates the standard that governs much of the way that 5G, 4G, 3G all works. And we're very proud of the efforts that

we make in 3GPP. But, the—our business is global. We're based in San Diego, but we have a global business. Everyone wants to work with us, and we want to work with everyone. But, much of what we do is driven by the standards. All the spectrum bands, the multiplicity of bands that I talked about in my testimony, those all go through 3GPP, they all go through a standards process, all these different combinations. So, the bodies you mentioned are crucial.

Senator GARDNER. Thank you, Mr. Brenner.

Mr. Cowden, in some hour and 5 minutes——

[Laughter.]

Senator GARDNER.—unlicensed spectrum is a critical component of any wireless solution. And companies, like Charter, will play a major role in helping to offload traffic from licensed services and helping to power access to Wi-Fi and other technologies. As an engineer, I know you're familiar with particular characteristics of certain spectrum bands. And you've mentioned a few of those in your testimony this morning. But, one of the bands you didn't mention was the 6 gigahertz band. I have to be careful I don't end up in a "Back to the Future" flux-capacitor moment in gigawatts kind of thing.

[Laughter.]

Senator GARDNER. The 6 gigahertz band, do you believe there is any potential for unlicensed services in the 6 gigahertz band?

Mr. COWDEN. Thank you for your question, Senator.

Yes, of course. We definitely look at the 6 gigahertz band as an important opportunity for unlicensed capacity. It is to be stated, we have—there are existing incumbent users in that band, and we have to carefully look at how they would be—how we'd address interference issues or reallocation issues. But, if you look at where our Wi-Fi capacity is today, there are essentially three bands. There's a 2.4 gigahertz band. It's completely saturated. And then we have two bands in the 5 gigahertz, a lower and an upper. So, we talked about 5.9 as the—you know, just north of that upper band for some immediate relief, although that's not nearly enough. And so, we would look for 6 gigahertz as the next logical band, right adjacent to that, for a full-gigahertz potential to grow unlicensed Wi-Fi service. It's critical that we look at solutions like that.

Senator GARDNER. Well, thank you. I'm glad to hear that, because—that focus—because one of the provisions that Senator Hassan and I have in the bill would require the FCC to issue a rulemaking on permitting non-interfering unlicensed use in the 6 gigahertz band. And I hope that companies like Charter and others in the space will make sure that we've—that they are able to support the work we've done in AIRWAVES to unleash the positive opportunities that we have in the 6 gigahertz band.

And, Mr. Stroup, I'm out of time, but I have some questions. We may follow up with you.

Thank you very much, to all of you, for being here.

Thank you.

The CHAIRMAN. Thank you, Senator Gardner.

Senator Tester.

STATEMENT OF HON. JON TESTER,
U.S. SENATOR FROM MONTANA

Senator TESTER. Thank you, Mr. Chairman.

This has been enlightening, a little bit like speaking in a foreign language.

[Laughter.]

Senator TESTER. But—so, let me start out—and I don't want to put words in anybody's mouth, because I'm a rookie here, but 3.5, I get the impression that has the longest span, as far as distance goes?

Mr. COWDEN. Well, it depends which frequencies you're talking about. Compared to millimeter wave spectrum, which is much higher to enable——

Senator TESTER. Well, let me get right down to it. If we're using something in rural America, I'm hearing 3.5 is what you want to use. What's the span of 3.5? Can you tell me? And does the flatland versus mountains have an impact?

Mr. COWDEN. It does. Flatland/mountains, what—one of the biggest——

Senator TESTER. So, if we're on prairies, how far would it reach?

Mr. COWDEN. So, we've done testing in those different types of markets. And in prairies, where it actually is maximized, we——

Senator TESTER. Yes.

Mr. COWDEN.—we believe the cell edge between the tower and the edge of the cell, where——

Senator TESTER. Yes.

Mr. COWDEN.—so, where you can still get 25-by-3 megabit——

Senator TESTER. Yes, yes.

Mr. COWDEN.—coverage, it's 5 miles.

Senator TESTER. Five miles. OK. So, there are going to be a lot of boxes put up around. You guys have talked about it. What kind of money will it take, today's dollars, to make 5G a reality everywhere?

Ms. BAKER. So, our companies are prepared to invest $275 billion——

Senator TESTER. Yes.

Ms. BAKER.—of their own money——

Senator TESTER. And that——

Ms. BAKER.—to build out 5G.

Senator TESTER.—does it all? That does the whole country?

Ms. BAKER. That's where we're going to start.

Senator TESTER. OK. So, I'm trying to get an idea on how much it costs to do the whole country. Because my guess is, you're going to start in New York City and Chicago and Miami and Houston and Phoenix and San Diego, and Big Sandy will not be on that list. OK? So, the question is, What's it going to cost to make sure Big Sandy is on that list?

Ms. BAKER. Well, so, Senator, I think there are two important goals that we have. And one is to connect all of America, and the other is to make sure that we win this race. And I think the good news is that AIRWAVES and STREAMLINE do that, because AIRWAVES has this——

Senator TESTER. I——

Ms. BAKER.—rural dividend——

Senator TESTER. I got you.
Ms. BAKER.—that gives——
Senator TESTER. You're right. And if——
Ms. BAKER.—10 percent to——
Senator TESTER.—we're going to——
Ms. BAKER.—rural areas——
Senator TESTER. If——
Ms. BAKER.—that will help build it out.
Senator TESTER. I got you. And I love you. You know that.
[Laughter.]
Senator TESTER. OK? But, the truth is, if we're going to win the race, I want to make sure that—where did you go to the wedding at in South Dakota?
Mr. STROUP. Isabel.
Senator TESTER.—Isabel, South Dakota, is connected up, too. OK? Because the truth is, is if rural America—and, by the way, I get it. People's where the construction goes. If rural America isn't part of that equation, we don't win the race, in my town.
Ms. BAKER. I think it's important. I think the Mobility Fund at the FCC's important.
Senator TESTER. OK.
Ms. BAKER. I think the rural——
Senator TESTER. So——
Ms. BAKER. And I also, Senator, think that the low band that's in——
Senator TESTER. OK.
Ms. BAKER.—low band, not 3.5, is lower——
Senator TESTER. I got it. Is there——
Ms. BAKER.—it's also an——
Senator TESTER.—anybody on this panel that knows how much it would cost, in today's dollars, to have 5G everywhere in the country?
Mr. STROUP. Senator, our member companies are already launching the satellites to——
Senator TESTER. OK.
Mr. STROUP.—be able to do that.
Senator TESTER. All right. And is there any idea on how much of that total figure would be paid for by the taxpayers? Much like broadband that we're doing now, there's a fair amount of it's done private sector, there's a fair amount of it done by Congress. Is there any idea? Is it going to be a 50/50 split that we anticipate? Seventy-five Federal dollars, 25 private? Any idea?
Mr. STROUP. This is all with private equity, private property.
Senator TESTER. It's all going to be private dollars. So, we're not going to have to set aside any dollars for 5G?
Mr. STROUP. Not for satellite 5G.
Senator TESTER. OK. But, what about the others?
Ms. BAKER. The Mobility Fund is about $500 million a year over the next 10 years.
Senator TESTER. And that will get it done?
Ms. BAKER. That's why we think that the rural dividend will be a great additional boost to that.

Senator TESTER. OK. OK. But, the rural dividend is the opposite argument. That goes to rural America. How about everybody else? Is it—will it get it everywhere, is the point?

Ms. BAKER. Our——

Senator TESTER. What I'm trying to figure out is, is this, so you know, that, you know, it's going to cost some money to do this. Is it—what's the taxpayer's share going to be? And the taxpayer gets the benefit, by the way. So, what's the share going to be?

Ms. BAKER. Well, as we roll out these networks, we're—we want to roll them out as fast as we can, which is——

Senator TESTER. Yes.

Ms. BAKER.—one of the reasons why STREAMLINE is important, because the more——

Senator TESTER. Gotcha.

Ms. BAKER.—the longer it takes and the more it costs to roll out to the big cities, the longer it's going to take——

Senator TESTER. OK.

Ms. BAKER.—to get to the smaller cities.

Senator TESTER. OK. I've got a couple more questions. When did we start—first start implementing 4G? By—which, by the way, I still don't have where I live, but when did we first—don't even have 3G—when did we first start implementing 4G? How many years ago was it?

Ms. BAKER. About 2010.

Senator TESTER. Yes, 2010, so 8 years ago. And when do you anticipate rolling out the 5G? Has it already started, or is it due to start?

Ms. BAKER. Ever——

Mr. BRENNER. It's underway.

Senator TESTER. It's underway right now. And how many years do you think that it will take to roll that out?

Mr. BRENNER. Well, one of the things, Senator—it's a constant process, so it's never, quote/unquote, "finished."

Senator TESTER. Yes, 4G isn't finished. Yes.

Mr. BRENNER. 4G isn't finished, either. That's why I talked, in my testimony, we're constantly developing——

Senator TESTER. OK.

Mr. BRENNER.—enhancements.

Senator TESTER. So, is there a 6G out there?

Mr. BRENNER. Not yet, but——

Senator TESTER. You anticipate there will be.

Mr. BRENNER. I'm sure there will be, yes.

Senator TESTER. OK.

[Laughter.]

Mr. BRENNER. And——

Senator TESTER. All right.

Mr. BRENNER. And when we roll out——

Senator TESTER. It's OK.

Mr. BRENNER.—6G, we'll still be——

Senator TESTER. Yes.

Mr. BRENNER.—working on 4G to enhance it.

Senator TESTER. So—OK. So—that's good. So, I want to talk about precision ag just for a second. So, this is more for you, Mr. Stroup. It's operated by GPS right now, at least the precision ag

that I am aware of, the one that sets the seed, from your previous round to the next round, 8 inches apart, or 6 inches apart, or 3 inches apart. It's an amazing technology. We don't have 5G where I'm at. But, we've got that amazing technology. Why do we need 5G for precision ag?

Mr. STROUP. The 5G capability is to provide connectivity for monitors, other types of sensors. So, in addition to the location capability, it will provide access to additional information.

Senator TESTER. So, at some point in time—there still needs to be an operator in the combine or the tractor now—at some point in time, we need 5G to go to a point where you can remotely operate that piece of equipment.

Mr. STROUP. You have the opportunity remote—to remotely operate the equipment. You have the opportunity to use sensors to establish the right amount of——

Senator TESTER. Right.

Mr. STROUP.—fertilizer, et cetera.

Senator TESTER. I will have about 380,000 questions for the record.

[Laughter.]

Senator TESTER. Thank you all very much.

The CHAIRMAN. Sounds like the Senator from Montana's trying to lessen his tractor time.

[Laughter.]

The CHAIRMAN. I have next up Senator Capito.

STATEMENT OF HON. SHELLEY MOORE CAPITO, U.S. SENATOR FROM WEST VIRGINIA

Senator CAPITO. Thank you, Mr. Chairman.

I'm actually pleased that I'm following my fellow Senator from Montana, in terms of him trying to simplify, a little bit, what the message is.

So, I have three, kind of, basic questions. I'm going to go back to rural. I know we're beating this. This is very important to me. I created the Rural Broadband Caucus as my goal, and you've been very helpful, many of your organizations. So, thank you for that.

The repeating thought is, it's too costly, there's not enough market for it, and there's no competition in a lot of areas in rural America. I'm from West Virginia. I did hear a little bit about a mountain, but I'm going to—I'll let that one go.

[Laughter.]

Senator CAPITO. How will the development of 5G solve these three major issues in the rural areas? Will the—will there be more competition that will come to the rural area? Will the market be able to bear this? And is the cost going to be cost prohibitive to certain parts of rural America, which we know are, in some cases, more lower-economic areas? So, I'm just going to throw it open, maybe, to Ms. Baker.

Ms. BAKER. Sure. I do think that the goals are intertwined of connecting all America and winning the race to 5G. And I think that what this committee and its leadership has done is put forth two very important bills, one in AIRWAVES, because AIRWAVES also focuses on low band, which Senator Tester kind of got there,

but 3.5 is mid-band. The lower the spectrum, the further it goes. So, it's very important in rural America——

Senator CAPITO. OK, let me stop you there, from a technical standpoint. When you say "lower band," you know, a nonscientific person in this, that implies to me slower, lower. Is that—am I seeing that wrong? It's the same speeds that can go through a lower band as through a——

Mr. BRENNER. Yes. What we're talking about is how far the signal can transmit——

Senator CAPITO. OK.

Mr. BRENNER.—between towers. And——

Senator CAPITO. OK.

Mr. BRENNER.[—if it's lower-band spectrum, the signal goes further.

Senator CAPITO. But, it doesn't affect the service——

Mr. BRENNER. Has nothing to do with the——

Senator CAPITO. OK.

Mr. BRENNER.—service

Senator CAPITO. OK. OK.

So, go ahead.

Ms. BAKER. Right. So, I think that AIRWAVES both has low-band spectrum, which is important, and isn't also internationally harmonized, so it will be cheaper to roll it out, as well as this rural dividend, which I think is going to be very important to add money to the underserved areas.

Senator CAPITO. Well, I mean, I think—I accept that, and—I do think this is a—it's a repeating theme with a lot of us that we keep talking about it, and we're still not getting there. So, I'm a bit frustrated by that.

When you talk about competition with other countries for 5G, can you frame that in an economic—I know that the arguments that we've been able to deploy faster in 4G has increased our productivity in healthcare and all kinds of different economic—is that the concern, that the race to the economic benefits of 5G, if we don't get there sooner, we're not going to realize it and somebody else realizes it? Is that the main competition? Mr. Brenner, do you have a——

Mr. BRENNER. Yes, I agree with the way you just framed that. You know, I have to say, again, Qualcomm, we're a global company. We're based in San Diego, but our business is global. And so, we really do want to see 5G roll out broadly and rapidly everywhere, all around the world. And we think that's a good thing for the United States, if 5G is rolled out everywhere and the phones that are used for 5G have a chip that's designed in San Diego by people employed in the United States.

Senator CAPITO. Right. OK.

Ms. BAKER. So——

Senator CAPITO. Yes.

Ms. BAKER.—I would say, being first in 4G added $100 billion to our economy. And that was jobs and—but, what it really did was, it unlocked the app industry. It unlocked the sharing economy, which is based here in the United States.

Senator CAPITO. Right.

Ms. BAKER. When they designed 4G, they thought they were putting a dongle into a netbook. They thought that they were making a netbook go mobile. Instead, they unlocked all these industries that we'd never thought about. So, when we talk about 5G and we talk about the numbers—it's going to add $500 billion to our economy—I think we kind of don't know, because we don't really know what it's going to unlock.

Senator CAPITO. So, not getting there first, or at least close to first, it's not that—it doesn't mean that we won't get there. It means that we might be locked out of any other—some economic expansions that maybe another country might be able to market better or get there faster. And that's what it means. It doesn't mean we're not going to get there.

Ms. BAKER. Global leadership and innovation.

Senator CAPITO. Right.

OK, last question is on the regulatory. We really haven't had much conversation on that. I, again, throw it open to the panel. I know you said anything regulatorily or legislatively needs to be neutral on the technology. Understood and agree with you there. Are there any other regulatory burdens that you see us facing, in the last 15 seconds that I have, as we're racing to 5G?

Mr. Cowden, do you have anything?

Mr. COWDEN. You know, I would just repeat the theme of technology neutrality. It's—there's certainly a focus on wireless regulation. And that's important. But, it shouldn't be at the expense of not looking at some of the burdens on the wireline side. If you think about 5G, it really is about creation of small cells. But, think about what that means. There is wireline infrastructure that has to connect to those small cells. So, it's——

Senator CAPITO. Well, I mean, coming from a mountainous state, I know wireless is not going to work in a lot of different areas. So——

Mr. COWDEN. That's right.

Senator CAPITO.—I'm with you there.

Mr. COWDEN. Yep.

Senator CAPITO. Thank you all very much.

The CHAIRMAN. Thank you, Senator Capito.

Senator Klobuchar.

STATEMENT OF HON. AMY KLOBUCHAR,
U.S. SENATOR FROM MINNESOTA

Senator KLOBUCHAR. All right. Thank you very much, Chairman. And thank you, to Senator Schatz and everyone else that's focused on this issue.

Minnesota is—actually was just ranked as the number-one state for wireless speed. Senator Blumenthal asked me if that was by the Minnesota Chamber of Commerce.

[Laughter.]

Senator KLOBUCHAR. It was not. It was ranked by a national ranking entity. And also, Minneapolis and Saint Paul were ranked as the number-one and -two cities in America for wireless speed. And I think you know, Ms. Baker, that this makes a difference for people wanting to move to our state, do business. And, in fact, in advance of this past Super Bowl, which was in Minnesota, carriers

made significant investments to increase capacity; in some cases, an increase of more than 220 percent LTE capacity. Can you talk about Minnesota's experience and how it can be used to—as a example to improve wireless service around the country?

Ms. BAKER. I agree with you, Minnesota and Minneapolis have both moved quickly to capitalize on small cells, and been carrier friendly. And the carriers have come. And, for that reason, as you say, they have 500 times—500 percent more capacity, and they have 230 small cells, because they were one of the first to actually embrace the—all the good things that are going to come from these new networks. And so, we hope other states and other cities—Indianapolis has been one that has moved very rapidly, as well. And in—but, you know, we want people to see this as, "You're going to save in energy consumption. You're going to save on your light bill," as opposed to, "Let's make more money off of siting on a tower." So, we've worked very hard in states to get small-cell builds. We've gotten 20 over the last 2 years. If we go at that rate, we're going to—5G's going to be over by the time we get 50 states builds. So, we hope that everyone will look at Minnesota, Minneapolis, as an example they want to emanate.

Senator KLOBUCHAR. And Saint Paul. Thank you.

And you don't have to have a Super Bowl to do this. Is that correct? OK.

The rural areas, of course, it's the hardest to reach, oftentimes. And Senator Fischer and I introduced the Rural Spectrum Accessability Act, and it was signed into law as part of the MOBILE NOW Act, thanks to the leadership on this committee. And it would require the FCC to explore ways to provide incentives for wireless carriers to lease unused spectrum to rural or smaller carriers.

Ms. Baker, how—could you talk about how that leasing could help improve service in rural areas?

Ms. BAKER. We embrace all areas of using spectrum more efficiently. And leasing, certainly in smaller—like private-sector leasing certainly seems one that's a good idea and one that we support. And we've supported you in that.

Senator KLOBUCHAR. Yep.

Mr. Cowden, the Dig Once was—a version of it, was included in MOBILE NOW. Could you talk about how physical infrastructure, including fiber conduit, play in enabling 5G? Just this idea that we're going to have to install things, and we try to do it at once, ought to make it easier and less expensive.

Mr. COWDEN. Sure. So—thank you for the question. As we talk about 5G and small cell deployment that enables high bandwidth and low latency, it's critical that we have wireline regulation that is streamlined, as well. As you think about connectivity to all those small cells, it needs a wired connection. So, if you think the overall call path of a wireless signal, it's more and more a wireline connectivity to get to that small cell. And so, it's crucial, when we talk about 5G, that we don't just think in wireless terms, but the wireline infrastructure required to actually connect all of those small cells. It all needs fiber to take traffic back from that, from that wireless small cell back to the network.

Senator KLOBUCHAR. OK. Last, I see Senator Lee over there, and he and I run the Antitrust Subcommittee of Judiciary. We just had a hearing with T-Mobile and Sprint about their proposed merger, and they've claimed that the combination of their spectrum assets would enable them to introduce nationwide 5G services more quickly. They claim their network would be superior in breadth and depth to anything that Verizon and AT&T could offer if they combined, and that their merger is necessary to enable the U.S. to win the global race to 5G. I'm not going to ask you to comment about this merger, but what I would like to know, if anyone wants to take this, is if further consolidation of wireless carriers, is that necessary to make deployment of 5G networks economically feasible?

No one wants to answer.

[Laughter.]

Ms. BAKER. I'm happy to say that—I leave judgment on the merger up to you all and your expertise, and those in the government. What I am very heartened to see is all these different players here at the table talking about 5G, and everyone joining in the race to 5G.

Mr. BRENNER. And what I would just add is, the goal for the government, in every action that it is taking in the wireless area, I think should be to accelerate the rapid broad rollout of 5G. And that should be the measuring stick.

Senator KLOBUCHAR. OK. Very good. Thank you.

The CHAIRMAN. Thank you, Senator Klobuchar.

Senator Moran.

STATEMENT OF HON. JERRY MORAN,
U.S. SENATOR FROM KANSAS

Senator MORAN. Chairman, thank you.

Thank you all for your presence here, and your testimony.

Mr. Cowden, let me start with you. We've advocated for unlicensed spectrum. And, in my view, it has been very successful in bringing new technologies, new devices to lots of consumers across the country. I'm of the belief that we can—must continue to pursue spectrum policy that includes both unlicensed and licensed. I would ask you, just briefly, if you agree with those comments? But, my real question is, What role will unlicensed spectrum play in the deployment of 5G or—if any?

Mr. COWDEN. Thank you for your question, Senator.

I unequivocally agree with that comment. Unlicensed spectrum, by any objective standard—unlicensed spectrum, in general, and Wi-Fi, in particular—has been the most successful policy in the history of the United States, from a spectrum policy standpoint, in terms of total tonnage of traffic, in terms of the efficient utilization of the spectrum, and in terms of the economic impact that Wi-Fi has brought to the economy. So, there's no question that we need to continue to advocate for unlicensed growth. We are approaching exhaust with Wi-Fi. And that is a critical concern that we should address.

As far as unlicensed spectrum for 5G, it's critical. It's definitely part of the equation. So, when we talk about 5G, there is a technology standard body that was referenced, 3GPP, that talks about 5G standards. There also is another body, IEEE—and I won't get

too wonkish here, but—that guides Wi-Fi technology standards. So, Wi-Fi has its own technology roadmap, right? And one of those roadmaps is different technology variants, 802.11ad and -ay—won't get any more in that—that really talks about providing services in the 60 gigahertz layer, or millimeter wave spectrum, using Wi-Fi. Right? And so, Wi-Fi will be critical, in terms of the future growth of 5G-like services. It'll just be on unlicensed spectrum instead of licensed spectrum.

Senator MORAN. This is a question for all. I serve in the role as the Appropriations Subcommittee Chairman for the group of entities at the Department of Commerce that includes NTIA, the National Telecommunications and Information Administration. So, I'm going to ask a couple of questions about NTIA. And I would start with—the President's budget that—the 2019 budget proposed authorization for NTIA to, quote, "negotiate leases with private entities that would expand their access to Federal spectrum." What kind of impact is this proposal expected to have on traditional licensing arrangements? And what are the barriers to effectively administering leases?

Mr. BRENNER. I could take that.

Senator MORAN. Mr. Brenner, thank you.

Mr. BRENNER. Senator, in the private sector, spectrum leasing is extraordinarily common. There are applications filed every day, where different private-sector companies lease spectrum from one another. The issue arises because the Federal Government has certain spectrum that they may not use 24/7 or they may not use coast-to-coast, so they have either in-time or in-location or even a part of a band, as opposed to a whole band that they could make available. And in the private sector, it would be done with a lease. And in the—with the Federal Government, there isn't actually a way—an easy way to do that. And I think the proposal is to create a way to do that. And that will only provide better connectivity wherever the spectrum happens to be available.

We—what we don't want to do is—if spectrum isn't available nationwide, and it isn't available 24/7, but it could be made available in pockets of time or geography, we ought to take advantage of that instead of just throwing up our hands and saying, "Sorry, the Federal Government can't lease spectrum."

Senator MORAN. So, this has potential. The issue is how to get the Federal Government to behave the way that the private sector already does.

Mr. BRENNER. To allow the Federal Government to behave that way, right.

Ms. BAKER. I think we've looked for innovative ways for both—for the government to use their spectrum more efficiently. And this is an idea. I will say that we led the world in 4G because of licensed. And I think this work that you've done on the Spectrum Relocation Fund deserves a lot of credit. And we appreciate that. Sometimes relocation just may be a better option, as in the FAA, for instance. They could get their sensor rater, and we could get the spectrum, and it's a win-win opportunity.

Senator MORAN. Thank you. Thanks for mentioning the Spectrum Relocation Fund Act. In that regard, in the 20 seconds I have left, NTIA was directed by the MOBILE Act NOW to report to Con-

gress with recommendations to incentivize Federal agencies to relinquish and share Federal spectrum for commercial wireless broadband. Does CTIA have suggestions, Ms. Baker, for this committee and NTIA in what additional incentives might look like?

Ms. BAKER. We're working closely with NTIA. I think that one reason that the AIRWAVES Act is so important is because they establish a schedule, and sometimes we all operate better when we have a deadline.

Senator MORAN. My deadline has expired——

[Laughter.]

Senator MORAN.—16 seconds ago.

Thank you.

The CHAIRMAN. Thank you, Senator Moran.

Senator Peters.

STATEMENT OF HON. GARY PETERS,
U.S. SENATOR FROM MICHIGAN

Senator PETERS. Thank you, Mr. Chairman.

Thank you, to our witnesses here today. I appreciate your testimony on a very important topic. Actually, Chairman Thune and I are working a great deal on self-driving cars, and there's going to be a tremendous amount of data that needs to be processed as a result of that, so getting to a 5G network is critical to the—realizing the full potential of these automobiles, issue that the two of us have been working a great deal on.

But, my question is about how we deal with the incumbent users that are with this technology, which is related to AV, as well. There are a number of open proceedings at the FCC targeting now low-, mid-, and high-band spectrum that could be made available, obviously for increased commercial licensed as well as unlicensed use. But, the common issue is—as policymakers, I think, is, How are we going to deal with the concerns of incumbent users? This committee has often heard me discuss the matter in the context of the 5.9 gigahertz band, which is currently allocated for intelligent transportation-system use. And in—and they are relying on this allocation. Automotive and tech companies have made investments in connected vehicle and infrastructure technologies. State and local transportation departments have begun to build out complementary roadside hardware, as well. And, in the case of 5.9, these countries and State and local Department of Transportations are the incumbents who are now being asked to share, much like the education broadband service entities in the 2.5 band and the satellite companies and broadcasters in the 3.7 to 4.2 band. And, as policymakers, we need to, I believe, ensure that their needs are met.

So, my question to the panel is, How can we increase the utilization of valuable spectrum while also protecting the interest of these numerous incumbents?

Ms. Baker.

Ms. BAKER. I would say—I'd take it—take us back one more step, to reiterate the fact that we are in a global race to 5G, and that China and South Korea are doing everything that they can to beat us, and we need to take action. And I would say, as far as incumbents go, we have a track record of being really good partners, and these incumbent activities are mission-critical, both to civilians and

to government, and we need to take care of them. But, we can do that. We just need to have a plan and get on this action, because it's important that we win this global race. I think, you know, whether it's AWS–3 or—I mean, we have a—or the broadcast incentive auction that just took place, all of those, we just need to make a plan, have a budget, and stick to it, stick to the schedule. And I think we can do that.

Mr. BRENNER. I'd like to add, Senator Peters. So, you put your finger on crucial issues, spectrum policy across the board, but specifically with respect to 5.9. I've worked on the 5.9 band since 2013, and there are really now two game-changers with respect to that band, because the whole issue is, Can we protect incumbent users? Because the band is supposed to be used to enhance highway safety——

Senator PETERS. Right.

Mr. BRENNER.—which has dramatic potential to save lives. The two game-changers are, first, we've got new technology, called "CV to X," using cellular, using, first, 4G and, ultimately, 5G to enable cars to communicate with cars with much better coverage, which—much lower latency, with a greater degree of reliability. So, that new technology has dramatic potential for a different use of the band than was envisioned back in 1999, when the band was allocated.

And then, the second is—which has been a—kind of alluded to here earlier, is—so, while the debate has gone on—and actually, in 2013, when spectrum-sharing in 5.9 was first proposed, the idea was, "Let's not have a long, long debate about it, because the upper 35 megahertz of the band can never be used by Wi-Fi." So, we're only talking about 40. I understand what Mr. Cowden is saying, that it's kind of a strategically located 40, but, at the same time, the game-changer is, now we can look at the 6 gigahertz band. Qualcomm and other companies have done a lot of work. And in the 6 gigahertz band, there's 40 times the spectrum than—there's 1200 megahertz compared to this little, strategically placed, I agree, sliver of 40.

So, I think—I'm hopeful that those two game-changers will cause a revisiting of the current debate over 5.9, and that we can move forward with something that doesn't endanger incumbent uses, and that allows highway safety to be enhanced with great new technology.

Senator PETERS. Thank you.

Mr. COWDEN. Senator, if I may add.

Senator PETERS. Yes.

Mr. COWDEN. Having run a company that developed sensing-based spectrum-sharing technology, a recommendation that I would make is for the new entrants to design their system to be able to share with the incumbents. It is far easier to be able to develop the technology for sharing with known incumbents than vice versa. So, as a policy matter, that is a recommendation that I'd make.

Senator PETERS. Right.

Thank you.

The CHAIRMAN. Thank you, Senator Peters.

Up next, I have Senator Baldwin.

STATEMENT OF HON. TAMMY BALDWIN,
U.S. SENATOR FROM WISCONSIN

Senator BALDWIN. Thank you, Mr. Chairman.

I'm going to start out by saying, every question that I prepared has already been asked——

[Laughter.]

Senator BALDWIN.—in various form. And my—a lot of the thrust of those questions has been about those who don't have access to high-speed broadband right now, and how we reconcile this global race that we want to win and lead with that access. And I think most of you are arguing, we have to do both.

I want to just share a little bit about what I hear at home when I travel to those areas that are still left behind, and then give each of you a real quick opportunity to make your case again.

I think about far northern Wisconsin, tourism-dependent Eagle River, where they did a study of their summer residents and found that, if there was some access to high-speed broadband, they would stay an additional 2 weeks every year. That would be a huge economic boon to the region. I think of far southern Wisconsin, in a rural community where homeowners—prospective homeowners are turned away because they want to be able to live out in the rural area, work at a high-tech place, and, if there's not high-speed Internet at home, they're not interested in this chance to live in God's country. You know, if there's not high-speed Internet, it's not going to work. Parents who drive their children to libraries for high-speed Internet access to do homework every night. Entrepreneurs who would be hiring people in rural America if they had access to high-speed Internet. And I can give you some great examples of folks who have made it a success, but, if they go 1 mile home, they can't work from home. You know, boy, I have so many stories, I would just love—but, I actually want to hear from all of you.

There are 700,000 Wisconsinites, mostly in rural areas, who do not have access to high-speed broadband. How should we allocate our resources between those twin goals of connecting all America and winning the 5G race? I know we can walk and chew gum at the same time, but make your case.

Start with you.

Ms. BAKER. OK. I'll start.

Again, I do think connecting America is critically important, and I think the people at this table have different ways of going about that, as our carriers have different bands of spectrum, and they are going to bring 5G in different ways. Some are going about it in a fixed mobile, some are going about it in a—I'm sorry—some are going about it in fixed wireless, some are going about it in mobile wireless. Fiber's important. Satellite's important. All of—unlicensed is important. All of this is important in bringing every America connected to what is important for—as we call, lifeblood broadband.

But, I also think that, as we win the race to 5G, something like STREAMLINE is increasingly important, because 5G is admittedly going to start in more urban areas, bigger cities, but the faster we can make those big cities connected, the more we're going to get to less populated areas, smaller communities. So, I think the more we can speed larger cities, the faster we can get to more rural areas.

So, I do think that the two goals of connecting all America, even though that's going to take all kinds of technologies, and it's not just going to be 5G, and winning the race to 5G, are inter—they are both interwoven.

Mr. BRENNER. Here's my case, Senator Baldwin. My company's whole existence is based on having as many people as possible connected with as many devices as possible that produce the greatest user experience, the highest-speed broadband. And, as I was saying to Senator Tester, we never give up. We're still working on enhancements to 4G at the same time that we're rolling out 5G. So, it's absolutely crucial for—from Qualcomm's point of view, that the rollout of 5G be as broad and as fast as possible.

And then one last point is, we spend a fortune, not just at the high end of the most expensive devices, but we spend a fortune to actually streamline our chip sets to have low-tier, mid-tier devices that people can afford. Not—in the history of the world, I've never heard of anyone who said, "I don't want a 4G phone anymore. Give me a 3G phone." Everyone wants better, faster broadband.

Senator BALDWIN. Mr. Cowden?

Mr. COWDEN. Real quickly.

I do think there is leadership and momentum for 5G technology. I do think, in general, that'll start in urban areas. We are very focused, at Charter, on the rural broadband issue. We are attacking this issue. We've gone to seven different markets all around the country to test what we think we can do right now—right?—with CBRS. And then, as we would get mid-band spectrum in 5G, the lower C-band, that would only add to the capabilities that we can produce in rural broadband. But, it's not something that we're waiting on, it's not something that we're saying, "Well, we can't solve this problem." We're attacking it right now. We don't have exact answers yet. We've learned a lot, and we are encouraged by the results. And so, we are really going after rural broadband, because we think there's a case there to be made.

Senator BALDWIN. Yes.

Mr. STROUP. Last year, in the FCC's 706 report to Congress, they included satellite broadband, and I—it's as a result of the recent launch of capability—satellites with 25.3 capabilities. And I noted, in my testimony, the ever-increasing speeds and capabilities of the industry. So, in many ways, ours is a challenge of awareness, making the consumer aware—your constituents—as well as continuing to have access to spectrum to be able to grow to meet those needs.

Senator BALDWIN. Thank you.

The CHAIRMAN. Thank you, Senator Baldwin.

Senator Wicker.

STATEMENT OF HON. ROGER F. WICKER, U.S. SENATOR FROM MISSISSIPPI

Senator WICKER. Thank you, Mr. Chairman.

This hearing has been going on an hour and a half now. Maybe it's time to sort of summarize what we've learned so far.

I'll start with you, Ms. Baker. We are behind in 5G. Are we in second place or third place? And how far behind are we? And how big of a problem is that?

I don't think Senator Schatz has elicited an answer yet about our SPECTRUM NOW Act, which he and I have introduced with Udall and Moran. So, maybe some of you have an opinion about whether that's a valuable thing for Congress to do.

What else is the role of Congress in getting us where we need to be on mid-band? And what's the role of the FCC, specifically? Do they need to act more quickly in addressing the mid-band spectrum, such as the proceeding on the C-band?

So, we'll start down here and see if we can bring this hearing up to date.

Ms. BAKER. Thank you for your question. That's a big one.

I would say we are behind. We announced that we were number three in the global race, behind China and South Korea. We were number one in industry readiness. We were number six in mid-band. That averaged out to number three. Since we announced that, this committee and its leadership, as well as the FCC, has stepped up, so we are making progress. We have a plan. We now have a plan on spectrum, which is AIRWAVES, and we have a plan on siting new—the new small cells, with STREAMLINE. So, we are making——

Senator WICKER. Who's "we"?

Ms. BAKER. We, as in this Committee and the FCC and the country as a whole, to win the race to 5G. We can still win, but we have to act. And so, I think it's very important, both for our economy—because of—we were leaders in 4G, it enabled the innovation of the app industry, the innovation of the sharing economy to be here in the United States. And we want the same thing for 5G. We don't know exactly what 5G is going to unlock, except for, we know it's going to be remote surgery, we know that, at 100-times faster in—you know, and virtually no lag time, we know it's going to unlock all kinds of things in transportation, in energy, in education. We want all of that to happen here so that we can export our innovation instead of taking the Chinese innovation here.

Senator WICKER. Anyone else? Yes.

Mr. BRENNER. Yes, Senator Wicker. Thank you so much for that question.

I want to clarify two important points. First, when Ms. Baker says the United States is behind, no one—no one—is ahead of Qualcomm in making the chips for 5G.

[Laughter.]

Mr. BRENNER. OK? That is—and that work is being done in the United States of America. Just this week, we announced something that no one in the wireless industry thought was possible. When 5G was first conceived, no one thought it was going to go into a phone, because, for these millimeter wave bands, you have many, many antennas, and the ability to have many antennas—you know, there's no place in one of these phones to put more antennas. What we announced this week is a module that's half the size of a paperclip, that has—supports four to eight antenna elements. And there will be three of these going in the first 5G smartphones. So, in terms of the technology, I mean, we're ahead. Qualcomm's ahead. And we're America.

Senator WICKER. Well, let me just interject, though. With regard to our SPECTRUM NOW Act, which we still don't have any testi-

mony on, it's intended to make spectrum available by providing support for users to research new and innovative ways to increase spectrum efficiency. Is this a bill any of you have looked at?

My goodness.

Ms. BAKER. Absolutely. And we support it.

Senator WICKER. Senator Schatz——

Ms. BAKER. Absolutely.

Senator WICKER. OK. I see.

Ms. BAKER. Absolutely. I apologize. It was a big question, and I didn't get to all of it.

Senator WICKER. That's right.

Ms. BAKER. We support it.

Mr. BRENNER. And then the other thing I wanted to clarify on mid-band is, there is something the—the FCC just announced this 3.7 to 4.2 Notice of Proposed Rulemaking, thick document, asking a lot of questions. That just happened. But, what they—so, they're going to have to wait for the private-sector companies to make their comments, and they're going to have a series of issues that they have to grapple with. But, what the FCC could do—and both Mr. Cowden and I have alluded to it—for more mid-band spectrum today is, the FCC's had this proceeding going on about the rules for the CBRS band, which is 3.5 to 3.7 gigahertz. That's 150 megahertz, which could be used for 5G. But, there's an FCC proceeding that they haven't finished up. It would be fantastic, and it would help us on the scorecard that Ms. Baker keeps, if we could finish the—if the FCC could finish that proceeding quickly.

Senator WICKER. In 10 seconds.

Mr. COWDEN. You know, real quickly, I would say, while there are some issues, in terms of technology, leadership, and ranking us in the world with 5G development, one of the critical issues with 5G, regardless, that many infrastructure providers are already doing anyway, is building out expansive wireline connectivity. Because when you go to 5G, you're going from these macro towers to small cells. Those small cells need wireline connectivity. And so, we're not stopping or waiting to build out that wireline infrastructure. And that really is the long pole in the tent, so to speak. And so, I want to be clear. While there are some technology issues to deal with, infrastructure providers are building out the wireline capacity to enable 5G when that equipment becomes available.

Senator WICKER. Thank you.

The CHAIRMAN. Thank you, Senator Wicker.

Senator Markey.

STATEMENT OF HON. EDWARD MARKEY,
U.S. SENATOR FROM MASSACHUSETTS

Senator MARKEY. Yes, thank you, Mr. Chairman, very much.

Federal agencies love to hoard spectrum. I mean, it's an absolute rule, right? Just the power of stasis. And that was the case back in 1992 and 1993, where the Defense Department had all this surplus spectrum after the Berlin Wall came down, but they were going to hold on, no matter what. And so, there was a three-star general there. I had the hearing. "We can't give it up. Absolutely impossible." So, we had to pass a law that actually took 200 megahertz away from them. At that time, this was the—that was the

kind of a—cellphone people are walking around with, right? And then, we licensed it for the third, fourth, fifth, and sixth cellphone license, so that's where this came from, right? And then, out of that comes Steve Jobs, saying, "Hey, I've got an even better idea." And out of that comes this, right? But, you've got to keep moving the spectrum if you want to keep the lead, right? You want to keep going.

So, Senator Cruz and I were looking at, you know, the issue of Federal agencies holding on to too much spectrum. And how do we get it out of their hands and move it over into the public sector? And, Secretary Baker, we—you and I, we worked on this issue, back in the day. So, what would you think about an incentive plan that they can keep part of the revenues—that is, the individual agency—if they give up some of their spectrum so that we can move it over into the private sector in order to get some of the benefits?

Ms. BAKER. Senator Markey, I feel like you're feeding me baby food, because you know I support that.

Senator MARKEY. I know you do.

Ms. BAKER. And we have been—we have been looking—with your leadership, we've been looking at spectrum efficiency for the government uses while maintaining mission-critical government activities for my almost entire government career. I think that it's really important. I think it's a great idea. I think any innovative ideas on how we can help the Federal Government continue their mission-critical use of it, but—use of spectrum, but——

Senator MARKEY. What would you think of——

Ms. BAKER.—use it more efficiency——

Senator MARKEY. What would you think of an incentive auction as a concept?

Ms. BAKER. Really good idea.

Senator MARKEY. OK, good. Thank you.

Mr. Brenner——

Mr. BRENNER. Yes.

Senator MARKEY.—really good idea or just a really great idea?

Mr. BRENNER. No, that's a really great idea.

[Laughter.]

Mr. BRENNER. Just as having you at—cellular penetration of 200 percent.

Senator MARKEY. Good. Thank you.

Mr. Cowden.

Mr. COWDEN. You know, one argument I would make, separating from incentive auctions, is the value of shared spectrum regimes. So, CBRS, we just talked about Citizens Broadband Radio Service, that 150 megahertz is an example of that, where there was the incumbent tier of the Department of Defense and the U.S. Navy, still is, and then there are two tiers underneath that, a licensed tier that hasn't happened yet, and then an unlicensed tier. But, that will drive the efficient utilization of that spectrum while still allowing incumbents, including, in this case, U.S. Government, to have access to that spectrum whenever they need it. I think we need to look at those types——

Senator MARKEY. Wi-Fi, Bluetooth, we need to find ways of incentivizing——

Mr. COWDEN. Yes.

Senator MARKEY.—movement in that direction. That's ——

Mr. COWDEN. Yes.

Senator MARKEY.—where the innovation is. The cable industry likes that idea.

Mr. COWDEN. Yes.

Senator MARKEY. Others like the idea. So, I think that's right on the money. And again, just a continuation of this incredible development, which we've been able to see over the years.

The E-rate program. In order to make sure it's there and it continues to be funded, and especially in terms of the expansion of Wi-Fi networks, just seeing this revolution continue. And then you just have an inability to really know what's going to happen, but, because you've incentivized the right area——

So, Mr. Brenner, what do you think about that, ensuring that we protect the E-rate?

Mr. BRENNER. Well, the—I have a very strong interest in the E-rate program, Senator Markey, because of the fact that the E-rate program doesn't support cellular, it only provides connectivity at the school, and non-cellular connectivity. And I would like to see the E-rate program—back in the—earlier in this decade, there were——

Senator MARKEY. Yes.

Mr. BRENNER.—pilot programs which showed dramatic improvement when students are able to use connectivity through the E-rate program at home, away from school, by having cellular.

Senator MARKEY. OK. Would you be concerned if the FCC decreased the amount of E-rate funding in the deployment of Wi-Fi for schools?

Mr. BRENNER. Sure. But, again, I would actually go the—in the other direction. I think——

Senator MARKEY. I'm agreeing with you.

Mr. BRENNER.—they should expand.

Senator MARKEY. OK? But——

Mr. BRENNER. Yes.

Senator MARKEY. Yes.

Mr. Cowden, what do you think?

Mr. COWDEN. I'm not the regulatory policy person at Charter. However, in some of my prior roles, I'm very familiar with the E-rate program, in general, in terms of deploying capacity to——

Senator MARKEY. Yes.

Mr. COWDEN.—to schools and to education institutions. I'm a firm believer in E-rate as a general concept. I don't know all the particulars of the dynamics between the policy of why they want to decrease it or increase it. So, I really can't comment on that.

Senator MARKEY. Yes. No, I got you.

Well, the FCC, in 2014, wisely expanded the E-rate program to cover schools and libraries. And we know that that's the future.

Mr. COWDEN. Right.

Senator MARKEY. And ultimately, you know, it empowers companies, actually, to be able to then provide those services for the schools and libraries in a much more effective way, and in a way that, again, keeps us at the cutting edge of how we not just help companies, but then help our people as we compete against China,

as we compete against South Korea, in the future. You want to make sure that information is at the fingertips of every child, every citizen in our country.

So, we thank you all for your testimony.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Markey.

Senator Hassan.

STATEMENT OF HON. MAGGIE HASSAN,
U.S. SENATOR FROM NEW HAMPSHIRE

Senator HASSAN. Well, thank you, Mr. Chair. And I want to thank you and the Ranking Member for this very important hearing today.

Also, without objection, I'd like to enter this letter from 16 different industry groups and associations, including CTIA, the American Library Association, and Public Knowledge, among others, supporting the AIRWAVES Act.

The CHAIRMAN. Without objection.

[The information referred to follows:]

June 11, 2018

The Honorable Cory Gardner
United States Senate
Washington, DC 20510

The Honorable Maggie Hassan
United States Senate
Washington, DC, 20510

Dear Senator Gardner and Senator Hassan,

On behalf of a diverse group of public advocates, educational organizations, taxpayer organizations and associations, we write to express our support for S. 1682, the Advancing Innovation and Reinvigorating Widespread Access to Viable Electromagnetic Spectrum (AIRWAVES) Act.

This bipartisan legislation is critical for the United States to produce a pipeline of spectrum necessary to reap the benefits that next-generation 5G wireless networks and new opportunities for unlicensed services will generate for U.S. consumers, innovation and economic growth. The AIRWAVES Act will also help close the digital divide by setting aside 10% of proceeds from the auctions required by the Act to build out wireless in unserved and often rural areas. This will help close the digital divide without using taxpayer dollars.

Winning the Global Race to 5G. Undeniably, there is a global race for 5G leadership and superiority. According to a new report from Analysys Mason, a telecommunications research firm, the U.S. is currently behind China and South Korea in the race for 5G deployment. These countries are aggressively making spectrum available for 5G. The AIRWAVES Act provides the certainty necessary for the U.S. to reclaim global wireless leadership by establishing clear auction deadlines for substantial amounts of low-, mid- and high-band spectrum.

Freeing Up Licensed and Unlicensed Spectrum for Commercial Use. The AIRWAVES Act provides a pipeline to make available both licensed and unlicensed spectrum necessary for next generation services. Without a healthy infusion of both exclusive use licensed spectrum and shared use unlicensed spectrum into the private sector on a predictable schedule, industry cannot adequately plan capital investment to support 5G services and devices.

Driving Economic Growth and Innovation. The wireless industry is poised to invest $275 billion to build out 5G networks, generating $500 billion in economic growth and 3 million new jobs. Not only will 5G networks transform our economy, but 5G networks will also prompt significant innovation and advancements for every sector including consumer tech, transportation, energy, agriculture, and healthcare. The AIRWAVES Act will help make that investment and future innovations a reality by providing a predictable supply of licensed and unlicensed spectrum. We need to ensure that leadership of the industries of the future and tomorrow's advancements in health care, transportation, energy are not exported overseas by ceding 5G innovation to other countries.

Helping Rural Communities. The AIRWAVES Act recognizes the importance of ensuring that all Americans, including those in rural areas, are connected. That's why the Act will fund the deployment of wireless broadband services in unserved and underserved areas through a set-aside of spectrum auction proceeds without taxpayer dollars. If this set-aside had been in place, the previous two spectrum auctions alone would have resulted in a rural broadband investment of more than $6 billion dollars—an amount more than the FCC's Mobility Fund will make available over the course of a decade.

The AIRWAVES Act will help ensure the U.S. leads the world in 5G, spur economic growth in industries of the future, and help rural communities. Thank you for your bipartisan leadership and we look forward to working with you to advance and pass this important bill.

Sincerely,

Senator HASSAN. Thank you.

A lot of my questions have also been asked, but I wanted to start, Mr. Stroup, just to give you an opportunity to expand a little bit on your testimony. You mention, in your testimony, that it's important for the United States to take a technology-neutral approach to spectrum policy. I agree that an all-of-the-above approach is the best way to ensure digital opportunity and broadband connectivity among our most hard-to-reach populations. Can you discuss the role of satellite communications in connecting rural areas, including really tough terrain like that in my home state of New Hampshire?

Mr. STROUP. Certainly.

Because of the ubiquitous coverage capability of the industry, and the increased capacity, the industry is taking on a greater role in providing those coverage—coverage to rural America. And I think that the point that you make, in terms of areas with difficult terrain, will be best served by the LEO and MEO systems. The geostationary satellites sometimes can have blockage as a result of a mountain range, perhaps.

Senator HASSAN. Yes.

Mr. STROUP. So, the LEO and MEO systems are in continuous orbit so that there will be multiple satellites that provide connectivity to devices or buildings. So, I think that, in terms of the difficult-terrain issue, it is the—the systems that are currently being launched, the LEO systems that I talked about that have communications capabilities are going through the testing of their first satellites and expect, within the next 2 years, to start launching the constellations.

Senator HASSAN. Great. Well, thank you.

I wanted just to finish, first of all, by thanking, Ms. Baker, your organization in particular, but all the folks who have written in to support the AIRWAVES Act, and to thank Senator Gardner for his partnership as we move forward with it. And a lot of our colleagues have joined us on the Act. So, I'm very grateful for the support, and I agree with everything that has been said here about our need to win 5G, our need to keep moving, our need to be flexible and discover new ways of doing this, and the really important relationship between the private sector and the public sector in moving this forward.

But, I also just want to highlight for constituents what this technology will mean for everyday people in my state and throughout the country. So, can you all speak a little bit, what 5G will mean for our efforts in telemedicine, in public safety? How will it work to improve the lives of people who experience disabilities? And maybe as you comment on that, how will the AIRWAVES Act help spur these benefits to consumers?

So, we'll start with you, Ms. Baker.

Ms. BAKER. Sure. Well, I just want to, first, thank you for your leadership and thank Chairman Thune again for holding this hearing to make sure that this is a national priority, because it should be, and it is, thanks to you.

One of the reasons that your all-of-the-above approach in AIRWAVES is so good is because it does have high-, medium-, and low-band spectrum in there in—which is going to all be utilized for our

5G leadership. And I think one of the things that it does is lay the schedule and give deadlines. And I think that's very important, because I really do think what 5G is going to bring to us is going to change every one of our days, the way that we live, work, and play.

Senator HASSAN. Right.

Ms. BAKER. And I think, whether—I mean, pick a subject—whether it's health and it's the $305 billion in savings annually, but it's not so much the money, it's what it means to my father to have the freedom to be able to check in at the doctor from his house or from his, you know, car. I mean——

Senator HASSAN. Right. And I think—and I'm going to quickly go down the line, because my time's almost up, but I just—I think one of the things I'd like you all to address is—we talk about winning the race to 5G, and that's very important, but, increasingly, Americans are feeling like there are winners and there are losers. We want everybody to be a part of this win, right? And so, this is really about how we partner together, you all doing what you do so well, and us all saying, "So, let's make sure every American gets this technology sooner rather than later."

So, Mr. Brenner—I didn't mean to cut you off, Ms. Baker, but we'll just go down the line and——

Mr. BRENNER. So——

Senator HASSAN.—have you all comment.

Mr. BRENNER.—I totally agree with everything that you said. And you actually hit a few topics that are of passionate interest to me, tomorrow being the 28th anniversary of the Americans With Disabilities——

Senator HASSAN. Yes.

Mr. BRENNER.—Act. So, disability groups are very excited about the potential of 5G for people who are blind or have low vision. There's a company called IRA, just to pick one——

Senator HASSAN. Yes.

Mr. BRENNER.—that has connected goggles that connects to remote agent who can then help the person see, in effect, where he or she wants to go, and to interact. For people with disabilities, autonomous vehicles, which are going to be an important part of 5G, are, you know, completely a game-changer. And then, in terms of connected medicine, the ability for people to have their doctors remotely monitor their condition, to do screenings, to do all the things today that you either would have to be in person or in a place that has wired high-speed access. So, it's very exciting for people—for those verticals.

Senator HASSAN. Well, thank you.

And I see that I'm over time, Mr. Chair, so perhaps the other two witnesses can submit an answer in writing.

Thank you very much.

The CHAIRMAN. Thank you, Senator Hassan.

Senator Blumenthal.

STATEMENT OF HON. RICHARD BLUMENTHAL,
U.S. SENATOR FROM CONNECTICUT

Senator BLUMENTHAL. Thank you. Thank you, Mr. Chairman. And I join in thanking you and the Ranking Member for having this hearing.

I know that Senator Klobuchar asked you about the T-Mobile and Sprint merger. When they came before the Judiciary Antitrust Committee last month to defend their merger plans, they both cited a lack of spectrum for 5G as one of the primary reasons for the combination. Of course, we heard similar arguments regarding 4G from T-Mobile and AT&T in 2011. That deal was rejected. Both companies launched successful 4G networks. And, in fact, before the Sprint/T-Mobile merger was made public in late April, T-Mobile's CEO said, in January, that his company already had, "massively bigger plans for a truly transformative 5G experience on your smartphone nationwide by 2019." Sprint's then-CEO, Marcelo Claure, promised just as much this past February, saying it would, "launch mobile 5G services," on its present spectrum holdings, "on a nationwide basis in the first half of 2019."

So, my question to you is—and maybe I'll begin with Ms. Baker—Doesn't each company presently have sufficient spectrum to launch 5G? If you believe their representations earlier this year, the answer is yes. But, I would like your independent assessments.

Ms. BAKER. I'm going to leave the merger questions up to the experts, like you and those in the administration and the FCC. I would comment on your spectrum, and I would say, over the last 4 years, we have had a quadruple in data usage. And as we look toward 5G—that is when we've just connected everyone—and when we look to connect everything, the data usage is going to go crazy. We are using spectrum bands, particularly the high bands, 24, 28, 39, 37, that we never thought we could use. And companies like Qualcomm have spent millions of dollars in research and development and being able to use more high bands. But, however you look at it, a bill like AIRWAVES is particularly important, because we're going to need more spectrum for 5G.

Senator BLUMENTHAL. I think we can agree that we need more spectrum. The question is, Do they need to merge in order to have that spectrum?

Ms. BAKER. Again, I'll leave merger questions up to the experts.

Senator BLUMENTHAL. Do they presently have sufficient spectrum to do 5G, each of them? That's not a question about the merger. They could still merge. My question is about the adequacy of their present spectrum.

Ms. BAKER. I'm not intimately enough familiar with the rollout plans of 5G to be able to make a comment.

Senator BLUMENTHAL. Anyone else have a comment? That's a pretty clear question, right? Do they have spectrum, each of them, presently, as they promised they did earlier this year? Were they lying then? Or—I don't want to say "Are they lying now?" but——

[Laughter.]

Senator BLUMENTHAL.—do they need to combine in order to have sufficient spectrum?

Mr. BRENNER. Yes, I'm going to say the same thing, Senator Blumenthal, that I said to Senator Klobuchar. Mindful, by the way, of the fact that I represent a vendor, right? So, you know, the yardstick—I don't have a comment on the merger. I don't have a comment on their 5G rollout plans before or after the merger. My only comment would be, through the regulatory process on that transaction, on every other single thing that the Federal Government

does in the wireless area, the measuring stick should be, Is it going to cause the 5G rollout to be broader, more—occur more rapidly, and is it going to be a net positive for 5G in this country? And I think you and the folks at the FCC and the people at the Justice Department will all have to weigh that.

Mr. COWDEN. You know, I would just say I can't comment on the specifics of their spectrum plans and what they would have also been planning to do independently that they may not now do together. So, I just don't know that.

I would say, in general—and I've mentioned this before—if we have technology-neutral policies that do not emphasize wireless or wireline, one over the other, and we position spectrum policy for both unlicensed and licensed so that we have competitive and innovative policies, that's the framework that Charter feels very comfortable with, in terms of competing against anybody, whether they're combined, or not.

Senator BLUMENTHAL. You know, if you don't want to answer specifically, I'm not going to put you on the spot. And my time has expired, anyway. So——

Mr. STROUP. It's not the satellite industry's position to look at the spectrum holdings of——

Senator BLUMENTHAL. And I don't want to be unfair to the two companies by the characterization of lying then or lying now. That is a vast oversimplification, I recognize. But, I thought it might be helpful to get a clear answer.

Thank you all.

The CHAIRMAN. Thank you, Senator Blumenthal.

Senator Lee.

STATEMENT OF HON. MIKE LEE,
U.S. SENATOR FROM UTAH

Senator LEE. Thank you very much, Mr. Chairman.

Thanks, to each of you, for being with us today.

It's clear to me that the United States economy has benefited tremendously from the fact that we have been more or less on the cutting edge of technology in this area. There is a big opportunity for us that awaits us with the possible rollout of 5G, but we've got to do it right. It's clear that the status quo in the United States with regard to 5G spectrum allocation is going to have to change if the United States is going to maintain its edge in this area and if it's going to be in a good position for global leadership in wireless innovation.

It's imperative that we free up more spectrum for licensed used—licensed use and for unlicensed use, particularly in the 3-gigahertz to 6-gigahertz band. But, when we're looking at available frequencies, it becomes increasingly clear that spectrum-sharing agreements will need to function as a commonly used alternative to current methods, to the traditional exclusive-use kinds of arrangements that have come to define our market in many instances. We're going to have to find more efficient ways to allow for the balance of market interests between incumbents, between Federal users, and between non-Federal, non-incumbent users.

So, Mr. Brenner, we'll start with you. In light of the need for more spectrum-sharing that we see coming in the very near future

if we're going to do this, and do it right, do you agree that it'll be far easier for newer entrants into wireless—for new entrants to develop wireless systems that are built to minimize interference with incumbents than for incumbents to go back and retrofit their systems for sharing arrangements?

Mr. BRENNER. Absolutely. And that's why, when we are designing 5G, Senator Lee, from the very beginning, we're designing versions of 5G that can operate in shared—in a shared-spectrum mode.

Senator LEE. Can you describe the current state of play with regard to advancements in interference mitigation technology?

Mr. BRENNER. Yes. So, I think I explained this a little bit in a prior answer. The way spectrum-sharing works today, if the four of us were sharing a band—and it almost doesn't matter what technology we were using—we would do it on time. We would each get the spectrum one-fourth of the time. But, what that means is, when Ms. Baker is transmitting, Mr. Stroup, Mr. Cowden, and I have to be silent. So, the spectrum is used by one person, one-fourth of the time. It's—while—seriatim. What we're designing in—and we call that "listen before talk." You have to be quiet until it's your turn. What we're designing, though, with 5G, we now have this vast new radio, and we have many, many antennas in the base station and in the devices that are transmitting in very thin beams, very highly directional. So, if all four of us know in what direction we're each going to transmit, we can each use the spectrum, all four of us could use the spectrum simultaneously, and thereby have much more capacity, have a much better user experience.

Senator LEE. That's good to know, and certainly gives a lot of us hope for the future, and hope for how this is all going to work.

With regard to the 6 gigahertz band, can you expound a little bit of—on what you see as the—some of the potential for device innovation, for Wi-Fi evolution, for the development of gigabit LTE with license-assisted access, if the FCC were to open up this band for unlicensed use?

Mr. BRENNER. Yes, Senator Lee.

We're very excited about the potential of opening that band, because there's 1200 megahertz. So, it's a very wide band. Now, there are incumbent systems all over the place in that spectrum, but what's good about it is, they're all fixed. We know where they are. And so, we can work around them, because we—these incumbents are not moving around. So, the technology that I just described, which uses what we call "look before talk" instead of "listen before talk," this idea that the four—that multiple transmitters can all use the spectrum at once, would be perfect for some part of the 6 gigahertz band, because it's a brand-new technology. Everyone who's using that—the spectrum needs to have this—that technology. So, that's one reason we're excited about it.

Another reason is, Mr. Cowden's company, he described in his testimony, is—just announced they're launching next-generation Wi-Fi. We call it 802.11ax. And that's a whole——

Senator LEE. It's a really catchy name.

[Laughter.]

Mr. BRENNER. Yes, exactly. Exactly.

Senator LEE. Sounds kind of like a bill that I would name——
Mr. BRENNER. Exactly.
Mr. COWDEN. You can call it "ax" if you want to sound cool.
Mr. BRENNER. Yes. Yes. And——
[Laughter.]
Senator LEE. Ax.
Mr. BRENNER. And "ax" would be perfect for the 6 gigahertz band. And then the third technology that you spoke about, called LAA, which is being rolled out all over the country now, and it is why Minneapolis, that Senator Klobuchar said is the number one in the United States in wireless speeds, because they have LAA rolled out with small cells—that could also go in the 6 gigahertz band.

So, we have the technologies. There obviously is a lot of work that has to be done with the FCC technical team. But, we're very optimistic that a large swath of unlicensed spectrum could become available and would be great for all these technologies.

Senator LEE. So, if they get this part right at the FCC——
Mr. BRENNER. Exactly.
Senator LEE.—big difference.
Mr. BRENNER. Exactly.
Senator LEE. I see my time's expired.
Thank you, Mr. Chairman.
The CHAIRMAN. Thank you, Senator Lee.
Senator Udall.

STATEMENT OF HON. TOM UDALL,
U.S. SENATOR FROM NEW MEXICO

Senator UDALL. Thank you, Mr. Chairman. And thank you for focusing on this very important issue.

You know, once again we're talking about 5G when too many of my constituents are living in rural New Mexico and our tribal land, and still don't have access to Internet. As major wireless companies talk about catching up with China in this race for 5G, we must not leave those behind in rural and tribal parts of our country. These communities must be included in the economic growth that faster connections give us. In my state, too many students are unable to complete homework because they do not have reliable Internet connections at home. And that is why Senator Gardner and I have introduced a bill requiring the Federal Communications Commission to make Wi-Fi access on schoolbuses eligible for E-rate support. That means students who don't have Internet at home can complete their homework on the bus. So many of these kids ride the bus 45 minutes, or sometimes an hour and a half, each day, to and from school, and they're on the bus for hours, traveling for sports. This is one change that can make all the difference in whether students finish their homework on a daily basis and succeed in school.

While we see some expansion of broadband carriers in rural New Mexico, we must do much more to connect everyone. And I want to know how we can incentivize carriers to partner with other entities to provide wireless coverage?

Ms. Baker, many of the rural areas of New Mexico that currently have connectivity are served by small carriers. These carriers do not have the financing to buy spectrum in large geographic areas.

One way to help the smaller carriers is for the Federal Communications Commission to publish an inventory of the owners of the spectrum in certain areas. How can the FCC incentivize your members to participate in spectrum inventory so that smaller carriers can reach out to the appropriate owners?

Ms. BAKER. Well, first of all, I want to share your concern that all Americans need to be connected, and how important it is. And regarding the Universal Service subsidies, mobile is not actually allowed to participate in many of the subsidies. And I think that that probably needs to be looked at, because mobile is a very important on-ramp for many low-income to be able to become part of the broadband world, which I think is very important.

I think you are entirely correct that a lot of the smaller carriers do lease from the larger carriers, or have agreements. And I think it is important for the FCC to help enable that secondary market.

Senator UDALL. Yes. And how can the FCC incentivize your members to lease spectrum in rural areas to entities who will develop that spectrum to serve those who are currently unserved?

Ms. BAKER. Well, we have many small members at CTIA, and most—and they all have partnerships with the larger carriers so that they can have nationwide coverage. That's part of being a small carrier in this—today's reality.

Senator UDALL. Mr. Cowden, too often major wireless providers have come to me claiming they will serve rural areas and devote money to build infrastructure in unserved areas if they can just get better conditions for building. Yet, time and again, I've been disappointed, because we still see no service. What technology do you believe can bring robust broadband to rural and hard-to-serve areas?

Mr. COWDEN. Thanks for the question, Senator.

We are looking at that problem right now, and attacking it aggressively. We've done rural broadband proof-of-concept studies in seven different markets around the country, all with different characteristics with climate and foliage density to test the performance. We believe we can deploy a cost-effective rural broadband solution to significantly increase serviceability for rural broadband, and we would use a combination of the 3.5 CBRS band for extended coverage, and then also 5 gigahertz, which is unlimited band—or unlicensed band, but we can use that in combination with 3.5 as more of a capacity layer. The whole point of that is, we think we can extend—in any given cell tower, we can extend out to 5 miles, to the very edge of that cell, with the service that can offer at least 25-by-3 megabit to really extend and expand rural broadband. It's something we're aggressively looking at right now. We intend to do that, going forward.

Senator UDALL. Great. Thank you very much.

And I have a couple of more questions for the record, but I'm out of time, so I'll just put them in the record.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Udall.

Senator Cruz.

STATEMENT OF HON. TED CRUZ,
U.S. SENATOR FROM TEXAS

Senator CRUZ. Thank you, Mr. Chairman.

Good afternoon. Welcome. Thank you for your testimony. Thank you for being here.

Ms. Baker, according to Accenture, the U.S. wireless industry is poised to invest roughly $300 billion in deploying 5G networks, which could create 3 million new jobs and boost GDP by $500 billion. Personally, I'm excited that we're seeing some of that investment in Texas already moving forward, with at least three of our cities slated to be among the very first in the country to get 5G. AT&T previously announced that Waco and Dallas will see 5G services this year. And, just yesterday, Verizon announced that Houston, my hometown, will be getting 5G, as well, including five traditionally under-resourced neighborhoods. How important, in your judgment, is having a predictable supply of spectrum and a long-term schedule of auctions to deploying the spectrum and to rolling out 5G?

Ms. BAKER. Thank you for your question, Senator.

I absolutely think it is incredibly important. I think that's why AIRWAVES, as a bill, is so important, to give us a schedule and a—timelines for us to see this. If we're going to invest $275 billion of our own money, then we need to know when and how the spectrum is going to roll out. So, we really appreciate this committee's leadership with AIRWAVES. And I thought I was excited about Chip and Joanna in Waco until my hometown, also of Houston, was going to get 5G. So, I share your excitement about it all. And I hope everyone gets it soon.

Senator CRUZ. Me, too.

As you know, the United States is in a global race against China and other countries to be the global leader in deploying next-generation 5G mobile broadband networks. A European commission spokesman for the Digital Economy and Society said, "In the mobile equipment industry, we had 80 percent of the market in 2008, and, because we were not ready for 4G mass deployment, the EU industry lost almost the entire market share for mobile phones." What would be the consequences for the United States if we lose the global 5G race to China or to another nation?

Ms. BAKER. I think, Senator, that's a great question.

I think the same thing happened to Japan. So, we need to learn the lessons from the leadership that Europe and Japan had in 2G and 3G, and not lose our leadership in 4G. It will mean that—particularly if China wins, that Chinese companies will be leading the race, they'll be leading innovation, they'll be pushing their products to us instead of America and the United States pushing our products to the world.

Senator CRUZ. As you know, last January, a memo was leaked from the National Security Council, which called for nationalizing 5G mobile broadband networks. And, since then, there has not been a clear denunciation of that policy of plans to nationalize the networks from the administration. That's why, this week, Senator Cortez Masto and I introduced the E-Frontier Act, which will prohibit the Federal Government from nationalizing our Nation's tele-

communications network without explicit authorization from Congress.

Let me ask each of the witnesses here. What would it mean if the Federal Government were to nationalize our Nation's 5G networks?

Ms. BAKER. I'll start, I suppose.

We appreciate your leadership in this bill. We think that nationalization is a wrong approach. We think our carriers are already announcing plans to roll out 5G this year, and building upon that. I—part of the reason we're the envy of the world is the competitive market here. We compete on investment, we compete on coverage, we compete on speed, you know, prices. It's one of the few areas where prices are dropping and data is increasing. So, it really—you know, I think I noted earlier that we've had data increase four times since 2014, and our networks are covering it by speeding up 40 percent in the last 2 years. And meanwhile, the prices are down 13 percent over the 2 years. I'm not sure why we would nationalize it. It's the wrong direction.

Mr. BRENNER. I totally agree with that, Senator Cruz. We're working, as I said in my testimony, at a feverish pace from our headquarters in San Diego, to roll out the chips for 5G. We've accelerated our plans. We originally brought the deadlines in by a year. Just on Monday, we had tremendous announcement about these new antenna modules that solve a problem for 5G smartphones that no one in the industry thought could be solved. So, we would like to just keep on doing what we're doing and get 5G out there absolutely as quickly as possible.

Mr. COWDEN. Yes, I would just say I'm not exactly familiar yet with the Frontier legislation, but, in general, I never think it's a good idea to have government-owned networks. I do think it disincentivizes financial investment from private-sector carriers. And so, we would not support that.

I think one of the goals of the perceived nationalization was that—to improve network security. I think there are many other ways to do that with private-sector coordination. That would be much more effective. I do think, if it was nationalized, it would absolutely slow down the rollout of 5G. It would be counterproductive to what we're trying to achieve.

Senator CRUZ. Mr. Stroup.

Mr. STROUP. The satellite industry is deploying multiple satellites from several different operators to play a role in 5G. It's hard to envision how that could be nationalized where the government would be providing the comparable kinds of services. And we also take security very, very seriously. So, we think that there are better ways to address that issue.

Senator CRUZ. Well, thank you. And I look forward to working with each of you—continuing to work with each of you on this important issue.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Cruz.

I think we—we don't have anybody else coming back, do we, that we know of? OK.

I've got one last question I'd just ask. I think it's maybe one that hasn't been. Pretty much everything's been asked, I think, today, but——

Ms. Baker, with the completion of the broadcast incentive auction last year, it appears that there are few options left for low-band spectrum. And a recent study commissioned by CTIA found that spectrum at 1.3 and 1.78 gigahertz could be an extraordinary resource for 5G, especially given our experience with the AWS-3. One estimate puts the value of this spectrum at more than $50 billion after paying to relocate incumbents. Is this spectrum Congress ought to be considering for next-generation wireless?

Ms. BAKER. I really appreciate the question.

It's prime low-band spectrum that's internationally harmonized. As you mentioned, the value of it is big for the Federal Government. If you take that rural dividend from AIRWAVES there, you've got another $6 billion. I think we have the experience of protecting mission-critical and working with the Federal Government in AWS-3 and with the non-Federal Government in the broadcast incentives, to where we can create win-win situations. So, this is important spectrum that we know that we've been working with the Federal Government on, but we could certainly use some help.

The CHAIRMAN. OK.

Senator Schatz, anything else? You're the order? OK, good.

Well, thank you all very much. Been a great hearing, a lot of good questions and responses. Thank you for your insights. We will look to you as we try, in the future, to move legislation. As has been mentioned earlier, there are some that's already passed, some that we're hoping to get done this year, that we'll continue to open the door to more spectrum being made available for commercial use. And if we're going to win the 5G race, it just flat has to happen. So, if you have insights—further insights about things that we can be doing, please convey those to us, and we'll continue to work on refining our legislation, in hopes that we can get that across the finish line this year, as well.

I would say, to all of our panelists, that Members will have questions for the record, as you heard some of them suggest earlier, and that, if you could, get your responses back to those questions as quickly as possible. We'll keep the hearing record open for a couple of weeks.

Thanks again for your testimony and for your responses.

With that, this hearing is adjourned.

[Whereupon, at 12:15 p.m., the hearing was adjourned.]

A P P E N D I X

WASHINGTON STATE UNIVERSITY
Portland, OR, September 20, 2017

Governor JERRY BROWN,
Sacramento, CA.

Re: *Please VETO SB 649*

Dear Governor Brown:

I am Dr. Martin Pall, Professor Emeritus of Biochemistry and Basic Medical Sciences at Washington State University. I am a published and widely cited scientist on the biological effects of electromagnetic fields (EMFs) and speak internationally on this topic. I am particularly expert in how wireless radiation impacts the electrical systems in our bodies. I have published 7 studies showing there exists exquisite sensitivity to electromagnetic fields (EMFs) in the voltage sensors in each cell, such that the force impacting our cells at the voltage sensor has massive impact on the biology in the cells of our bodies [1–7]. These papers are discussed in over 360,000 websites, which can be easily found by Googling (Martin Pall electromagnetic). I received my PhD at Caltech, one of the top scientific institutions in the world.

I am writing to recommend you veto SB.649.

EMFs act by activating channels in the membrane that surrounds each of our cells, called voltage-gated calcium channels (VGCCs). The EMFs put forces on the voltage sensor that controls the VGCCs of about 7.2 million times greater than the forces on other charged groups in our cells [4,6,7]. This is why weak EMFs have such large biological effects on the cells of our bodies. EMFs work this way not only on human and diverse animal cells [1–7] but also in plant cells [7] so that this is a universal or near universal mechanism of action.

Thousands of published studies show biological and health effects from electromagnetic fields. We now know the mechanism that can explain these effects. The mechanism is a function of the electromagnetics of each cell—not solely about heating effects from the radiation (on which present FCC guidelines are based).

This new understanding [1–7] means we can debunk the claims of the wireless industry that there cannot be a mechanism for effects produced by these weak EMFs. The 20 years plus of industry propaganda claims are false. Rather the thousands of studies showing diverse health impacts of these EMFs can be explained. We now have a mechanism, one that is supported by both the biology and the physics, both of which are pointing in exactly the same direction. I am sending as a separate document a list of 142 reviews, each of which provides from 12 to over a thousand individual citations showing health impacts of low intensity EMFs, EMFs that the telecommunications industry claims cannot have such effects. These 142 reviews and thousands of primary scientific papers they cite show that the industry propaganda has no scientific support whatsoever.

The consensus among independent scientists on this is further confirmed by the 2015 (and later) appeal made to the United Nations and member states, stating that the current EMF safety guidelines are inadequate because they do not take into consideration non-thermal effects. This was signed by 225 scientists from 41 countries, each of whom had published peer reviewed studies on EMF health effects—a total of 2,000 papers published in this area by the signers, a substantial fraction of the total publications in this area.

According to industry, the forces electromagnetic fields place on electrically-charged groups in the cell are too weak to produce biological effects. However, the unique structural properties of the voltage-gated calcium channel (VGCC) protein can, it turns out, explain why the force on a cell's voltage sensor from low-intensity EMFs are millions of times stronger than are the forces on singly-charged groups elsewhere in the cell.

It would be a disaster for the health of Californians to be exposed to the antennas envisioned in SB 649. The State of California would be making a grave mistake to proceed with supporting the commercial interests of the wireless industry with this legislation. You would best veto this bill, Governor Brown, and pause to understand the gravity of the biological effects, and the ramifications for physical and mental health, as well as consequences from continual damage to human DNA, and learn the facts from scientists who are independent of the wireless industry, not from the industry lobbyists who have a gigantic conflict of interest.

VGCC activation in cells produced by low intensity EMFs can explain long-reported findings that electromagnetic fields cause a wide range of biological changes and health effects. The first 6 of these (see below) were well documented 46 years ago in the U.S. Office of Naval Medical Research report, published in 1971 [8]. The others that follow have been extensively documented subsequently in the peer-reviewed scientific literature:

(1) Various neurological/neuropsychiatric effects, including changes in brain structure and function, changes in various types of psychological responses and changes in behavior. (2) At least eight different endocrine (hormonal) effects. (3) Cardiac effects influencing the electrical control of the heart, including changes in ECGs, producing arrhythmias, changes that can be life threatening. (4) Chromosome breaks and other changes in chromosome structure. (5) Histological changes in the testes. (6) Cell death (what is now called apoptosis, a process important in neurodegenerative diseases).

Since 1971 many other effects of such EMFs must be added to that list: (7) Lowered male fertility including lowered sperm quality and function and also lowered female fertility (less studied). (8) Oxidative stress. (9) Changes in calcium fluxes and calcium signaling. (10) Cellular DNA damage including single strand breaks and double strand breaks in cellular DNA and also 8–OHdG in cellular DNA. (11) Cancer which is likely to involve these DNA changes but also increased rates of tumor promotion-like events. (12) Therapeutic effects including stimulation of bone growth. (13) Cataract formation (previously thought to be thermal, now known not to be). (14) Breakdown of the blood-brain barrier. (15) Melatonin depletion and sleep disruption.

They may be low intensity but with regard to the VGCCs, electromagnetic fields can have a tremendously powerful impact on the cells of our bodies. Furthermore, published studies showing that calcium channel blocker drugs block or greatly lower biological effects from electromagnetic fields confirm there is a VGCC activation mechanism that is causing various effects. Higher frequency electromagnetic fields from 5G technologies on the horizon pose even greater biological concern than those to which we are exposed today. We should be moving, instead, to wired technologies at every opportunity, based on what we know in science today, not expanding and supporting the proliferation of wireless.

I want to make several additional points very clear:

The Physics and the Biology are both pointing in the same direction. Both show that EMFs act primarily via activating the VGCCs in the cells of our bodies.

DNA damage known to be produced by these EMFs occur in human sperm and may also occur in human eggs, leading to large increases in mutation in any children born. It is thought that an increase in mutation frequency of 2.5 to 3-fold will lead to extinction because of accumulation of large numbers of damaging mutations. We may already be over this level, and if so, simply continuing our current exposures will lead to eventual extinction. Further increases in exposures will be more rapidly self-destructive.

Pulsed EMFs are, in most cases, more biologically active and therefore more dangerous than are non-pulsed (continuous wave) EMFs. All cordless communication devices communicate via pulsations, because it is the pulsations that carry the information communicated. All the industry claims of safety are based on a theory (only thermal effects) that was known to be wrong back in 1971 [8]—and that was before many thousands of additional studies were published providing massive confirmation that industry claims are false.

The industry is trying to move to much higher frequencies with 5G because these much higher frequencies allow much higher pulsations and therefore much faster transmission of information. However, these higher pulsation rates make these ultra-high devices vastly more dangerous. This is part of the reason why it is so important to vote down SB 649.

None of our wireless communication devices are ever tested biologically for safety—not cell phone towers, not cell phones, not Wi-Fi, not cordless phones, not smart meters and certainly not 5G phones, or radar units in cars—before they are put out to irradiate an unsuspecting public.

The telecommunications industry has corrupted the agencies that are supposed to be regulating them. The best example of this is that the FCC which regulates EMFs in the U.S. is a "captured agency", captured by the industry it is supposed to regulate, according to an 8-chapter document published by the Edmond J. Safra Center for Ethics at Harvard University [9]. Is it any wonder, therefore, that the industry keeps touting that their devices are within the safety guidelines set by the FCC?

We know how the EMFs work in the body and that the industry propaganda has no science behind it. But what can we say about the 5G EMFs and what effects it will have on our bodies? 5G will be much more active in activating the VGCCs and producing health impacts because of its rapid absorption by materials in the body, because of its very rapid pulsations and because of the huge number antennae they are planning to put up, at least 200 times the number of antennae from all current cell phone towers. What this means is that the impacts on the outer one to two inches of our bodies will be massive.

Because of this we can expect humans to suffer from:

1. Very large increases in blindness from each of the four major causes of blindness: cataracts, macular degeneration, glaucoma and retinal detachment. Each of these involves excessive calcium levels in different parts of the eye and 3 of them also involve excessive voltage-gated calcium activity. I conclude that each of them is likely to be massively elevated by 5G.
2. Large increases in hearing loss and tinnitus, leading in many cases to deafness.
3. Very large increases in male infertility, as well as universal drops in sperm count.
4. Very substantial numbers of melanoma skin cancer and leukemia and possibly other types of cancer. EMFs appear to be particularly active in causing cancer in children and consequently children are at special risk from 5G.
5. Impacts on the peripheral nervous system leading to near universal neuropathic pain and peripheral neuropathy.
6. Large increases in thyroid dysfunction, because of the location of the thyroid gland near the surface of the body.
7. Impacts on the immune system cells, possibly leading to autoimmune diseases and other deficiencies.
8. Impacts on the erythrocytes (red blood cells), leading to stacking of the erythrocytes into rouleaux (long chains) and also cell lysis, leading to very low oxygen in the tissues and lowered nutrients transport to the tissues.

Because plants and animals are affected much as we are, but they have much larger parts of them are highly exposed to the 5G radiation, *the impacts on insects (including bees and other pollinators), birds, small mammals and almost all plants will be much more severe than the effects of humans.* Even large trees have their leaves and reproductive organs highly exposed to 5G radiation. It is quite possible that the attempts by industry to put 5G in rural areas of California will have tremendous impact on California's unique agriculture. It is hard to imagine the chaos that will be generated on thousands of different species. To put 5G out with no biological safety testing is, in my view, a travesty.

I urge you to do the right thing on behalf of the health of Californians and future generations: *Please VETO SB 649.* Please let me know if I can provide further information, or if you'd like to meet in person to learn more, feel free to contact me at (503) 232–3883.

Respectfully,

MARTIN L. PALL, PH.D.,
Professor Emeritus,
Biochemistry & Basic Medical Sciences,
Washington State University.

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RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. JOHN THUNE TO HON. MEREDITH ATTWELL BAKER

Question. The administration has proposed spectrum leasing as a means of making more spectrum available, if only for a limited time.

- What are your thoughts on that proposal?
- Are you concerned that leasing could supplant traditional spectrum licensing?
- How long would lease terms need to be in order for carriers to recoup their investment in the infrastructure and other costs associated with providing service in a particular spectrum band?
- Would it be advisable to have a pilot program to test spectrum leasing before proceeding with any other leasing activities?

Answer. We commend your leadership in MOBILE NOW and the Committee's efforts to ensure the wireless industry has access to the cleared licensed spectrum we will need to compete globally. It is critical that the Federal Government continue to make additional *cleared* spectrum available to mobile broadband providers so that the United States can win the race to deploy 5G networks and services.

Licensing of exclusive use spectrum provides carriers with the certainty they need to develop and execute on their business plans, which in turn generates billions of dollars in investment. Other countries are releasing hundreds of megahertz of new cleared spectrum to promote 5G because they recognize that spectrum is key to winning the 5G race and unlocking the corresponding economic and societal benefits.

Although licensing of exclusive use spectrum remains the gold standard of spectrum policy, CTIA does support consideration of alternative approaches in the limited circumstances where cleared spectrum is not possible. To that end, we would support exploration of Federal spectrum leasing opportunities.

We agree that a pilot program would be an appropriate and necessary preliminary step, and it would be advisable to limit such a pilot to a single band where there is a single agency with spectrum allocations to avoid the complexity of inter-agency coordination and balancing different objectives and requirements. We would also need to ensure the agency has the resources and requisite expertise to participate in a more commercial market-style transaction.

As you note, the lease terms would be critically important. Wireless carriers would need long-term certainty to justify the significant expenses of building out new spectrum bands across the country and incorporating those bands in its device portfolio. Today, the FCC typically sets a 10-year term on wireless carrier license, as well as a renewal expectancy. Replicating that approach in the context of spectrum leases would be appropriate to incentivize wireless investment.

We would be happy to engage with the Committee, the Administration, and the FCC to consider the challenges that would need to be addressed prior to pursuing a new Federal spectrum leasing strategy.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JERRY MORAN TO HON. MEREDITH ATTWELL BAKER

Question 1. It is clear that rapid deployment of a nationwide 5G wireless network means more than just improved technical broadband capacity and speeds that this technology provides. According to studies, the deployment of this technology is expected to contribute $275 billion in new investment, $500 billion in economic growth, and up to 3 million new jobs to the U.S economy. These projected benefits highlight why the U.S. needs to keep pace and surpass our foreign competitors like China and South Korea. What exactly does "winning the race" to 5G mean for our Nation's economy and telecommunications capabilities, especially for our rural communities like those in Kansas?

Answer. We know what U.S. 4G leadership meant to our country. By deploying first, we saw $100 billion added to our economy and an 84 percent increase in wireless-related jobs, according to Recon Analytics. Moreover, 4G was the platform that unlocked the apps and sharing economy that allowed companies like Uber to start up and flourish.

The nation that leads in 5G will capture millions of new jobs and billions in economic growth, as you note in your question. Every industry, including farming, healthcare, energy, transportation, law enforcement, e-commerce, logistics, and education will be positively impacted by winning the race to 5G. In Kansas, the wireless industry contributes over $7 billion to the state's economy and drives over 63,000 wireless-related jobs resulting in $2.9 billion in pay and benefits, according to Accenture. That will grow significantly with 5G.

In order to win the race to 5G, we must get spectrum and infrastructure policies right to enable the industry to deploy those networks to more communities, including rural communities, faster. Congress can help by incentivizing industry investment and providing new support to commercial providers to bring wireless to areas that are challenging to serve.

That's why CTIA strongly supports the AIRWAVES Act "rural dividend," which would allocate 10 percent of auction proceeds to wireless deployment in unserved and underserved areas. In addition, as you are well aware, state and local rules for wireless infrastructure have not kept pace with innovative new technologies and network architecture. By streamlining these rules, policymakers can drive down the cost of deployment, helping speed deployment and enable more deployments in more areas. CTIA stands ready to work with you to push forward common-sense policies to expedite and expand the deployment of 5G wireless networks to Americans everywhere.

Question 2. While I have supported legislation like the RAPID Act and the MOBILE NOW Act to streamline overly-cumbersome regulations, what else can Congress be doing to increase U.S. competitiveness in 5G deployment?

Answer. Thank you for your leadership in introducing the RAPID Act. Modernizing siting rules that were put in place to govern 200-foot macro towers is critical to speed 5G deployment. In addition to modernizing the Federal review process as contemplated in your RAPID Act, Congress and the FCC also need to prioritize the efficient deployment of wireless infrastructure and set nationwide guidelines for how localities treat siting requests.

CTIA commends the FCC for taking steps to stop states and localities from imposing siting moratoria, and Congress and the FCC should continue to modernize the approval process for 5G networks and equipment, including enactment of the STREAMLINE Small Cell Deployment Act and the SPEED Act.

Spectrum is also critical to 5G deployment. Congress should pass the AIRWAVES Act, a bipartisan bill that provides a clear, robust pipeline of spectrum necessary to deploy 5G, and would help with rural deployment as well (as noted above). The AIRWAVES Act will enhance existing wireless service and unleash next-generation broadband in communities across America by creating a schedule of future spectrum auctions, and reallocating underused spectrum for future mobile broadband use.

Question 3. Of the spectrum sharing regimes under consideration, the prioritization and coordination of operations within the band are facilitated through the use of Spectrum Access Systems. Will you please describe to this committee how these automated systems optimize efficient use of available spectrum for all while protecting the higher-tier users from interference from others?

Answer. In 2015, the FCC approved a three-tiered, experimental sharing framework to make up to 150 megahertz in the 3.5 GHz band available for wireless use. Initially proposed over five years ago, this sharing regime represents an important technical and policy experiment, and CTIA has been committed to exploring this new approach to spectrum management.

In this three-tiered sharing framework, existing government users like the U.S. Navy would occupy Tier 1, license holders (to be determined by auction) would occupy Tier 2, and those seeking opportunistic use—similar to unlicensed bands—would occupy Tier 3.

These tiers will operate through Spectrum Access System (SAS) databases, which will contain information about use of the 3.5 GHz spectrum, including by incumbent operators. The SAS Administrator will authorize use of the airwaves, playing a role in protecting higher-tier users from interference. More specifically, SAS Administrators will coordinate frequency assignments based on channel requests from users by using sensing technology to detect if higher-tier users, like Navy radar systems, are present.

The 3.5 GHz regime is an experiment and we commit to working with the Administration, Congress and other stakeholders to evaluate how this novel sharing mechanism works as well as if, and where, it would be appropriate to use again for other spectrum bands where clearing spectrum is particularly challenging. Key to ensuring a successful experiment are rules changes the FCC is considering right now to ensure that Tier 2 auction winners have the certainty and rights they will need to invest in the band.

Question 4. The MOBILE NOW Act directed NTIA to study the mid-band spectrum of 3100–3550 megahertz to assess the feasibility for allowing commercial wireless services in that spectrum. In February, NTIA identified 100 megahertz of spectrum currently used by DOD (for military radar systems) that could potentially be repurposed for commercial use. Could you please describe the utility that this spectrum could provide mobile wireless broadband providers in improving their services for customers?

Answer. MOBILE NOW helped jump-start our Nation's focus on mid-and high-band spectrum, which is critical to the deployment of 5G services. As you indicate, NTIA has undertaken a study of the 3450–3550 MHz band, which is currently allocated to the Defense Department. This band, adjacent to spectrum at 3.5 GHz and 3.7 GHz that is being considered for 5G services, could be combined with those airwaves to offer a wide swath of mid-band spectrum that offers economies of scale and beneficial technical characteristics for next-generation wireless broadband.

CTIA strongly supports NTIA's efforts so that the U.S. can keep pace with countries around the world that are taking steps to allocate mid-band spectrum for mobile broadband. Overall, the U.S. ranks 6th globally in terms of mid-band spectrum availability, and expedited review of the 3450–3550 MHz band could enhance our Nation's competitive position and provide access to much-needed 5G spectrum.

Historically, it can take 10 years or more from the time a spectrum band is identified as a candidate for commercial reallocation to the time commercial deployments begin in the band. Accordingly, we have encouraged NTIA to complete its study expeditiously, so that all stakeholders—including NTIA, DoD, the FCC, and industry—can move on to the next steps necessary to realize the benefits of commercial reallocation of this band while ensuring critical national security objectives remain protected.

Response to Written Questions Submitted by Hon. Dan Sullivan to Hon. Meredith Attwell Baker

Question 1. We're here today because of the excitement and anticipation of the rollout of 5G networks. In these conversations, I always make the joke that in my state, we are still trying to get to 2G in far too many communities. Jokes aside, it's a very important conversation to have, and just because many places in the United States have a lot of progress to make before they can realistically look forward to the consumer experience that 5G would bring, doesn't mean we shouldn't enthusiastically support its deployment. As we draft policy in the Senate to encourage 5G, what advice can you provide regarding how to ensure rural does not get left behind? Also, what benefits could rural see from the deployment of 5G?

Answer. Alaska presents unique challenges for broadband deployment—including sparse populations over expansive areas that contain extremely difficult topography and conditions. I agree we need to both expand coverage to those areas unserved today while we also move forward to compete globally for 5G service.

I'm proud of our industry's efforts to reach more and more Americans. According to government data, we connect over 99 percent of Americans, but we have more work to do in Alaska and other rural areas around the country. The good news is Congress has proposals before it that would address both challenges.

First, the U.S. needs a long-term spectrum plan to provide the certainty companies need to invest in 5G services. A growing bipartisan consensus has emerged in

Congress in support of the AIRWAVES Act—legislation that provides a five-year schedule for future spectrum auctions as well as a rural dividend to fund deployment in unserved and underserved areas (as discussed below).

Second, we need the FCC and Congress to update its nationwide guidelines for how localities treat siting requests. State and local rules for wireless infrastructure have not kept pace with innovative new technologies and network architecture. Chairman Thune and Senator Schatz's STREAMLINE Small Cell Deployment Act is the right approach. By modernizing these rules, policymakers can drive down the cost of deployment, helping enable more deployments in more areas.

5G will be faster, have more capacity, be more responsive, and will connect more rural Americans to friends and family, to healthcare and transportation services, as well as job opportunities and educational resources. In addition, every industry, including farming, healthcare, energy, transportation, law enforcement, e-commerce, logistics, and education will be positively impacted by the deployment of 5G infrastructure and products. As wireless unlocks new services in other industries, we can help bring these benefits to more of rural America. For example, wireless connectivity helps enable remote access and telemedicine, reducing unnecessary costs and ensuring that time and distance are not barriers to early interventions and preventative care for Alaskans and all rural Americans.

Question 2. I am very interested in the AIRWAVES Act's direction to the FCC to allocate 10 percent of the auction proceeds to create a fund supporting wireless infrastructure in unserved or underserved areas. Can you share any details about how the funds would be disseminated, and in the absence of clarity in the bill currently, share your recommendations on how that rural funding mechanism should be allocated and dispersed?

Answer. CTIA supports the AIRWAVES Act, and believes the rural dividend is one of the most innovative solutions to expand rural broadband. The AIRWAVES Act will help bridge the digital divide and connect more rural communities across our country by providing more financial support for areas that are challenging to serve. If the dividend was in place for the last two auctions—the incentive auction and the AWS–3 auction—over $6 billion would be newly available for wireless deployment in these areas. That's more than the entire FCC Mobility Fund will make available over the next ten years.

The rural dividend provisions in the AIRWAVES Act currently contemplate that the FCC would determine how to allocate the funds and what constitutes "underserved" and "unserved" areas. Such funds could not be combined with monies from other funding mechanisms, including the FCC's programs administered pursuant to Section 254 of the Communications Act. CTIA would welcome further clarity from Congress regarding how the funds distributed pursuant to the AIRWAVES Act would be allocated and dispersed and believes that available funds should go first to areas where there is limited service today, such as rural and remote Alaska.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. CATHERINE CORTEZ MASTO TO HON. MEREDITH ATTWELL BAKER

Urban Cellular Coverage Gaps

There was a recent article in the Las Vegas Review Journal that featured a map of where cellular coverage is still, in 2018, weak or nonexistent in the Las Vegas Valley. In this committee, we have talked a lot about access to broadband in rural areas, which is incredibly important for ensuring opportunity for all citizens, but having these coverage gaps in a major metropolitan area is unacceptable. As we know, because 5G will rely on millimeter waves, it will have a harder time penetrating obstacles like trees, walls, and windows.

Question 1. In the near to medium term, can we expect that 5G will mostly be available in heavily trafficked "hot spots?"

Answer. You are correct that 5G will use millimeter wave technology, which can help provide much faster speeds and better connectivity in high-traffic areas. That said, 5G will be deployed over low-, mid-, and high-band spectrum that will bring faster speeds and lower latency to consumers in both urban and rural areas.

Stepping back, when the wireless carriers began discussing 5G rollouts, the talk had been about rollouts of 5G networks in the 2020-plus timeframe. Because of the urgency of being first both nationally and globally, wireless carriers will be turning on these networks in 2018. Wireless carriers have announced cities nationwide that will have 5G networks this year, including Las Vegas, New York, Indianapolis, and Dallas, but also many mid-size cities, such as Raleigh, Oklahoma City, and Waco.

Question 2. In the longer term, how do we ensure that this technology is reaching all parts of a community and how is this challenge different from the current issues with 4G?

Answer. I'm proud of our industry's efforts to reach more and more Americans. According to government data, we connect over 99 percent of Americans, but there is more work to be done. The good news is Congress has proposals before it that will help address these challenges.

First, the U.S. needs a long-term spectrum plan to provide the certainty companies need to invest in 5G services. I am grateful for the Committee's engagement on spectrum policy and your co-sponsorship of the AIRWAVES Act. This legislation provides a five-year schedule for future spectrum auctions, and a rural dividend from auction revenues to fund deployment in rural areas (an amount that would have been in the billions if this provision had been in place during previous auctions).

Second, we need the Federal Communications Commission (FCC) and Congress to update guidelines for siting requests. The SPEED Act is a great step to ensure duplicative reviews do not slow down and add unnecessary costs to wireless infrastructure deployment. But state and local rules for wireless infrastructure have not kept pace with innovative new technologies and network architecture. The rules for 200-foot macro towers should not govern the installation of small cells. Chairman Thune and Senator Schatz have proposed a sensible approach to this problem in the STREAMLINE Small Cell Deployment Act. By modernizing siting rules, policymakers can speed the installation of necessary equipment and drive down the cost of deployment, helping enable broader deployments in more areas. The FCC also plays a critical role in expediting the deployment of wireless infrastructure and has taken significant steps to streamline the siting process. A recent study by Corning showed that siting reform efforts could lead to more than $2.5 billion in additional investment in rural and suburban areas.

Third, we need to continue to support Universal Service Fund (USF) programs such as the Mobility Fund to reach unserved communities. There are areas in the U.S. where it is not currently economic to serve with private capital alone and in these cases, there should be appropriate government support.

Rural Spectrum/Nevada

In Nevada we have two main metropolitan areas and the rest of the population lives in small towns and rural areas often separated by hundreds of miles. Many Senators on this committee know well the challenges of getting Internet services to these areas and we have worked in a bipartisan way to help address these challenges. But unlike a lot of states Nevada is covered in mountains, and pretty much every rural town is separated by at least one large mountain range which presents a large obstacle that may not exist in many other places around the country.

Question 3. What is being done with spectrum to bring fixed wireless to rural areas and what challenges remain with some of this low and mid band spectrum?

Answer. CTIA's member companies currently offer fixed wireless as a way to bring broadband to more consumers, and we recognize the value of having a mix of technologies in providing solutions to consumers' broadband needs. Recently, U.S. Cellular announced it would be offering a fixed wireless broadband product to rural customers where a wired connection may not exist. I expect wireless broadband providers will continue to invest in and leverage wireless connectivity to reach rural and other areas that have proved difficult to serve via wired connections.

Having a robust mix of low-, mid-, and high-band spectrum is essential to meeting the connectivity demands of consumers. One of the benefits of low-band spectrum is that it can cover vast areas, and can make it more cost effective to serve geography where there are fewer consumers. While mid-band spectrum does not travel as far as low-band, it does allow for faster speeds, creating a beneficial blend of coverage and increased speeds.

More spectrum, low-, mid- and high-bands, will need to be reallocated to commercial broadband usage to meet the growing needs of consumers. As we saw with the broadcast incentive and AWS–3 auctions, there is high demand for these bands, as these licenses brought billions of dollars. Like their urban counterparts, rural consumers are using more data. We need to find new opportunities to allocate spectrum resources that are best suited to meet this burgeoning demand.

Particularly with regard to mid-band spectrum, we need to get moving. The U.S. currently ranks 6th globally in terms of mid-band spectrum availability. We are pleased that NTIA is studying the 3450–3550 MHz band, and hope for an expeditious review. We are also encouraging the FCC to finalize its rules for the 3.5 GHz band, and are pleased that the agency has opened a proceeding considering the 3.7

GHz band for 5G services. Swift action in these areas will mean better coverage and faster speeds for more Americans.

Question 4. What would you recommend Congress do to free up some of this spectrum specifically?

Answer. CTIA is a strong supporter of the AIRWAVES Act—legislation that will help bridge the digital divide and connect more rural communities across our country by directing the auction of specific spectrum bands over the next five years for wireless broadband. Additionally, the AIRWAVES Act would provide financial support for areas that are more challenging to serve by devoting 10 percent of auction revenues to building wireless in rural areas. If the dividend was in place for the last two auctions—the incentive auction and the AWS–3 auction—over $6 billion would have been available for wireless deployment. That is more than the entire FCC Mobility Fund will make available for rural broadband over the next ten years. Thank you for your co-sponsorship of this critical legislation.

Question 5. What are the challenges posed by areas with large obstacles, such as mountain ranges?

Answer. Mountains and other difficult topography present challenges to broadband deployment—especially when there are sparse populations over expansive areas. To serve these areas, it is critical that appropriate spectrum, particularly low-band spectrum, be reallocated to bring greater coverage to these areas. Low-band spectrum's propagation characteristics are ideal to serve large areas with difficult topography. Second, reducing the costs to serve these areas will mean providers have the ability to cover more Americans. As detailed above, legislation such as the SPEED Act and STREAMLINE Small Cells Act will reduce duplicative or non-related fees, which can unnecessarily drive up the cost of deploying service. I would further point out that these are the exact types of areas that can be uneconomic to serve with private capital alone. The Mobility Fund plays a crucial role in building wireless networks in these areas, and we should continue to look at new funding models, such as the rural dividend as envisioned in the AIRWAVES Act.

Spectrum Leasing

In the MOBILE NOW Act, Congress is requiring the FCC, in coordination with the NTIA, to conduct a study on "bidirectional" spectrum sharing. The idea behind bidirectional sharing is that Federal agencies are able to share spectrum with commercial users without limiting access for themselves because it is done with bands that are able to be used in geographically separate locations or are otherwise compatible with the commercial user's needs.

Question 6. What is being done with spectrum to bring fixed wireless to rural areas and what challenges remain with some of this low and mid band spectrum?

Please see the answer above regarding fixed wireless.

Question 7. What are some of the challenges, and what can Congress do, to advance this concept and ensure it works for both Federal agencies and the commercial sector?

Answer. It is important to stress that the wireless services we enjoy today are built on the foundation of licensed, exclusive use spectrum. As consumers increasingly live mobile-first lives and with 5G being rolled out now, we need to continue to focus on that approach. That said, we recognize that sharing regimes can play an important limited role in meeting the needs of the wireless industry and Federal agencies alike. Wireless carriers are open to exploring further ways to allow Federal users to leverage commercial spectrum and networks to help serve mission-critical functions.

The FCC's current sharing experiment in providing commercial access to government spectrum at 3.5 GHz may provide valuable lessons. We would encourage policymakers await an evaluation of that sharing experience before exploring additional new and novel spectrum approaches.

With respect to 3.5 GHz, in 2015, the FCC approved a three-tiered, experimental sharing framework to make up to 150 megahertz in the 3.5 GHz band available for wireless use. Initially proposed over five years ago, this sharing regime represents an important technical and policy experiment, and CTIA has been committed to exploring this new approach to spectrum management.

In this three-tiered sharing framework, existing government users like the U.S. Navy would occupy Tier 1, license holders (to be determined by auction) would occupy Tier 2, and those seeking opportunistic use—similar to unlicensed bands—would occupy Tier 3.

These tiers will operate through Spectrum Access System (SAS) databases, which will contain information about use of the 3.5 GHz spectrum, including by incumbent operators. The SAS Administrator will authorize use of the airwaves, playing a role

in protecting higher-tier users from interference. More specifically, SAS Administrators will coordinate frequency assignments based on channel requests from users by using sensing technology to detect if higher-tier users, like Navy radar systems, are present.

The 3.5 GHz regime is an experiment and we commit to working with the Administration, Congress, and other stakeholders to evaluate how this novel sharing mechanism works, as well as if, and where, it would be appropriate to use again for other spectrum bands where clearing spectrum is particularly challenging. Key to ensuring a successful experiment are rules changes the FCC is considering right now to ensure that Tier 2 auction winners have the certainty and rights they will need to invest in the band.

Workforce Development

According to a recent report by Accenture, speeding up the timeline for 5G could add up to $100 billion to the U.S. economy. 5G will enable countless new innovations in things such as unmanned aerial vehicles and smart communities, in both urban and rural areas, and I've been proud to introduce bipartisan legislation to reduce regulatory barriers for 5G and encourage the growth of these technologies. At the same time, it is crucial that, as we work to ensure the United States is the global leader in 5G, the workforce is prepared for these new jobs and that opportunity is available to people from every zip code.

Question 8. What challenges do you face when hiring workers?

Answer. An educated workforce is essential for the United States' continued leadership in all areas of the economy, and that is true for the wireless industry as well. The varying skillsets needed to power the wireless industry, from erecting towers, to network engineering, to customer service, and software development, are all critical to providing world class networks. As an example, AT&T earlier this year began a $1 billion reskilling program to retrain half of its workforce. They are not alone. Many of CTIA's member companies have educational programs aimed at today's students to ensure they are developing the skills that will be needed not just in the wireless industry, but throughout the broader economy.

Question 9. What are the primary areas/qualifications/skill sets that Congress should focus on as we prepare our workforce for 5G?

Answer. One area in particular Congress could continue to focus on is Science, Technology, Engineering and Mathematics (STEM) education. The skillsets developed through STEM will help prepare Americans for careers in telecommunications and technology, ensuring that the next generation of innovators thrives here in the U.S.

5G Cybersecurity

With the huge increase in connected devices that is projected to occur as we transition to 5G, it is critical that we keep cybersecurity in mind as a key feature of America's leadership on this technology. As you know, 2G rogue base stations, which are fake base stations designed to lure a phone into connecting are able to access sensitive information. If a bad actor is able to use technology like a jammer to downgrade a mobile device connection to 2G, it can still be vulnerable even though 3G and up have better security standards.

Question 10. What challenges are there with 5G that we should be aware of given the massive increase in connected devices?

Answer. The wireless industry continually works to enhance the security of its networks and improve security capabilities with every generation of technology. 5G builds upon the capabilities of previous generations of wireless technologies and will add additional security features such as enhanced privacy protections, the ability to leverage 5G home-network wireless security to extend to Wi-Fi and when roaming, and device-specific security updates.

5G is up to 100 times faster, five times more responsive, and able to support 100 times more devices—thereby accommodating the massive increase in connected devices. In preparation for this growth in the Internet of Things (IoT), CTIA and the wireless industry recently announced an IoT Cybersecurity Certification program for connected devices as a complement to the many security features built into the wireless networks of today and tomorrow.

The IoT Cybersecurity Certification program is the first of its kind to be developed in collaboration with the nationwide wireless providers and builds upon IoT security recommendations from the National Telecommunications and Information Administration (NTIA) and the National Institute of Standards and Technology (NIST). By offering certification for IoT devices built from the ground up with cybersecurity in mind, the program will protect consumers and wireless infrastructure, while cre-

ating a more secure foundation for smart cities, connected cars, mHealth and other IoT applications.

Question 11. Recognizing the 2G is still a standard for some rural areas, how can Congress balance the need to promote connectivity in these regions with ensuring that these more vulnerable networks are put out of commission?

Answer. Rural carriers have already upgraded 2G networks or are in the process of upgrading to 3G and 4G, and the industry has provided tools on mobile devices for consumers to manage and limit 2G connectivity. Ovum data indicates the share of 2G in the U.S. at 0.3 percent and quickly declining. As 5G continues to gain momentum, global economies-of-scale will further drive and accelerate the decommissioning of 2G technology.

I would like to reemphasize the importance of both the Mobility Fund and the rural dividend in the AIRWAVES Act in achieving this connectivity. The Mobility Fund will provide support for areas that lack 4G coverage. This means that an area that has only 2G service would be eligible for support to transition to a modernized network. Additionally, the rural dividend would also play a meaningful role in connecting rural Americans with fast, secure networks.

Private Industry

As you are aware, the Trump administration has suggested that nationalizing the 5G network could be necessary for national security. Senator Cruz and I have introduced the E–FRONTIER Act, which protects private networks from nationalization unless specifically authorized by Congress.

Question 12. What are the benefits for consumers of private industry operating the national 5G network?

Answer. Today, the wireless industry supports 4.7 million jobs and contributes $475 billion each year. That accounts for 2.6 percent of America's GDP, making the U.S. wireless industry the 24th largest economy in the world. Every wireless job creates an additional 7.7 jobs throughout the broader economy, making the industry's contribution bigger than full-service restaurants and hardware manufacturing. Wireless jobs also pay about fifty percent more than the average American job.

The wireless industry has not been content to rest on past success and leadership. Instead, the industry works relentlessly to improve our networks with faster speeds and innovative services for consumers, and 5G will be no different.

Simply put, the United States leads the world in wireless and leadership from commercial providers has delivered significant benefits to the larger economy. That success is based on supporting commercial networks and private deployments. And right now, carriers are rapidly deploying 5G networks in cities across the country—networks that will add 3 million additional jobs and $500 billion in economic growth. As the industry is poised to invest $275 billion more as we move to 5G networks, I am confident that consumers will be the ultimate winners.

I also want to thank you for your leadership in introducing the E-Frontier Act. This is an important measure to ensure we do not jeopardize these consumer benefits by unnecessarily nationalizing wireless networks. The Federal Government has wisely created policies that put spectrum in the hands of the private sector companies that are building 5G right now. I want to stress that since the introduction of the E-Frontier Act, we have seen significant deployment and important announcements showing the private sector is more than up to the task to build globally competitive 5G networks.

Efforts now to divert much needed spectrum or other resources to government-run systems or experimental approaches would only serve to slow down the growth of the wireless sector, and ultimately the substantial 5G benefits to consumers. Congress can ensure that the key 5G spectrum bands are auctioned to the commercial users building 5G as soon as practicable. Thank you for recognizing that the most dynamic innovation develops through the private sector, and protecting industry investment in the networks that make this innovation possible.

Question 13. What are the benefits for rural and marginalized communities?

Answer. The ability to connect to friends and family, to healthcare and transportation services, to job opportunities and educational resources, is vital for all Americans. 5G will bring more of these opportunities to even more Americans. I'm proud of our industry's efforts to reach more and more Americans. I also recognize more needs to be done. That's why it is so important we get the spectrum and siting policies right so that every American community has access to the connectivity and power of wireless networks. I also would encourage the government to continue policies that help fund connectivity to these communities. The FCC's Universal Service programs, such as the Mobility Fund and Lifeline, are designed to reach these communities. Coupled with new mechanisms such as the AIRWAVES Act's rural divi-

dend, these policies will help ensure all Americans can reap the benefits of wireless connectivity.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN THUNE TO DEAN R. BRENNER

Question 1. You mentioned that Qualcomm is developing versions of 5G that will use new spectrum sharing techniques better than possible today in any unlicensed band. Can you explain what that will look like?

Answer. As I explained at the hearing, Qualcomm is developing two versions of 5G that will be optimized for deployment in shared spectrum bands. The first version is a 5G-based evolution of the spectrum sharing techniques used in 4G known as Licensed Assisted Access or LAA. 4G-based LAA has been deployed in the U.S. and around the world, and it is significantly improving 4G mobile broadband for consumers.

The second version uses revolutionary new spectrum sharing techniques that will in fact substantially improve the user experience in shared spectrum over what is possible today. Let me explain this. LAA, Wi-Fi and other existing technologies all enable spectrum sharing based on time. Under this existing technique, each user on a shared channel uses a shared channel for its proportionate share of the time, but each user must be silent when awaiting its turn to use the channel. So, if there are ten users on a shared channel, each user uses the spectrum for one-tenth of the time and is silent for nine-tenths of the time.

The new 5G spectrum sharing techniques that Qualcomm is developing are spatial-based—spectrum is shared by enabling users to use a shared channel in different directions so that each user can use the shared channel simultaneously. 5G uses a very fast new radio, and each 5G base station and device has many antennas that transmit and receive in very narrow, highly directional beams. The new spectrum sharing technique takes advantage of these attributes. So, under this new technique that Qualcomm is developing, if there are ten users on a shared channel all using this new technique, each user can use the spectrum for 100 percent of the time and will not interfere with one another by transmitting in different directions, instead of being able to use the channel for only one-tenth of the time as is the case today. This technique substantially increases the overall capacity of a shared channel for all users, increases the efficiency and utilization of spectrum, and enables a vastly better mobile broadband experience for each user.

More information about our work on this new spectrum sharing technique is available on this website: *https://www.qualcomm.com/invention/5g/spectrum-sharing.*

Question 2. A July 1, 2018, Politico article, "Telcogeopolitics: West vs. China in 5G Race," reported that "Over the last two years, Huawei, ZTE and other Chinese players have increased their share of patents underpinning the global standards—the higher the amount of intellectual property a company holds in the overall global telecoms rulebook, the greater control it can exert on how the mobile technology will be used." The article also stated that "Qualcomm alone accounts for more than 15 percent of current 5G patents," while Nokia—a Finish company—accounts for 11 percent and Ericsson—a Swedish company—holds roughly 8 percent of 5G patents. Is that report accurate? Can you describe how Qualcomm is engaging in the 5G standards-setting process and what the U.S. needs to do to maintain our leadership in the race to develop and commercialize 5G technology?

Answer. Qualcomm is exercising leadership in the development and standardization of 5G, just as it has for prior generations of wireless technology. Here is some additional information on the 5G standards process and Qualcomm's role.

5G, which is formally known as 5G New Radio or 5G NR, is being developed in a global industry standardization group called 3GPP. Cellular communications are based on standards. Therefore, many of the innovations in cellular technology go through a standardization process in 3GPP. Virtually all companies involved in cellular communications around the world participate in 3GPP. This includes U.S. companies such as Qualcomm, all of the U.S. cellular carriers, and other U.S. tech companies, and it also includes participants from diverse areas such as automotive, public safety and first responders, broadcasting and more. As noted, 3GPP is truly a global group with participants from all over the world. Several Chinese companies are also active members of 3GPP, a reflection of the growing penetration of smartphones and of cellular communication in China.

Qualcomm has been part of 3GPP from its inception and has been a very active participant for quite a long time. Qualcomm is a major contributor to 3GPP's work, and a large number of the advancements in cellular communications over the years

standardized in 3GPP originate from Qualcomm. The same has been true during the 5G standardization process. A significant number of Qualcomm's innovations in key aspects of 5G technology, including air interface design, protocol design, security and system architecture, have successfully gone through the 3GPP standardization process and have eventually been incorporated into the 5G standard. Thus, the 5G standard already includes many important innovations developed by Qualcomm.

Moreover, Qualcomm's technical work in developing additional important aspects of 5G—such as the technologies referred to in my answer to Question 1 above—and our leadership in standardizing them in 3GPP is ongoing.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. CATHERINE CORTEZ MASTO TO DEAN R. BRENNER

Urban Cellular Coverage Gaps

There was a recent article in the Las Vegas Review Journal that featured a map of where cellular coverage is still, in 2018, weak or nonexistent in the Las Vegas Valley. In this committee, we have talked a lot about access to broadband in rural areas, which is incredibly important for ensuring opportunity for all citizens, but having these coverage gaps in a major metropolitan area is unacceptable. As we know, because 5G will rely on millimeter waves, it will have a harder time penetrating obstacles like trees, walls, and windows.

Question 1. In the near to medium term, can we expect that 5G will mostly be available in heavily trafficked "hot spots?"

Answer. Qualcomm is the world's leading developer of chips for smartphones and other wireless devices and the world's leading inventor and licensor of new wireless technologies. Our inventions are deployed throughout the wireless ecosystem by wireless operators, infrastructure vendors and handset manufacturers. Our focus for the last several years has been on ensuring that 5G will be available as soon as possible and as widely as possible. For example, under our leadership, 3GPP, which is the international standards body involved in developing the 5G standard, a decision was reached to advance the date for finalizing the initial 5G standard, known as "Release 15," by one year. We did this to enable consumers to benefit from the promising new features of 5G as soon as possible. 5G will take advantage of all types of spectrum—low, mid and high band, (including millimeter wave)—and all regulatory paradigms, including licensed, unlicensed and shared. Each type of spectrum has both advantages and disadvantages. While signals travelling over millimeter wave spectrum have harder time penetrating obstacles, the millimeter wave bands do allow for wider swaths of spectrum and therefore higher capacity and higher speeds. Low band spectrum allows for signals to travel farther and therefore can enable network operators to deploy new technology at lower cost. Low band spectrum is especially well-suited for rural areas where the economic case for technology upgrades is more challenging. Qualcomm is not actually involved in deciding where 5G will be deployed, but our efforts in making 5G available as soon as possible and as widely as possible will benefit both rural and urban areas.

Question 2. In the longer term, how do we ensure that this technology is reaching all parts of a community and how is this challenge different from the current issues with 4G?

Answer. Making as much spectrum available as possible as soon as possible is critical to ensure that 5G technology reaches the most people. In addition, it's essential that regulations regarding small cell deployments keep pace with technology. Today 4G-based small cell deployments are occurring around the country, and this process will need to continue and accelerate for 5G to be successful. Congress should enact the STREAMLINE Small Cell Deployment Act to ensure that 5G infrastructure build-out is not impeded by outdated regulations.

Rural Spectrum/Nevada

In Nevada we have two main metropolitan areas and the rest of the population lives in small towns and rural areas often separated by hundreds of miles. Many Senators on this committee know well the challenges of getting Internet services to these areas and we have worked in a bipartisan way to help address these challenges. But unlike a lot of states Nevada is covered in mountains, and pretty much every rural town is separated by at least one large mountain range which presents a large obstacle that may not exist in many other places around the country.

Question 3. What is being done with spectrum to bring fixed wireless to rural areas and what challenges remain with some of this low and mid band spectrum?

Answer. Low and mid band spectrum is the key to improving rural broadband, not just with fixed wireless, but also with mobile broadband, including Gigabit LTE and soon, 5G. A challenge with low and mid band spectrum has been making the transition from older uses, such as television broadcasting, to mobile broadband uses, such as video streaming, and eventually the many new use cases that 5G will enable, such as autonomous driving and the massive Internet of things.

Question 4. What would you recommend Congress do to free up some of this spectrum specifically?

Answer. Congress did the right thing in the *Middle Class Tax Relief Act of 2012* by requiring the FCC to conduct an auction to repurpose the 600 MHz spectrum from television broadcast use to commercial mobile broadband, which will include 5G. In 2017, the FCC completed the auction, which was the world's first voluntary incentive auction, repurposing 84 megahertz of spectrum—70 megahertz for licensed use and another 14 megahertz for wireless microphones and unlicensed use. The auction yielded $19.8 billion, including $10.05 billion for broadcast bidders and more than $7 billion for deficit reduction.

With the auction completed, it's essential that Congress conduct regular oversight of the clearing process to ensure that television broadcasters currently occupying the 600 MHz band meet the 39-month deadline that the FCC established for clearing. In some cases, broadcasters have already vacated the spectrum, and it is being used today for 4G LTE, including Gigabit LTE, which provides a foundation for 5G. These locations will be ready to upgrade quickly to 5G as soon as it becomes available. In other cases, broadcasters continue to use the spectrum. It's imperative that Congress continue to monitor the process to ensure no slippage in the deadline.

In addition, Congress should enact the Spectrum NOW Act (S. 3010/H.R. 6017), which will help spectrum sharing, in particular mid-band spectrum. This spectrum is also very well-suited for improving rural broadband. More about the Spectrum NOW Act and Qualcomm's work on 5G and spectrum sharing can be found in this blog post.

Question 5. What are the challenges posed by areas with large obstacles, such as mountain ranges?

Answer. Areas with large obstacles, such as mountain ranges, pose unique challenges for wireless networks. Signals need to travel farther in rural areas, but if communities are separated by mountains, it can be challenging for wireless signals to get through. Ensuring a steady stream of low band and mid band spectrum is the key to improving rural broadband because signals can travel further in these frequencies.

Spectrum Leasing

In the MOBILE NOW Act, Congress is requiring the FCC, in coordination with the NTIA, to conduct a study on "bidirectional" spectrum sharing. The idea behind bidirectional sharing is that Federal agencies are able to share spectrum with commercial users without limiting access for themselves because it is done with bands that are able to be used in geographically separate locations or are otherwise compatible with the commercial user's needs.

Question 1. What is being done with spectrum to bring fixed wireless to rural areas and what challenges remain with some of this low and mid band spectrum*?*

Answer. Please see response to this question above.

Question 6. What are some of the challenges, and what can Congress do, to advance this concept and ensure it works for both Federal agencies and the commercial sector?

Answer. Spectrum leasing holds great promise to expand access to spectrum without hindering the Federal Government's use of the spectrum. Spectrum leasing occurs frequently in the private sector and is very successful. In some cases, the Federal Government has exclusive access to spectrum, but only makes use of it at certain times or in certain locations. Therefore, spectrum leasing could provide an economic incentive for Federal agencies to make portions of spectrum available to commercial entities in geographic locations or at times when they are not in use.

Workforce Development

According to a recent report by Accenture, speeding up the timeline for 5G could add up to $100 billion to the U.S. economy. 5G will enable countless new innovations in things such as unmanned aerial vehicles and smart communities, in both urban and rural areas, and I've been proud to introduce bipartisan legislation to reduce regulatory barriers for 5G and encourage the growth of these technologies. At the same time, it is crucial that, as we work to ensure the United States is the glob-

al leader in 5G, the workforce is prepared for these new jobs and that opportunity is available to people from every zip code.

Question 7. What challenges do you face when hiring workers?

Answer. At Qualcomm the greatest investment we can make as a company is in our employees. We believe strongly in the need for increasing access to STEM education through programs that reach and inspire students at all levels and from all backgrounds. More information about our work in this area is available here.

Question 8. What are the primary areas/qualifications/skill sets that Congress should focus on as we prepare our workforce for 5G?

Answer. We rely on software engineers, hardware engineers, and systems engineers to help us advance all facets of wireless technology, including 5G.

5G Cybersecurity

With the huge increase in connected devices that is projected to occur as we transition to 5G, it is critical that we keep cybersecurity in mind as a key feature of America's leadership on this technology. As you know, 2G rogue base stations, which are fake base stations designed to lure a phone into connecting are able to access sensitive information. If a bad actor is able to use technology like a jammer to downgrade a mobile device connection to 2G, it can still be vulnerable even though 3G and up have better security standards.

Question 9. What challenges are there with 5G that we should be aware of given the massive increase in connected devices?

Answer. There is no question that in the future there will be a massive increase in the number of connected devices and things and that 5G will enable this incredible growth in connectivity. In addition, so many industries will be impacted by that connectivity including in sensitive areas such as banking and health care. At Qualcomm, we are working on new ways to improve the security of devices, including robust authentication. Our Qualcomm Mobile Security platform is designed to provide three layers of security at the chip, device, and system levels. It's engineered to use hardware protections to more securely authenticate the user, validate a device's location, and confirm that the device isn't compromised. With this foundation, effective cybersecurity is achievable.

Question 10. Recognizing the 2G is still a standard for some rural areas, how can Congress balance the need to promote connectivity in these regions with ensuring that these more vulnerable networks are put out of commission?

Answer. Congress should focus on enacting the AIRWAVES Act, the STREAMLINE Small Cell Deployment Act, and the Spectrum NOW Act. Together, these bills will ensure a steady stream of low, mid and high band spectrum, and will modernize regulations that govern wireless infrastructure and will help advance 5G as soon as possible and as widely as possible. Advancing 5G is the best way to improve the security of the wireless ecosystem.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. JOHN THUNE TO
CRAIG T. COWDEN

Question. How will the launch of Spectrum Mobile change the competitive landscape in mobile wireless?

Answer. Charter is excited about the recent launch of our mobile wireless service in our regional footprint. Spectrum Mobile will combine Charter's robust indoor-outdoor WiFi network and Verizon's cellular network (a Mobile Virtual Network Operator –MVNO), to provide a high quality mobile service at a great value. The next step in our mobile evolution will be to deploy LTE licensed small cells and then 4G LTE and 5G wireless access technologies and integrate them with our existing infrastructure.

That said, providing mobile service through Charter's MVNO resale arrangement with Verizon is materially different from providing service as a nationwide or even regional facilities-based mobile carrier. The contractual and technical limitations of the MVNO agreement limit the competitiveness of Charter's mobile service.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. JERRY MORAN TO
CRAIG T. COWDEN

Question. I understand that there is support from both licensed and unlicensed spectrum-use communities for making mid-band spectrum available in wider blocks to maximize the usefulness of spectrum. From the perspectives of each of your respected companies and organizations, could you please describe your stance on wid-

ening the spectrum blocks for commercial use? If supportive, please describe a target size if able.

Answer. Charter is actively exploring the use of mid-band and high-band spectrum to deliver fixed and mobile wireless service to its customers. We're conducting 5G and 4G LTE trials using the 3.5 GHz band that is immediately adjacent to the 3.7–4.2 GHz band. Generally speaking, mid-band spectrum will be a critical part of the 5G story, because it allows more bandwidth than low-band spectrum, but also greater coverage than high-band spectrum. While we support the use of mid-band spectrum for 5G, it needs to be done carefully. Charter and other cable operators currently provide critical video services to over 50 million cable customers using this band. It's important for policy makers to ensure that consumers will not be harmed by reallocation and that existing users are fully compensated for costs incurred by changes in that band.

To that end, we believe that the 6 GHz spectrum band has long-term potential for unlicensed use and support the FCC examining this option later this year, although there are similar issues to address with the interference or reallocation management of existing incumbent users of the band. The 5.9 GHz band however is more of a near-term priority as it offers the opportunity for almost immediate enhancement of WiFi capacity without a need for costly new equipment or interference management, due to its location adjacent to the most-used WiFi band in the country. That said, the 5.9 GHz band offers a maximum of 75 MHz of spectrum, less than a 1/10th of the spectrum needed to meet the forecasted demand of future Wifi growth in 2025, as published in a recent study from the Wifi Alliance. So Charter is also interested in exploring the potential use of the 6 GHz band for long-term capacity growth of unlicensed spectrum.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. CATHERINE CORTEZ MASTO TO CRAIG T. COWDEN

Urban Cellular Coverage Gaps

There was a recent article in the Las Vegas Review Journal that featured a map of where cellular coverage is still, in 2018, weak or nonexistent in the Las Vegas Valley. In this committee, we have talked a lot about access to broadband in rural areas, which is incredibly important for ensuring opportunity for all citizens, but having these coverage gaps in a major metropolitan area is unacceptable. As we know, because 5G will rely on millimeter waves, it will have a harder time penetrating obstacles like trees, walls, and windows.

Question 1. In the near to medium term, can we expect that 5G will mostly be available in heavily trafficked "hot spots?"

Answer. Yes, which is why it is important to support policies that promote investment in all areas. To that end, Charter is investing in network infrastructure and actively conducting trials of innovative wireless access technologies to enable us to deliver next-generation wireline and wireless technologies to our customers in cities, suburban and rural areas. With additional unlicensed and licensed spectrum and technology neutral policies to spur competition and continued investment, I am optimistic consumer needs will continue to drive innovation in the years ahead.

Question 2. In the longer term, how do we ensure that this technology is reaching all parts of a community and how is this challenge different from the current issues with 4G?

Answer. Charter's experiences in the wireless market have made clear that the success of 5G requires a full range of wired and wireless technologies and a complete toolkit of unlicensed and licensed spectrum. We urge Congress and the FCC to ensure policies are technology-neutral and to search for ways to make both unlicensed and licensed spectrum available for wireless broadband.

Rural Spectrum/Nevada

In Nevada we have two main metropolitan areas and the rest of the population lives in small towns and rural areas often separated by hundreds of miles. Many Senators on this committee know well the challenges of getting Internet services to these areas and we have worked in a bipartisan way to help address these challenges. But unlike a lot of states Nevada is covered in mountains, and pretty much every rural town is separated by at least one large mountain range which presents a large obstacle that may not exist in many other places around the country.

Question 3. What is being done with spectrum to bring fixed wireless to rural areas and what challenges remain with some of this low and mid band spectrum?

Answer. Charter is actively testing to understand how different types of spectrum can be used to extend our existing wireline network and bring broadband services efficiently to more consumers, including those in rural areas. We have conducted extensive fixed wireless testing using 3.5 GHz spectrum and are encouraged by the results—we're seeing speeds that exceed the FCC's definition of high speed broadband, allowing for video streaming and the use of multiple apps simultaneously. We also recently submitted an application, granted just recently by the FCC, to conduct fixed wireless experiments in the 3.7–3.8 GHz band. We believe this mid-band spectrum could be used to extend the reach of our network and provide cost-effective, wireline-like connectivity to less densely populated areas.

Question 4. What would you recommend Congress do to free up some of this spectrum specifically?

Answer. Congress should pursue a balanced spectrum policy that promotes technological neutrality and makes more licensed and unlicensed spectrum available to spur greater innovation and competitiveness.

Question 5. What are the challenges posed by areas with large obstacles, such as mountain ranges?

Answer. Bringing broadband to rural and remote areas is expensive and complex, and requires multiple solutions. In some instances, it is not commercially viable to build wireline infrastructure over mountainous terrain and the reliability of wireless signals can be limited. 5G itself requires a network of small cells that transmits large amounts of data over short distances, which is probably not well suited to deliver broadband in very rural and mountainous areas. Charter continues to explore a range of wireline and wireless technologies to extend broadband services into less densely populated areas.

Spectrum Leasing

In the MOBILE NOW Act, Congress is requiring the FCC, in coordination with the NTIA, to conduct a study on "bidirectional" spectrum sharing. The idea behind bidirectional sharing is that Federal agencies are able to share spectrum with commercial users without limiting access for themselves because it is done with bands that are able to be used in geographically separate locations or are otherwise compatible with the commercial user's needs.

Question 6. What is being done with spectrum to bring fixed wireless to rural areas and what challenges remain with some of this low and mid band spectrum?

Answer. Charter is actively testing to understand how different types of spectrum can be used to extend our existing wireline network and bring broadband services efficiently to more consumers, including those in rural areas. We have conducted extensive fixed wireless testing using 3.5 GHz spectrum and are encouraged by the results—we're seeing speeds that exceed the FCC's definition of high speed broadband, allowing for video streaming and the use of multiple apps simultaneously. We also have filed an application, granted just recently by the FCC, to conduct fixed wireless testing in the 3.7–3.8 GHz band. We believe that this testing will advance our understanding of 5G technology and the potential of mid-band spectrum, which will help to advance the potential deployment of 5G fixed and mobile services.

Question 7. What are some of the challenges, and what can Congress do, to advance this concept and ensure it works for both Federal agencies and the commercial sector?

Answer. Congress should support policies that promote the innovative and efficient use of spectrum that is shared between government and the private sector. This can be done by making additional licensed and unlicensed spectrum available for commercial use, which will allow existing, as well as future, technologies, to continue to proliferate at the same time.

Workforce Development

According to a recent report by Accenture, speeding up the timeline for 5G could add up to $100 billion to the U.S. economy. 5G will enable countless new innovations in things such as unmanned aerial vehicles and smart communities, in both urban and rural areas, and I've been proud to introduce bipartisan legislation to reduce regulatory barriers for 5G and encourage the growth of these technologies. At the same time, it is crucial that, as we work to ensure the United States is the global leader in 5G, the workforce is prepared for these new jobs and that opportunity is available to people from every zip code.

Question 8. What challenges do you face when hiring workers?

Answer. Charter's workforce is the key to the success of our company. We are proud to employ 97,000 diverse employees in 41 states, having added over 20,000

American workers since 2012. However, like any increasing number of companies, we face challenges in attracting and retaining qualified technical workers, which is why we are committed to investing in our workforce. We ensure that every employee receives a minimum wage of $15 per hour, provide comprehensive medical and retirement benefits and opportunities for career advancement. We have found apprenticeships, with a particular emphasis on veterans, to be an effective means of recruiting, training and retaining the talent we need to service our customers. Earlier this year, Charter became one of the first companies to take advantage of the VALOR Act and approval of our U.S. Department of Labor registered broadband technician apprenticeship program to receive national approval for GI Bill benefits through the Department of Veterans Affairs. Charter also sees opportunities to expand the apprenticeship model to other key areas of our business.

Question 9. What are the primary areas/qualifications/skill sets that Congress should focus on as we prepare our workforce for 5G?

Answer. Charter heavily invests in employee training to ensure we have a 21st century workforce, which is why we recently expanded our Spectrum Broadband Technician Apprenticeship program to all 41 states in our footprint. We believe policies in this area should support private sector training programs that prepare Americans for the jobs of the 21st Century.

5G Cybersecurity

With the huge increase in connected devices that is projected to occur as we transition to 5G, it is critical that we keep cybersecurity in mind as a key feature of America's leadership on this technology. As you know, 2G rogue base stations, which are fake base stations designed to lure a phone into connecting are able to access sensitive information. If a bad actor is able to use technology like a jammer to downgrade a mobile device connection to 2G, it can still be vulnerable even though 3G and up have better security standards.

Question 10. What challenges are there with 5G that we should be aware of given the massive increase in connected devices?

Answer. With the explosion of devices, applications and use cases enabled by 5G, a continued focus on security is important. 4G/LTE security features offer a good baseline as well as a benchmark for 5G security. This is particularly true with respect to mobile broadband use cases. However, 5G must also be able to adopt more robust and flexible security concepts to support the additional uses cases envisioned for 5G besides mobile broadband, such as autonomous driving, industrial automation and IoT (Internet of Things).

Question 11. Recognizing the 2G is still a standard for some rural areas, how can Congress balance the need to promote connectivity in these regions with ensuring that these more vulnerable networks are put out of commission?

Answer. It is important that continued investment in 4G and 5G infrastructure occurs in all geographic areas, including rural America. The pace of this investment will allow for the eventual de-commissioning of 2G networks, which are more vulnerable to security attacks. In both 4G and 5G standards, security measures have been identified to protect the identity of the real mobile user, and to provide more robust authentication mechanisms. With these mechanisms in place, it is more difficult for rogue actors to steal the identify information of real users.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. CATHERINE CORTEZ MASTO TO TOM STROUP

Spectrum Leasing

In the MOBILE NOW Act, Congress is requiring the FCC, in coordination with the NTIA, to conduct a study on "bidirectional" spectrum sharing. The idea behind bidirectional sharing is that Federal agencies are able to share spectrum with commercial users without limiting access for themselves because it is done with bands that are able to be used in geographically separate locations or are otherwise compatible with the commercial user's needs.

Question 1. What is being done with spectrum to bring fixed wireless to rural areas and what challenges remain with some of this low and mid band spectrum?

Answer. While not considered traditional "fixed wireless" service, satellite communications services are positioned to be the keystone for bringing 21st century broadband capabilities to the entirety of the U.S. These services are capable of providing broadband to rural and remote areas of the country where it remains uneconomical for terrestrial services to deploy, and provide both speeds and prices comparable to terrestrial alternatives. These services are available directly to the con-

sumer today, covering all 50 states and delivering broadband offerings up to 100 megabits per second (Mbps). Satellite broadband is also used by business and government enterprises, for both fixed and mobile purposes, using a range of spectral bands to deliver assured access to broadband communications. Further, satellites are providing critical backhaul Internet connectivity to local Internet Service Providers and community institutions in remote locations.

Satellite service providers are always striving to improve and expand service so that all Americans can take advantage of its capabilities. Approximately 2 million customers nationwide are enjoying high-quality satellite broadband services at reasonable rates, and at speeds that meet and exceed the FCC's definition of broadband service. Commercial satellite operators, that have already invested billions of dollars in the construction and deployment of high throughput satellites, offer service to those consumers today, no matter where they are located.

The satellite industry is today investing tens of billions of dollars to innovate and increase broadband connectivity in the United States and across the globe. High throughput satellites, for example, rely on frequency re-use and spot beam technology to produce increased output factors upward of 20 times that of traditional satellites. The industry has seen similar increases in the capacity of its systems. The first broadband satellite began service in 2008 with a capacity of 10 gigabits per second (Gbps); today's satellites have capacities of up to 260 Gbps, a number expected to increase to 1000 Gbps by the end of the decade. These terabit capacity geostationary satellites will provide orders of magnitude capacity increases and resulting consumer broadband benefits, remaining competitive with terrestrial offerings.

In another highly-anticipated advancement in the industry, thousands of new high throughput (non-geostationary) satellites will soon join existing operators in Low-Earth and Medium-Earth orbits to provide additional high-speed broadband at low latency levels; prototypes of these satellites have already begun to launch. Existing high throughput satellites currently support the delivery of 3G and 4G services, as well as enable global machine-to-machine communications. Future satellite fleets will be a part of a system architecture that delivers new 5G, IoT, and intelligent, connected transportation services to consumers.

Question 2. What are some of the challenges, and what can Congress do, to advance this concept and ensure it works for both Federal agencies and the commercial sector?

Answer. Because of the many different types of services that use spectrum, each band and sharing scenario may offer different challenges and opportunities. Generally, Congress can help ensure minimal disruption and interference to incumbent operations by requiring that new entrants into any frequency band design its system to share with the incumbents since that is more efficient than requiring existing operators in a band to retrofit or otherwise modify its system. In some cases, sharing may not be possible and Congress should reflect this in its legislation and views.

Workforce Development

According to a recent report by Accenture, speeding up the timeline for 5G could add up to $100 billion to the U.S. economy. 5G will enable countless new innovations in things such as unmanned aerial vehicles and smart communities, in both urban and rural areas, and I've been proud to introduce bipartisan legislation to reduce regulatory barriers for 5G and encourage the growth of these technologies. At the same time, it is crucial that, as we work to ensure the United States is the global leader in 5G, the workforce is prepared for these new jobs and that opportunity is available to people from every zip code.

Question 3. What challenges do you face when hiring workers?

Answer. Like most technology industries, the satellite industry needs employees with STEM backgrounds. Policies that encourage STEM education at an early age will be beneficial to our industry's ability to grow.

Question 4. What are the primary areas/qualifications/skill sets that Congress should focus on as we prepare our workforce for 5G?

Answer. As noted above, STEM skill sets are important to employees within the satellite industry.

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