IMPROVING FEDERAL SPECTRUM SYSTEMS

HEARING

BEFORE THE

SUBCOMMITTEE ON COMMUNICATIONS AND TECHNOLOGY

OF THE

COMMITTEE ON ENERGY AND COMMERCE

HOUSE OF REPRESENTATIVES

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CONTENTS

	Page
Hon. Greg Walden, a Representative in Congress from the State of Oregon, opening statement	1
Prepared statement	3
Hon. Anna G. Eshoo, a Representative in Congress from the State of California, opening statement	4
Hon. Marsha Blackburn, a Representative in Congress from the State of Tennessee, opening statement	5
Hon. Frank Pallone, Jr., a Representative in Congress from the State of New Jersey, opening statement	6
Prepared statement	7
Hon. Fred Upton, a Representative in Congress from the State of Michigan, prepared statement	60
WITNESSES	
Phillip Berenbroick, Counsel, Government Affairs, Public Knowledge	9
Prepared statement	11
Dennis A. Roberson, Vice Provost, Research Professor in Computer Science, Illinois Institute of Technology	16
Prepared statement	18
Jeffrey H. Reed, Willis G. Worcester Professor of Electrical and Computer Engineering, Virginia Polytechnic Institute and State University	26
Prepared statement	28

IMPROVING FEDERAL SPECTRUM SYSTEMS

WEDNESDAY, OCTOBER 7, 2015

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

The subcommittee met, pursuant to call, at 10:15 a.m., in Room 2322 Rayburn House Office Building, Hon. Greg Walden [chairman of the subcommittee] presiding.

Members present: Representatives Walden, Latta, Shimkus, Blackburn, Lance, Guthrie, Olson, Bilirakis, Johnson, Long, Ellmers, Collins, Cramer, Eshoo, Welch, Clarke, Loebsack, DeGette, Butterfield, and Pallone (ex officio).

Staff present: Ray Baum, Legislative Associate, Energy and Power; Rebecca Card, Assistant Press Secretary; Andy Duberstein, Deputy Press Secretary; Gene Fullano, Detailee, Subcommittee on Communications and Technology; Kelsey Guyselman, Counsel, Subcommittee on Communications and Technology; Grace Koh, Counsel, Subcommittee on Communications and Technology; Tim Pataki, Professional Staff Member; David Redl, Counsel, Subcommittee on Communications and Technology; Charlotte Savercool, Legislative Clerk; Greg Watson, Legislative Clerk; Jeff Carroll, Staff Director; David Goldman, Chief Counsel, Subcommittee on Communications and Technology; Jerry Leverich, Counsel; Lori Maarbjerg, Detailee, FCC; and Ryan Skukowski, Policy Analyst.

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

Mr. WALDEN. I am going to call to order the subcommittee on Communications and Technology and our hearing on improving federal spectrum systems.

During my time as chairman of this subcommittee, one of the most important topics that we have addressed is spectrum, how to better use it, how to allocate it and how to value it. And through our work, we found bipartisan agreement on many of the policy issues around this valuable resource.

Three-and-a-half years ago, the Congress passed the Middle Class Tax Relief and Job Creation Act that included the spectrum incentive auction provisions the subcommittee brought to the table. And it properly conducted the upcoming broadband incentive auction and will successfully free up a wide swath of valuable spectrum for new purposes. But with worldwide demand for wireless connectivity expected to grow 400 percent in the next 3 years, and

given that the U.S. Government is nowhere close to meeting the goal of repurposing 500 megahertz as called for in the national broadband plan, it is clear we have more work to do.

One way we can continue to free up additional spectrum is through the use of the Commercial Spectrum Enhancement Act. Under the SCEA, commercial providers bear the cost of moving federal incumbents to clear spectrum. Given the budgetary pressures facing the country and the significant challenges our defense agencies face as a result of fiscal belt tightening, I think we have an opportunity to work together to optimize the value of under utilized spectrum and upgrade equipment and services used by the federal agencies.

Although there are many hurdles to overcome in clearing and reallocating federally-held spectrum, we have proven it can be done with great success. The best example of this is the AWS–3 Auction which made 65 megahertz of spectrum available for wireless broadband and raised more than $44 billion.

The AWS–3 Auction worked. Now let us move forward by giving agencies new tools that will allow them to become more innovative and efficient in how they use spectrum.

Under current law, federal spectrum users receive compensation for relocating spectrum-based systems and can upgrade equipment to further their mission. Carriers get the opportunity to purchase a resource that they desperately need and above all, consumers love better mobile broadband service allowing them to access the services and information they so clearly want and need.

Building on this successful process, today we are considering two pieces of legislation that will help move America forward. First, Representatives Guthrie and Matsui's Federal Spectrum Incentive Act allows interested agencies to take part in an incentive auction where they are compensated for relinquishing spectrum through auction proceeds. Currently, agencies are only allowed to be reimbursed for sharing or relocating. This legislation would actually incentivize agencies to take a hard look at their spectrum use and to give up the spectrum that they do not need.

We are also considering a bill that would require the FCC to report back to Congress with draft auction plans. Now this legislation is intended to help establish a more consistent and predictable supply of spectrum going forward through a formal process between the Congress, the FCC, and NTIA and other agencies.

While the speed of innovation and technology is blindingly fast, the time line for reallocating spectrum often is reflective of the tangled bureaucracy of government, and the fiscal and operational restraints on agencies. This conflict illustrates the urgent need for legislation to reform the federal system, bring about predictable and transparent auction rules, and provide clear incentives for agencies to free up under used or unneeded spectrum.

We can move forward on this front while at the same time making sure agencies who rely on the resource for mission-critical operations have the most modern communications technology in the world.

I would like to thank Ranking Member Pallone and Representative Clarke for working with us on this bipartisan discussion draft and I look forward to our continued collaboration with all the mem-

bers of the subcommittee. Working together we can provide the framework and incentives to increase efficiency, upgrade government systems, and make more spectrum available to meet our country's wireless broadband needs and raise a little money for the taxpayers. With that, I will yield the balance of my time to the gentleman from Ohio, Mr. Latta.

[The prepared statement of Mr. Latta follows:]

PREPARED STATEMENT OF HON. GREG WALDEN

During my time as chairman of this subcommittee, one of the most important topics that we've addressed is spectrum—how to better use it, how to allocate it, how to value it. And through our work we've found bipartisan agreement on many of the policy issues around this valuable resource.

Three-and-a-half years ago Congress passed the Middle Class Tax Relief and Job Creation Act, including the spectrum incentive auction provisions this subcommittee brought to the table. If properly conducted, the upcoming broadband incentive auction will successfully free up a wide swath of valuable spectrum for new purposes. But with world-wide demand for wireless connectivity expected to grow 400 percent in the next three years, and given that the U.S. government is nowhere close to meeting the goal of repurposing 500 MHz as called for in the National Broadband Plan, it's clear we have more work to do.

One way we can continue to free up additional spectrum is through use of the Commercial Spectrum Enhancement Act. Under the CSEA, commercial providers bear the cost of moving federal incumbents to clear spectrum. Given the budgetary pressures facing the country—and the significant challenges our defense agencies face as a result of fiscal belt-tightening—we have an opportunity to work together to optimize the value of underutilized spectrum and upgrade equipment and services used by federal agencies.

Though there are many hurdles to overcome in clearing and reallocating federally held spectrum, we have proven it can be done to great success. The best example of this process is the recent AWS–3 auction, which made 65 MHz of spectrum available for wireless broadband and raised more than $44 billion.

The AWS–3 auction worked. Now, let us move forward by giving agencies new tools that will allow them to become more innovative and efficient in how they use spectrum.

Under current law, federal spectrum users receive compensation for relocating spectrum-based systems and can upgrade equipment to further their mission. Carriers get the opportunity to purchase a resource they desperately need, and above all, consumers will have better mobile broadband service, allowing them to access the services and information they so clearly want and need.

Building on this successful process, today we are reviewing two pieces of legislation that will help move America forward. First, Representatives Guthrie and Matsui's Federal Spectrum Incentive Act allows interested agencies to take part in an incentive auction where they are compensated for relinquishing spectrum through auction proceeds. Currently, agencies are only allowed to be reimbursed for sharing or relocating—this legislation would incentivize agencies to take a hard look at their spectrum use and to give up the spectrum they don't need.

We're also reviewing a bill that would require the FCC to report back to Congress with draft auction plans going forward. This legislation is intended to help establish a more consistent and predictable supply of spectrum going forward through a formal process between the Congress, the FCC, the NTIA, and other agencies.

While the speed of innovation in technology is blindingly fast, the timeline for reallocating spectrum often is reflective of the tangled bureaucracy of government, and the fiscal and operational restraints on agencies. This conflict illustrates the urgent need for legislation to reform the federal system, bring about predictable and transparent auction rules, and provide clear incentives for agencies to free up underused, or unneeded, spectrum.

We can move forward on this front while at the same time making sure agencies who rely on the resource for mission-critical operations have the most modern communications technology available.

I'd like to thank Ranking Member Pallone and Representative Clarke for working with us on this bipartisan discussion draft and I look forward to our continued collaboration. Working together we can provide the framework and incentives to increase efficiency, upgrade government systems, and make spectrum available to meet our country's wireless broadband demand.

Mr. LATTA. Well, I thank the chairman for yielding and this subcommittee has long recognized a demand for wireless spectrum capacity as technologically advanced products and devices are becoming an integral part of our everyday lives.

In 2014, the number of mobile-connected devices exceeded the world's population. It is clear that in order to accommodate advanced mobile innovation we must examine every avenue to expand access to spectrum. That is why we are here today. The Federal Government is the largest single user of spectrum. Therefore, we have the challenging opportunity to make spectrum currently used by federal agencies available for commercial use.

The discussion draft and Mr. Guthrie's and Ms. Matsui's bill before us today will begin the process to evaluate approaches that efficiently utilize spectrum. I am confident that industry experts and federal agencies can find a way to optimize the cyber real estate to the interest of all parties.

In order to remain the world's leading innovator and ensure consumer demands, we must work together to utilize spectrum more efficiently.

Mr. Chairman, I look forward to hearing from today's witnesses and I yield back.

Mr. WALDEN. The gentleman yields back. Now at this time, the chair recognizes the ranking member from California, Ms. Eshoo, for opening comments. Good morning.

OPENING STATEMENT OF HON. ANNA G. ESHOO, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Ms. ESHOO. Good morning, Mr. Chairman. Thank you and welcome to the witnesses. We appreciate it.

Mr. Chairman and members, I think it is important to take a moment to consider that Americans use 11.1 billion megabits of mobile data every day. That is an astounding number. That is equivalent to about 22.2 million hours of streaming standard definition moves.

As our dependence on smart phones and tablets for mobile video and other bandwidths' intensive applications grow, so will our need for more licensed and unlicensed spectrum. So we need a plan; a spectrum pipeline for the future that fits with consumer expectations and also ensures a seamless user experience.

According to a 2012 GAO report, federal agencies have exclusive access to about 18 percent of the most highly valued spectrum. A far larger percentage of spectrum is shared between federal and nonfederal users. Increasing the efficiency of how more than 60 federal agencies and departments use over 240,000 frequency assignments, obviously, it is not an easy task. But I think it is one that our subcommittee should tackle and will tackle. We did it before and we are going to have it do it again.

The Spectrum Pipeline Act of 2015 is an important step in this process. As the chairman said, building on the success of the AWS–3 Auction, the draft under discussion today calls for a plan for the reallocation or sharing of spectrum bands held by federal agencies and a time line, which is very important, for bringing the spectrum to auction.

Recognizing that federal agencies operate very differently than commercial wireless providers, we also need a plan to incent federal agency participation. And that is why I am pleased to support Representatives Guthrie and Matsui's legislation as an original co-sponsor because the bill directs itself toward accomplishing that. It will get federal agencies a direct financial incentive. Money always does it, almost always anyway—yes, it is the magic ingredient. It gives them the incentive to either terminate or share with other federal agencies their existing spectrum.

More than three years ago, our subcommittee established a bipartisan working group to examine how the Federal Government can use the nation's airways more efficiently. We put a lot of time into it and it was time well spent. It was time well spent. So in pursuit of our shared goals and this is, I believe, a real bipartisan effort to deliver fast, reliable, wireless broadband service to all Americans. I want to thank the chairman and members of the subcommittee that have really put in time and thought, not only to the bills that we are going to talk about today, but the efforts that really got us to step up and prove that we can do it.

So with that, Mr. Chairman, I will yield back the balance of my time.

Mr. WALDEN. The gentlelady yields back the balance of her time. The chair recognizes the gentlelady from Tennessee, Ms. Blackburn, for 5 minutes.

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

Mrs. BLACKBURN. Thank you, Mr. Chairman. I want to say thank you to the witnesses. We appreciate that you are taking the time and being here. It is an important topic. As you all know, it is not the first hearing that we have done on this issue.

We know that spectrum is the lifeblood of the wireless industry. It is essential to connectivity. Ms. Eshoo was just talking about the amount of utilization of spectrum and the airways that are there.

One of the things we hear from our constituents is the importance of this as an education and economic development issue and how the access is incredibly important to them and having the Spectrum Pipeline Act and Incentive of 2015 is something that is a good step. It is going to move us forward. If we are all reading the CTIA report properly, then we see we need to get to work on making certain that the 350 additional megahertz that are needed by 2019 are in the pipeline and that is what the usage is going to demand. So we do have some work to do. And at this time, I yield the balance of the time to Mr. Guthrie.

Mr. GUTHRIE. Thank you. Thank you for yielding. I appreciate that and I am pleased to speak in support of 1641. It is a bipartisan bill that I reintroduced this year with my colleague from California, Ms. Matsui, Congresswoman Matsui. I always appreciate working together as co-chairs of the Congressional Spectrum Caucus and we hope to see this bill advance.

I said before and I know my friend, Mr. Berenbroick, is from Radcliff in my district and I said before when I went around the 2nd District of Kentucky I never had a platform or sat up and said

send me to Washington and I will deliver you spectrum. It was something that I didn't know I would get involved in until I got here. But how important it is and it is important to the 2nd District of Kentucky and people out in the country because whether you use it to browse apps or news articles on your mobile phone or you are a first responder just trying to get resources for an emergency situation, we all rely on it. And while we can't see spectrum, we know it is a limited critical resource for nearly every aspect of our daily lives.

And in January, we saw a huge success with FCC's Advanced Wireless Services Spectrum Auction raising an unprecedented $44.8 billion. And I am hopeful we can achieve similar success.

I want to thank Chairman Walden for bringing this important legislation before the subcommittee and I thank my friend, Congresswoman Matsui.

One of the other great things about being on the Spectrum Caucus is making a great friend with Congresswoman Matsui and working together with her. So I appreciate it and I yield back my time.

Mr. WALDEN. The gentleman yields back the balance of time. The chair recognizes the ranking member of the full committee, Mr. Pallone, for an opening statement.

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

Mr. PALLONE. Thank you, Mr. Chairman. I appreciate the opportunity to continue this subcommittee's conversation on spectrum policy. Spectrum policy is a bipartisan issue and I am proud of the bipartisan approach this subcommittee has been taking.

As I have noted before, we are witnessing a mobile revolution. The consumers' insatiable demand for wireless service is a critical engine driving our economy. And this engine is powered by spectrum. Fortunately, Congress, the FCC, and the National Telecommunications and Information Administration, have been hard at work to meet this demand and keep the mobile economy moving forward. With support from this subcommittee, the FCC completed a record-shattering auction earlier this year that raised over $40 billion and we are all hoping for success in the upcoming incentive auction which was authorized by a law that came out of this subcommittee.

So today, we will continue to drive the effort to free more spectrum. We are taking the next step to make sure consumers continue to reap the benefits of the mobile economy. Together, the pair of bills we are looking at this morning have the potential to establish a spectrum pipeline to meet consumer needs well into the future.

Like the broadcast incentive auction, the Matsui-Guthrie bill would encourage federal users to either vacate their current spectrum or relocate to another band in exchange for a percentage of the auction proceeds. This bill demonstrates that innovative thinking in the tech sector is not confined to the private sector.

I am also pleased for examining the bipartisan discussion draft offered by Representatives Clarke and Walden. This is an impor-

tant effort that would require agencies to continue to think about additional innovative ways to expand commercial broadband. I want to commend Representative Clarke who, of course, is relatively new to the committee for her immediate and keen understanding of the importance of addressing spectrum.

Together, these bills are the first step in authorizing new auctions that can help serve the skyrocketing mobile needs of consumers.

[The prepared statement of Mr. Pallone follows:]

PREPARED STATEMENT OF HON. FRANK PALLONE, JR.

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I'm also pleased we are examining a bipartisan discussion draft offered by Representatives Clarke and Walden. This is an important effort that would require our agencies to continue to think about additional innovative ways to expand commercial broadband. I want to commend Representative Clarke, who is new to the Energy and Commerce Committee, for her immediate and keen understanding of the importance of addressing spectrum.

Together these bills are the first step in authorizing new auctions that can help serve the skyrocketing mobile needs of consumers.

Again, thank you, Mr. Chairman for keeping this subcommittee focused on spectrum in a bipartisan way. I'd like to yield the remainder of my time to Ms. Clarke.

Mr. PALLONE. Again, thank you, Mr. Chairman and Ms. Eshoo for keeping this subcommittee focused on spectrum in a bipartisan way and I would like to yield the remainder of my time to Ms. Clarke.

Ms. CLARKE. Thank you, Ranking Member Pallone. And I also would like to extend my gratitude to the chairman for this bipartisan effort. I am thrilled that we are discussing this bipartisan draft of the Spectrum Pipeline Act of 2015.

As everyone knows here, the future is wireless. Our lives are more connected every day. It is not just our phones or our tablets. We are moving to a world of connected cars, connected homes, connected lives. I can see it clearly when I go home to Brooklyn. We have become one of the most tech savvy places in the country. Everyone has a device or two in their hands and the innovations coming out of start ups in my district are mobile and data hungry.

It is our job to make sure that these consumers and these innovators have the spectrum they need. That is why I am proud

of our efforts today, that bipartisan discussion draft that takes necessary first steps toward creating a spectrum pipeline to meet that challenge. I made sure to develop this bill to ensure that will have a steady flow of licensed and unlicensed spectrum to meet consumer needs and demands.

I hope that this draft helps get the conversation started. I look forward to hearing ideas from my colleagues and our witnesses on how to improve the bill as we move forward. I thank you and I look forward to our continued bipartisan effort on this important issue. I yield back to the ranking member.

Mr. PALLONE. Mr. Chairman, I would like to yield the remainder of my time to Ms. Matsui.

Ms. MATSUI. Thank you very much for yielding me time, Mr. Pallone.

Today, the subcommittee's focus is on how to improve the efficiency of federal spectrum users and free up spectrum for innovation and commercial use. The success of the AWS–3 Auction earlier this year highlighted the incredible demand for spectrum in the marketplace. Spectrum is our nation's invisible infrastructure of the 21st century. Making more spectrum available is essential to meet the demands of American consumers and to keep the United States as a world leader in the wireless economy.

The Federal Spectrum Incentive Act, a bill that I am sponsoring with Congressman Guthrie, Chairman Walden, and Ranking Member Eshoo, is one of the proposals we are examining today. Our bipartisan bill creates a new approach to spectrum management by offering new incentives for federal users to relinquish or share spectrum. It would create the first ever incentive auction for federal agencies and allow federal spectrum users to share in the revenues from the auction.

Last Congress, the committee reported the bill with strong bipartisan support. We need to continue to support additional solutions to put more spectrum in the pipeline. I look forward to working with all my colleagues to see this legislation become law. I yield back. Thank you.

Mr. WALDEN. Thank you. The gentleman yields back the balance of his time, and the gentlelady yields back and I thank the gentlelady, both, all my colleagues for their work on these bills.

We are going to go now to our witnesses. We want to really thank you all for coming. I have read your testimony. It is most insightful and helpful and we look forward to your sharing it with everyone and so we will start with Phillip Berenbroick, the counsel for Government Affairs at Public Knowledge. Sir, we are delighted to have you here. Pull that microphone fairly close. Make sure the light is lit and the floor is yours.

STATEMENTS OF PHILLIP BERENBROICK, COUNSEL, GOVERNMENT AFFAIRS, PUBLIC KNOWLEDGE; JEFFREY H. REED, WILLIS G. WORCESTER PROFESSOR OF ELECTRICAL AND COMPUTER ENGINEERING, VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY; AND DENNIS A. ROBERSON, VICE PROVOST, RESEARCH PROFESSOR IN COMPUTER SCIENCE, ILLINOIS INSTITUTE OF TECHNOLOGY

STATEMENT OF PHILLIP BERENBROICK

Mr. BERENBROICK. Good morning, Chairman Walden, Ranking Member Eshoo, Ranking Member Pallone, and members of the subcommittee. I am Phillip Berenbroick, counsel for Government Affairs at Public Knowledge, a public interest nonprofit dedicated to the openness of the internet and open access for consumers to lawful content and innovative technology.

I will make two key points. First, it is critical for Congress to lay the groundwork for consistent, robust pipeline of spectrum. As Chairman Walden and Ranking Member Eshoo referenced, the demand for spectrum continues to grow. Congress should do so in a way that promotes more competition and choices for consumers, better service quality, lower prices, and greater innovation.

Second, unlicensed spectrum has become critical for economic growth and permissionless innovation. Efforts to increase available spectrum should strike a balance and increase the amount of spectrum available for unlicensed use.

Turning to my first point, critical missions across the government depend on federal spectrum including early warning missile systems and air traffic control systems. At the same time, America's broadband providers, consumers, innovators, and new technologies are demanding more and more spectrum. This is why we encourage Congress, along with the federal agencies responsible for spectrum allocation, the National Telecommunications and Information Administration, and the Federal Communications Commission, to work together to devise a consistent and reliable spectrum pipeline that can meet this growing spectrum demand.

Public Knowledge supports policy initiatives that enable federal users to accomplish their critical missions in a manner that also maximizes opportunities for spectrum sharing or relocating federal users to enhance federal availability for commercial competition and innovation. If done thoughtfully and in collaboration with Congress, agencies and other stakeholders, creative solutions to increase spectrum availability have the opportunity to be a rare win-win-win in public policy.

The first win is freeing up additional spectrum for mobile broadband use to meet the increasing demand on our wireless networks; second, by encouraging more efficient federal use of scarce public resources; and third, by expanding the amount of spectrum available for innovative, unlicensed uses like next generation Wi-Fi networks.

Legislation under consideration by this committee is a good start. Public Knowledge supports HR 1641, sponsored by Representative Guthrie and Representative Matsui. Providing financial incentives for federal spectrum users to relocate from their existing bands is

a creative way to free up much needed spectrum for commercial users and unlicensed innovation.

Public Knowledge also supports the goals of the subcommittee's discussion draft legislation to lay the groundwork for the FCC to engage in long-term planning on relocating federal users from various spectrum bands, auctioning the cleared spectrum, and finding a balance between licensed and unlicensed uses.

Turning to the importance of unlicensed spectrum, the economic activity and consumer benefits derived from mobile broadband use are immense. Today, a majority of mobile device traffic is offloaded onto fixed broadband networks via Wi-Fi and that traffic only continues to grow. Unlicensed spectrum has democratized internet access and encouraged permissionless innovation. The value unlicensed spectrum contributes to the U.S. economy is estimated to exceed $220 billion annually. Unlicensed uses of spectrum include more than just Wi-Fi. Unlicensed frequencies are open for any person and any device to use, for any legal purpose. Uses include cordless phones and baby monitors, Bluetooth, radio frequency identification or RFID which is used for making mobile payments for paying tolls on highways and tracking baggage in transit. Unlicensed frequencies are also necessary for connecting the burgeoning internet of things which Representative Clarke has referenced.

Given the enormous benefits of unlicensed spectrum, any legislative effort to increase the licensed spectrum pipeline should also expand the amount of spectrum made available for license-exempt use. One option would be to create a cut for unlicensed spectrum in newly freed up bands. Commissioner Rosenworcel has called this the Wi-Fi dividends. And to open up even more spectrum for unlicensed use, Congress may consider opportunities to allow for unlicensed sharing of bands where federal users reside including asking the FCC to examine the possibility of an unlicensed underlay while establishing mechanisms to protect critical bands and prevent interference.

Thank you to the members of the subcommittee for your time. I look forward to the opportunity to answer your questions.

[The prepared statement of Mr. Berenbroick follows:]

Testimony of Phillip Berenbroick
Counsel, Government Affairs
Public Knowledge

Before the
U.S. House of Representatives
Committee on the Energy and Commerce
Subcommittee on Communications and Technology

Hearing On:
Improving Federal Spectrum Systems

Washington, DC
October 7, 2015

Testimony of Phillip Berenbroick
Counsel, Government Affairs
Public Knowledge

Before the
U.S. House of Representatives
Committee on Energy and Commerce
Subcommittee on Communications and Technology

Hearing on "Improving Federal Spectrum Systems"
October 7, 2015

It is critical that Congress consider opportunities to increase the amount of spectrum available for use by wireless devices and services, including unlicensed spectrum, and approaches to encourage Federal spectrum users to relocate to other spectrum bands, relinquish spectrum, or share spectrum with commercial and unlicensed users. Finding solutions to create a consistent, robust pipeline of spectrum that helps to promote competition, deploy broadband to unserved or under-served areas of the country, and foster innovation is key to promoting America's economic growth, universal service goals, and technological leadership.

Freeing Up Federal Spectrum

Today, Federal agencies have substantial spectrum assignments. Critical missions across the government depend on Federal spectrum, including early warning missile systems and air traffic control systems.

Traditionally, when commercial spectrum demands rise, Federal agencies are asked to relocate and make new frequencies available for private sector use. Federal bands ideal for commercial use are identified, government users relocate to other spectrum, and the cleared spectrum is auctioned for commercial use.

While this model has served us well in the past, looking forward we need a new framework allows the Federal Communications Commission ("FCC") to free up spectrum that

meets the needs of America's economy, consumers, and innovators. Thus, Congress and the Federal agencies responsible for spectrum allocations – the National Telecommunications and Information Administration and the Federal Communications Commission – should to work together to devise a consistent and reliable spectrum pipeline that can meet growing spectrum demand.

Public Knowledge supports policy initiatives that enable Federal users to accomplish their critical missions in a manner that also maximizes opportunities for spectrum sharing or relocating Federal users to enhance spectrum availability for commercial competition and innovation. If done thoughtfully and in collaboration with Congress, the agencies, and other stakeholders, creative solutions to increase spectrum availability have the opportunity to be a rare 'win-win-win' in public policy:

- First, freeing up additional spectrum for mobile broadband use to meet the increasing demand on our wireless networks
- Second, encouraging more efficient Federal use of scarce public resources
- Third, expanding the amount of spectrum available for innovative unlicensed uses like next-generation Wi-Fi networks.

Legislation currently under consideration by this subcommittee is a good start. First, Public Knowledge supports H.R. 1641, the Federal Spectrum Incentive Act, sponsored by Representative Guthrie (R-KY) and cosponsored by Representative Matsui (D-CA), Chairman Walden (R-OR), and Ranking Member Eshoo (D-CA). Providing financial incentives for Federal spectrum users to relocate from their existing spectrum bands is a creative way to free up much needed spectrum for commercial uses and for unlicensed innovation.

Public Knowledge also supports of the goals of the Subcommittee's discussion draft legislation, the Spectrum Pipeline Act of 2015, that would lay the groundwork for the FCC to engage in long-term planning on how it would relocate Federal users from various spectrum bands, auction the cleared spectrum, and balance between licensed and unlicensed use.

The Importance of Unlicensed Spectrum

The economic activity and consumer benefits derived from mobile broadband use are immense. Licensed spectrum allocated to mobile broadband providers, and unlicensed spectrum, over which Wi-Fi operates, play separate, but complementary roles in the mobile broadband ecosystem. Today, a majority of mobile device traffic is offloaded on to fixed broadband networks via Wi-Fi, leading to a revolution in efficient small-cell spectrum re-use, worldwide Wi-Fi standards, and decentralized investment, innovation, and competition.

Unlicensed spectrum has democratized Internet access and encouraged permissionless innovation, and its value to the U.S. economy is estimated to exceed $220 billion annually.[1] Unlicensed uses of spectrum include more than just Wi-Fi. Unlicensed frequencies are open for any person and any device to use, for any legal purpose. Uses include cordless phones and baby monitors, Radio Frequency Identification ("RFID") to make mobile payments, pay tolls on the highway, tracking baggage in transit, and enabling the Internet of Things.

Given the enormous benefits of unlicensed spectrum, any legislative effort to increase the licensed spectrum pipeline should also expand the amount of spectrum made available for license-exempt use. To open up even more spectrum for unlicensed use, Congress should consider opportunities to allow for unlicensed sharing of bands where Federal users reside, ranging from a cut for unlicensed, or Wi-Fi dividend, as FCC Commissioner Rosenworcel

[1] Telecom Advisory Services, LLC, *Assessment of the Economic Value of Unlicensed Spectrum in the United States*, 73 (2014), *available at* http://www.wififorward.org/wp-content/uploads/2014/01/Value-of-Unlicensed-Spectrum-to-the-US-Economy-Full-Report.pdf.

describes it,[2] to the FCC examining the possibility of an unlicensed underlay, while establishing mechanisms to protect critical bands and prevent interference.

Conclusion

Again, Public Knowledge welcomes the opportunity to work with Congress to develop policies to free up additional spectrum that can be allocated for commercial and unlicensed uses.

[2] Written Testimony of Commissioner Jessica Rosenworcel, before the Senate Committee on Commerce, Science, and Transportation, Jul. 9, 2015, *available at* https://apps.fcc.gov/edocs_public/attachmatch/DOC-334645A1.pdf.

Mr. WALDEN. Mr. Berenbroick, thank you for your testimony and your support of our efforts. We appreciate it as always.

Now we go to Jeffrey H. Reed, the Willis G. Worchester Professor in—OK, forget that. We will now to Dennis A. Roberson, Vice Provost, Research Professor in Computer Science, Illinois Institute of Technology. We welcome you, sir. Please pull that microphone close. Make sure the light is lit and the floor is yours.

STATEMENT OF DENNIS A. ROBERSON

Mr. ROBERSON. Good morning, Chairman Walden, Ranking Member Eshoo, and members of the subcommittee. Thank you for the opportunity to participate in this vitally important discussion on the management and usage of federal spectrum and related systems.

As chairman of the FCC's Technological Advisory Council, I can assure you that there is no more pressing issue than spectrum use and management. Through the council's expertise and multi-stakeholder processes, the Technological Advisory Council, along with the Department of Commerce Spectrum Management Advisory Committee, where I also serve, have become ground zero for many of the core spectrum policy issues that challenge us today.

As these challenges and future issues arise, we must be up to the task of understanding the data behind spectrum usage and to develop forward-looking technologies and policies designed to optimize the most efficient use of spectrum. Such optimization has been the technical focus and a personal passion over the course of much of my career, whether it was as Motorola's Chief Technology Officer, or in my current role as Vice Provost for Research at Illinois Institute of Technology and as President and CEO of a technology and management consulting firm.

With few minor exceptions, our nation's spectrum resources have, for decades, been fully allocated for various government and commercial applications. Given this reality, the only way to expand existing applications and support the introduction of next generation technology is to either clear and relocate spectrum or to share it.

The proposition of clearing spectrum, federal or otherwise, is an increasingly daunting task involving the identification of applications in spectrum that can either be relocated or terminated, negotiating and finding the financial means to support relocation costs or to pay the incumbents for service termination, and establishing the plans and estimating the time it will take to accomplish this transition.

The so-called millimeter wave band, a spectral area above 30 gigahertz and extending to 60 plus gigahertz, is an area where significant quantities of cleared spectrum seem feasible today. The propagation characteristics of this spectrum pose a huge challenge, but research into the application of new technologies, massive, multiple input, multiple output, antenna arrays, show great promise, especially for this millimeter wave band and should certainly be encouraged as well as supported financially.

The process for sharing spectrum is notoriously slow. However, things can happen at a faster pace, if and onlyif the new user is able to share the spectrum in such a manner that the incumbent experiences little to no actual harm or perceivable impact from the

presence of the new service, or if the harm is outweighed by the benefits flowing from shared use of the spectrum.

There are several emerging classes of spectrum-sharing opportunities the committee should be aware of. Satellite spectrum, similar to the spectrum liberated in the AWS–3 Auction can be shared and reapplied to terrestrial use. Radar and communication spectrum can be shared, especially for lightly used weather radar bands, the 2.7s, the 2.9 gigahertz band and radar altimeters at the 4.4 to 4.6 gigahertz band. Bi-directional sharing which would, among other things, enable the government to employ lightly used or unused commercial spectrum when they need it for government activities such as DOD tests. And satellite spectrum allocations around the GNSS band that would efficiently be used for terrestrial purposes.

We cannot make more spectrum, but we can utilize spectrum more efficiently. The key point in all of this is that nearly all spectrum that is not currently being fully utilized can technically be used with spectrum management policies that are forward looking and driven by efficient use. The emerging use cases of these particular spectrum frequencies will enable the rapid transition to next generation technologies like 5G, thereby maintaining the U.S. leadership in cellular technology deployment.

Eight years ago, I set up the world's first spectrum observatory in Chicago where we looked at how heavily particular spectrum and frequencies are being used over a period of time, down to the second level. Wide-scale deployment of similar spectrum monitoring equipment in high spectrum usage environments could help policy makers identify spectrum for either clearing or sharing.

In conclusion, we have also learned that another major challenge to efficient spectrum use is receiver designs that promote inefficient spectrum use. Poorly designed receivers have a huge impact on spectrum availability and adjacent bands encouraging industry to adopt its own standard-setting methods for receivers will open the door to technological advances that can potentially produce billions of dollars of GDP growth while also creating significant spectrum efficiency.

Thank you for your prioritization of this critical issue. And I look forward to your questions.

[The prepared statement of Mr. Roberson follows:]

TESTIMONY OF DENNIS A ROBERSON

VICE PROVOST FOR RESEARCH
ILLINOIS INSTITUTE OE TECHNOLOGY

and

PRESIDENT AND CHIEF EXECUTIVE OFFICER
ROBERSON AND ASSOCIATES, LLC

Introduction

Good morning Chairman Walden, Ranking Member Eshoo, and Members of the Communications and Technology Subcommittee. Thank you for the opportunity to join you for this important session and discussion. By way of background, I am Dennis Roberson and I currently have dual roles serving as Vice Provost for Research and Research Professor of Computer Science at Illinois Institute of Technology, and as President and Chief Executive Officer of Roberson and Associates, LLC, a technology and management consulting firm serving government and commercial customers. Prior to my current roles I served as Executive Vice President and Chief Technology Officer of Motorola and over the years have held executive positions at AT&T, Digital Equipment Corporation (now part of HP), IBM and NCR. Currently I also serve as the Chairman of the FCC's Technological Advisory Council and serve on the Department of Commerce Spectrum Management Advisory Committee. My technical focus through my various roles and areas of engagement is aligned with my personal passion to optimize the use of our nation's increasingly valuable spectrum resources through both technology enhancements and enhanced spectrum management policies and practices.

I believe that each Member of the Subcommittee already has a great appreciation for the economic importance of this natural resource has and I know that others will speak to this point, so I will focus my comments today on the opportunities and challenges that face us from a technology and policy perspective. As you know, with a few minor exceptions, all of our nation's spectral resources have been allocated for various government and commercial applications for decades. Given this reality, the only way to introduce new applications and the next generation of technology or even to expand the capacity of existing applications is to either clear and reallocate the spectrum, or to find ways to share the use of the spectrum. We cannot make more spectrum, but we can utilize it more efficiently,

First, I would like to identify key considerations of clearing and reallocating spectrum. Although it should still remain a part of overall spectrum management policy, the proposition of clearing spectrum is an increasingly daunting task involving:

1) the identification of applications in valuable spectrum that can either be re-located or terminated;

2) negotiating and finding the financial means to support the relocation costs or pay the incumbents for service termination;

3) and finally establish the plans for how and how long (often 10 years or longer) it will take to accomplish the transition.

The millimeter wave bands present an area where significant quantities of "cleared" spectrum seems feasible today. The challenge here is that it has been both expensive to support from a technology standpoint and difficult to use based on the unique propagation characteristics, such as the fact that water vapor and even oxygen absorbs the energy of these signals. None-the-less, future technological advancements could address this and exciting research is being pursued in these spectral regions. Specifically, applying Massive Multiple Input, Multiple Output (or Massive MIMO) antenna arrays to create focused transmission beams to overcome the

atmospheric challenges and even use these challenges to our advantage. This research should be encouraged and supported financially.

Next, I would like to identify the key components of spectrum sharing where things can happen at a faster pace if

1) the new user is able to share the spectrum in such a manner that the incumbent experiences little or ideally no actual harm, which is a syno9nym for perceivable impact from the presence of the new entrant;

2) or if the actual harm is outweighed by the benefit of the new shared use.

There are several emerging classes of sharing opportunity areas including:

1) satellite spectrum shared and re-applied to terrestrial needs (e.g. NOAA's 1695-1710 that was initially liberated in the AWS-3 auction),

2) radar – communications sharing (especially for services such as the lightly used Weather Radar band 2700-2900 MHz and Radar Altimeters – 4400-4600 – where aircraft have known, broadcast positions that can be used to spatially and temporally avoid interference, and of course making the 3.5 GHz band that has been re-allocated available for widely scale usage),

3) bidirectional sharing, which would among other things enable the government to employ lightly used or unused commercial spectrum when they need it for specific government activities (e.g. a DoD field test or deployment),

4) appropriate use for terrestrial purposes of the satellite allocations around the GNSS band of the spectrum around GPS, even if the use is constrained.

The key point in all this is that nearly all spectrum that isn't currently being fully utilized (spatially and / or temporally) can technically be used spectrum management policies that are driven to maximize for the efficient use and support of forward-looking technologies.

While spectrum management policies should encompass both cleared and shared use of spectrum as described above, what's most crucial to better understand the use of this scarce natural resource is understanding and assessing the current level of use across all frequencies. I have spent a considerable portion of the past eight years establishing a better mean of assessing the current level of use through the deployment of a permanent Spectrum Observatory in the City of Chicago and building a database of spectrum measurements that covers the most heavily utilized portion of the spectrum, that is the spectrum from just below the low end of the original television band (30 MHz) to just above the high band for Wi-Fi (6 GHz). Figure 1 shows an example of this spectrum usage earlier this week as observed from the top of the IIT Tower on the south side of Chicago. Figure 2 shows a related spectrum occupancy chart from a few years ago illustrating the opportunity to identity bands of interest for potential reuse or sharing.

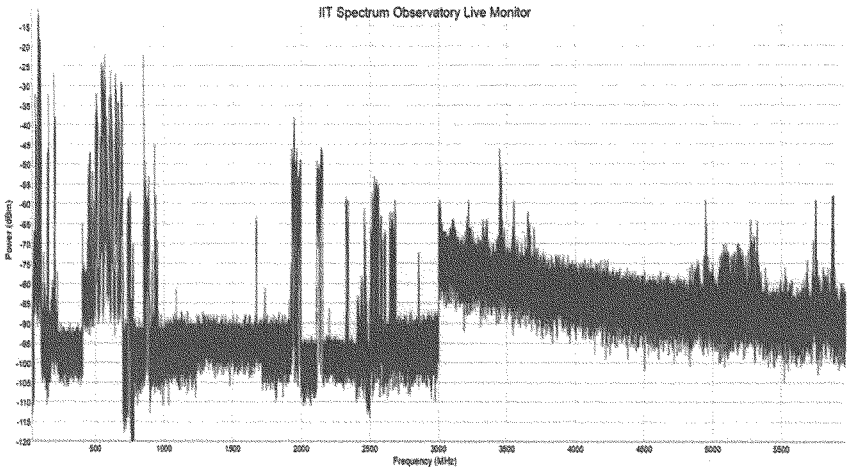


Figure 1 – Spectrum Usage in the City of Chicago – 5 October, 11:45 PM

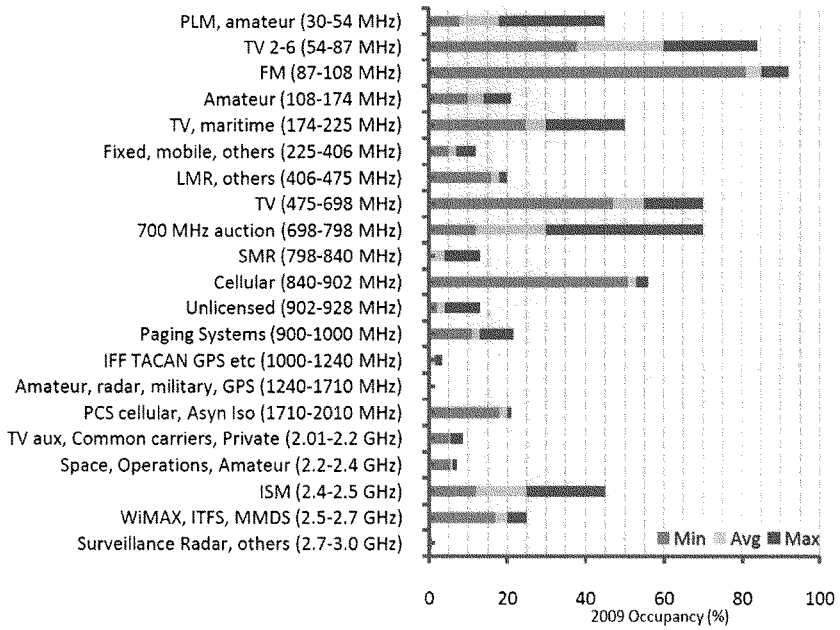


Figure 2 – Daily Average Spectrum Usage by major band for Calendar Year 2009

In simple terms, these charts show how, and how much of, the spectrum is being used over a period of time – monthly, weekly, days and hours. We can look at a particular frequency and understand down to the minute, how efficient that spectrum is being used and for what purpose it is being used. Through the wide scale deployment of similar spectrum monitoring equipment in various high spectrum usage environments (mostly urban centers and "high tech campuses"), we should be able to identify optimal spectrum bands to make available for either clearing and for sharing. In this chart the 1000 – 1240 MHz band, 1240 – 1710 MHz band and 2.7-3.0 GHz bands would be obvious bands to further investigate.

Beyond the spectrum that is observed to be readily available for enhanced usage, another major challenge to efficient spectrum usage is the "receiver standards" issue. Here poorly designed receivers for often critical functions have a huge impact on spectrum availability in adjacent bands. Since only transmitters are regulated today, and incumbents are protected relative to new entrant systems, we are effectively protecting companies that sell (or have sold) poorly designed receivers and not only continuing to allow them to sell their devices, but also impacting the ability to deploy new systems in adjacent bands. This happens based on the fear or reality that poorly designed incumbent receivers will see authorized adjacent band emissions operated within their regulatory limits as harmful interference. This is a real problem that needs to be

addressed with considerable urgency. Given the increasing value of the spectrum and its increasing impact on the U.S. economy, we need to insure that we aren't squandering valuable spectrum by allowing poorly designed receivers to limit our use of valuable areas of the spectrum. One way to address this issue is a balanced approach coming out of the FCC Technological Advisory Council called the I Interference Limits Policy. This approach uses a Harms Claims Threshold, a measured level of transmitted power to determine whether the receiver or the transmitter needs to be redesigned in the actual instance of harmful interference. The presence of such a Policy-based threshold would almost certainly lead to improved receiver designs since the cost of replacing or retrofitting receivers would likely be high relative to the cost of initial good design. This approach would also avoid the challenges of seeking to actually create a potentially innovation stifling receiver standard that the government would surely not want to pursue.

A third related area of need is for an independent testing body, a technical arbitration entity if you will, capable of adjudicating the technical differences of opinion on the suitability of new entrants to use spectrum either in a co-channel or shared band arrangement or in the adjacent band sense discussed in the previous paragraph. The organization that most closely resembles this structure that has recently been "stood up" is the National Advanced Spectrum and Communications Test Network (NASCTN) currently co-sponsored by the Department of Commerce (NIST and NTIA) and the Department of Defense with the Department of Transportation potentially sponsoring the organization in the future. This organization has a structured approach to selecting projects that are both appropriate to its independent test mission and are within its technical competence. This organization should be a significant asset to the cause of efficient spectrum allocation and management.

A fourth area to promote efficient spectrum management policies and understand technological opportunities and challenges is to create innovation zones where new wireless technologies can be tested. This concept of need is the concept of a Wireless Model City that has been spoken about in Washington for some time, but never deployed. Given the current state and urgency to meet growing demand for spectrum, it is time to implement policies that support deployment. The idea here is to create an innovation zone in one or more major cities where new wireless technologies can be tested at scale. Even though the FCC has become very responsive in making exploratory licenses or special temporary authority to use otherwise unauthorized spectrum available, often it is very difficult to obtain the local city permits to physically deploy the new technology at scale. A very modest amount of funding would be needed to provide the incentives to encourage a city to make this kind of innovation zone available to exciting and emerging companies.

The hope is that these recommendations will enable a more efficient and more certain path forward for those proposing new technology offerings. Today's consensus driven processes are often extremely long and the results very uncertain. This means that investors are often unwilling to put their money behind even promising new wireless communications technologies given the time required to navigate the regulatory processes and the unpredictability of the

ultimate results. This can place the United States at a disadvantage if other nations choose to pursue technologies in spectrum that is less encumbered than that available in the U.S.

Beyond the various technical notions as I have outlined, though this takes me outside my technical comfort zone, I would like to directly address the topic of offering incentives to federal government spectrum users. First, I completely support the idea of providing up front research funding to promote an improved understanding of various spectrum bands that have been identified as having the potential to be auctioned. Liberalizing the availability of auction funds for this purpose seems extremely appropriate and valuable. In addition, I believe expediting the development of new-shared use can be facilitated in the near term by taking steps by:

1.) Setting timeframes by which government processes should begin and end to enable decisions to be made on spectrum use at certain frequencies;
2.) Congressional support for to fund testing at one facility, like NASCTN, that will streamline the process among various federal agencies;

Requiring development of retrofit or replacement programs directly to end users or agencies that may be affected by proposed new uses of the spectrum

On the other side, while I applaud the notation of incenting good spectrum management behavior, I do not support the concept of offering various government entities incentives to either "turn in" their spectrum or offer it for shared use. In my mind, the various government entities should be budgeted in an affordable fashion to accomplish the mission that they have been assigned to perform, nothing more nothing less. Offering incentives to organizations to perform tasks that have been deemed inappropriate to be funded when we are running a budget deficit would not seem to make any logical sense. Furthermore, the government is not structured in the way that private industry operates where companies invest in various ideas and programs and are rewarded by customers and investors for their good decisions and punished for poor decisions. In turn, individual leaders in the companies and their investors reap significant personal benefits from their good decisions and find themselves seeking other employment when their decisions fail to produce marketplace results. In the government, individuals do not and really should not reap excess personal benefits for decisions that are deemed preferable by other government entities, especially on matters as critical as spectrum. Therefore we need executives with a broad perspective who can, with support from some of the structures described above, make the needed decisions on spectrum allocations.

To briefly summarize my comments, I recommend the following items:

1) Encouraging bidirectional sharing between commercial and government users.

2) Funding for research in the Millimeter Wave spectral region using Massive MIMO based communication systems should be expanded.

3) Initiating funding for selected deployments of Spectrum Observatory Systems in a few large Metropolitan areas.

4) Support be continued for the NASCTN effort housed in the Department of Commerce and supported by the Department of Defense and hopefully other Departments in the near future.

5) Provide matching funds to support a few (one or two) Wireless Model Cities.

6) Empowering senior government executives to make appropriate government decisions, supported by spectrum experts and the structures above and especially NASCTN and the Department of Commerce labs.

Mr. WALDEN. Mr. Roberson, thank you for testimony. I intend to follow up on the issue of sloppy front ends and receivers when we go forward.

We go now to Jeffrey H. Reed of the Willis G. Worcester Professor of Electrical and Computer Engineering, Virginia Polytechnic Institute and State University. Dr. Reed, we are delighted to have you here. Please go ahead.

STATEMENT OF JEFFREY H. REED

Mr. REED. Thank you, Chairman Walden and Ranking Member Eshoo and the subcommittee for the invitation to speak before you.

My goals are to address some of the key trends and emerging technologies that are impacting spectrum management and to discuss how R&D can make spectrum availability easier, how we can transition that spectrum in a much quicker way by doing the upfront R&D.

We all know that wireless traffic is growing very quickly. Sysco projects that the volume of wireless traffic will increase by a factor of 7X between 2014 and 2019. And there are reasons for this growth projection. There is a whole set of new applications that are just around the corner, applications such as augmented reality, where you get a super position of computer-generated images in your field of view. I would like to call it just-in-time learning and the ability to be able to do complex tasks through augmentation; ambient intelligence that predicts the way that we will use things; and telemedicine and elder care, huge benefits in having wireless technology for these particular areas. Being able to compensate for cognitive impairments, being able to keep people in their homes safely for a longer period of time. This is going to be made feasible by using wireless technology.

There is a whole bunch of new technologies that will help us to achieve this goal of greater wireless traffic, things such as small cells, miniature bay stations, bay stations that 20 years ago would have cost $1 million, now $200 bucks at Best Buy. Higher frequencies, higher frequencies like Dennis Roberson talked about, offer the potential of providing huge amounts of bandwidth. And then there are two technologies that I think are particularly relevant, spectrum sharing, which we are starting to see in AWS–3 as well as the 3.5 gigahertz band. And another one that is probably not quite as appreciated and that is software-based infrastructure. The basic idea behind this is that we digitize the signal with the antenna and we ship over fiber to the cloud to do processing. And that is going to have some major ramifications on the way that we can manage spectrum. It is going to enable sharing, both of federal spectrum and of commercial spectrum for federal users.

This is also going to allow us to greatly reduce cost and add flexibility.

So the role of R&D to speed this transition will—actually, I have been very encouraged by the way that policy has proceeded in the past few years. Changing spectrum policy has always been known to be incredibly slow and if you look back over the past few years some amazing things have happened. However, I think we can do better. And I think we can do better and be more prepared for this transition by doing our upfront R&D. For example, AWS–3 transi-

tion was very successful in bringing in revenue. But I think it could have been better. And the reason is that there are still unknown issues on how the commercial systems and the federal systems are going to coexist with each other. Those are R&D issues that should have been worked out beforehand. And the same with the 3.5 gigahertz transition. Things could have gone smoother if we had done more upfront R&D about the channel characteristics. The FCC struggled in their Notice of Proposed Rulemaking to get this information.

And in both cases, it delayed the transition of that spectrum, so I have a number of recommendations and I am running out of time. I think the key recommendation is to put funding into upfront R&D to make these bands easy to transition, quicker to transition. We have to do it anyway, so we might as well do it up front. And if you remove the risk, then we will be able to transition these bands quicker and we will be able to perhaps even save more money for the Federal Government because risk causes a discount in the pricing of that spectrum.

So in conclusion, I encourage more forward leaning in the planning and the R&D and this will shorten the transition times to make this valuable economic resource available to us.

[The prepared statement of Mr. Reed follows:]

The Importance of R&D in Improving Federal Spectrum Systems

Jeffrey H. Reed
Willis G. Worcester Professor and Founding Director of Wireless@Virginia Tech
Bradley Department of Electrical and Computer Engineering
Virginia Tech
[redacted]

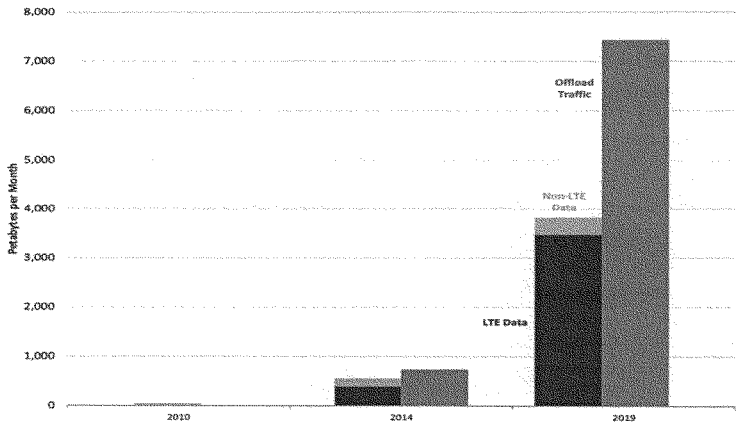
Thank you Chairman Walden, Ranking Member Eshoo, and Members of the Subcommittee for inviting us to appear before you today. I share your goals of putting more spectrum into productive commercial use to facilitate economy growth and innovation. The federal government though its policies can make a tremendous difference in our ability to develop and apply wireless communication technologies to achieve these goals.

My goals for this presentation are to address the key trends and emerging technologies affecting spectrum management, and to discuss how we can utilize R&D to accelerate the process of making more spectrum available for commercial use to address the rapid increase in demand for wireless services.

As we all know, the number, usage and bandwidth demand of wireless devices is growing at a rapid rate. The increased use of smart phones, particularly for video communication, has propelled the need for more bandwidth (spectrum) to support these devices and their applications. This is dramatically illustrated by, Figure 1, developed by Cisco, which projects a 7 fold increase in wireless data between 2014 and 2019. Data traffic growth will significantly increase demands on both licensed technologies such as LTE, and unlicensed technologies such as Wi-FI. The Internet-of-Things, enabled by wireless technologies is at the cusp of rapid expansion and it promises not only to greatly increase wireless traffic, but also change the characteristics of that traffic. To handle this demand, licensed and unlicensed technologies will

be augmented by the new technology of spectrum sharing, which will manage the interference between various devices.

Figure 1: Projection of capacity needs. 7x increase between 2014 to 2019.



Source: Substantial Licensed Spectrum Deficit (2015-2019): Updating the FCC's Mobile Data Demand Projections, Coleman Bazelon and Giula McHenry, Brattle Group, June 2015. Last accessed 10-4-15 http://www.ctia.org/docs/default-source/default-document-library/bazelon_mchenry_spectrum-deficit_2015-06-23.pdf and based on data presented in Cisco reports, Feb. 2015.

Impact of New Wireless Technologies

Advances in wireless technologies have brought significant new benefits to national defense, government services, and economic development. For this discussion, I will focus on the benefits to economic development. There are two categories of benefits. The first category comes from the direct development of technologies that constitute the wireless systems. The second category comes from indirect economic benefits that occur from the deployment and use of these systems.

The first category of benefit, for example, the creation of the hardware that forms the cellular infrastructure network, has diminished in the US. There was a time when major cellular infrastructure providers primarily developed and manufactured wireless technology within the US. Companies such as Motorola (now part of Chinese corporation Lenovo) and Lucent (now part of French corporation Alcatel) were key US players. Today there are no major US-based (or even North American with the demise of Nortel in Canada) base station provider. Furthermore, very few cell phones are made in the US. The US still designs cell phones and in some cases produces chips that enable smart phones, but compared to ten years ago, we have experienced a major decline in manufacturing of cellular infrastructure. So this is the bad news.

However, there is good news to share. Innovation is healthy in the US. Major equipment manufacturers have significant R&D facilities in the US. These facilities are the source of high-skill and high-wage jobs. For instance, the creation of applications, operating systems, and software defined infrastructure has progressed very well in the US. iOS (Apple's mobile operating system which powers the iPhone) and Android are US products. Furthermore, the US is pioneering the development of spectrum sharing technologies, which has been enabled by the federal government and the regulatory community's interest in investigating and experimenting with new and novel approaches that enhance spectrum utilization. We are seeing an emerging ecosystem to support spectrum sharing, which I am confident will be a major technology component of 5G.

The second category of economic benefit comes from deploying and using the technologies. Certainly the US has been a leader in the early deployment of these wireless technologies and consumers have been able to reap the benefits of the associated economic efficiency. The early deployments of LTE as well as the early mass deployments of Wi-Fi are examples where the US

has led the world. Reaping productivity gains using these new technologies is perhaps the most important economic benefit and there is much more to come in the way of new and innovative applications. It is these new applications that will continue to drive the need for greater amounts of spectrum and greater spectrum efficiency.

New applications of wireless technologies will bring all sorts of productivity gains and improvements to quality of life. Examples include connected cars that are self driving and that provide vastly improved safety; augmented reality that will help us to learn and perform complex tasks by superimposing computer generated images on our field of view (what I like to call just in time learning); ambient intelligence that will follow us and predict our needs; and telemedicine and wireless healthcare which promises to keep aging Americans to continue living in their homes safely, compensate for cognitive decline, and serve as one avenue for reducing the burden on the nation's healthcare system. These applications will be wireless enabled, and will of course need spectrum to support the data communication requirements. Hence the exponential growth curve in wireless data will continue for many years to come. If the US is to be a leader in the development and use of these technologies, we need the spectrum resources that will enable these applications. The phrase "build it and they will come" certainly applies to wireless technology. Build a solid spectrum management infrastructure, and the applications and services based on this infrastructure will come.

There are new technologies that will help in managing spectrum needs of the future. Small cells – miniature base stations are certainly one key technology. Small cells are very localized cellular technology that can reside in your home or office and provide low interference to others. The result is that these small cell can be densely packed and provide services to many users. Small cell technology has been developing along with automated deployment tools so that small cells

become "plug-and-play," requiring little set up effort and virtually no maintenance. Using higher frequencies is another way that we can improve bandwidth availability to users, but this approach does have its limitations since at higher frequencies radio waves tend to behave more like light and are subject to being blocked by objects in the environment, thus limiting coverage. Although higher frequency systems have a role in the future for supporting high-data rate systems, better use of lower frequencies is the best approach for providing bandwidth for wireless services for the near term.

Two of the most interesting and promising technologies for more effectively using lower frequencies are spectrum sharing and software-based infrastructure. Spectrum sharing takes previously allocated spectrum and allows new users to co-exist with legacy users through coordination. We are seeing spectrum sharing applied to AWS-3, the recently auctioned cellular band, and Citizens Broadband Radio Service (CBRS) at 3.5 GHz. These technologies are very important in allowing spectrum policy to rapidly adapt to match the demands of new users and applications while accommodating legacy users of that spectrum. In the case of AWS-3, service providers will be able to get access to the spectrum they paid for quickly. However, because of the long lead time necessary for federal users to transition to other bands, there will be delays and disruptions in some regions and frequencies that federal users have not vacated.

In the case of 3.5 GHz the sharing regime is more complicated. We still have protection of legacy federal users like that of AWS-3, but we also see a prioritization of spectrum access for the commercial users. An auction is used to grant priority access to some users (for a limited time) while lower priority access (General Authorized Access or GAA), similar to unlicensed devices, is granted without an auction payment. If the spectrum isn't being used then a GAA device may use that spectrum. The authority to use the spectrum is granted by a database. You

can think about the management of this spectrum like checking out a library book. That library book is available for loan and can be recalled when needed.

We are seeing some interesting business models develop from an adoption of a more sophisticated approach to spectrum sharing. In this case access to the spectrum is essentially rented and while service providers are expected to take advantage of this, non-traditional service providers can gain access to guaranteed spectrum without spending enormous amounts of money for a license. Anyone can obtain access to this spectrum. This spectrum use is different than that of unlicensed; it provides assurances of availability to those Priority Access users. Also the 3.5 GHz band is an international LTE band and hence it is feasible to obtain low cost LTE hardware from a mass market. It is likely we will see the establishment of private LTE networks that can serve a variety of industries such as transportation, healthcare, and manufacturing. This is a fundamental paradigm change in wireless communications that is being pioneered in the US, and will no doubt be applied in other parts of the world that are facing similar issues with spectrum availability.

Software defined infrastructure is another emerging technology area, which is different, yet complementary to spectrum sharing. This technology area is a combination of emerging technologies such as Software Defined Radio, Software Defined Networking, Network Virtualization Function, and Distributed Antenna Systems. An elementary way to view these combined technologies is that the infrastructure consists of antennas where the received signal is digitized, sent over fiber to a cloud infrastructure that can process the signal and implement the network functions in a flexible and dynamic fashion. So what are the implications of this technology on spectrum management? Such functionality will make spectrum sharing more cost-effective and add flexibility and scalability to deal with dynamic behaviors of incumbent,

priority and general access users. It will also potentially remove some of the barriers that have prevented federal systems from interacting with other federal systems or from sharing spectrum with commercial systems. Federal operators who have been reluctant to cede control of their networks will find the ability of this technology to customize commercial services to their needs very attractive. Furthermore, the incremental costs associated with supporting new users and additional bands are minimized since most of the incremental cost will be in renting additional fiber and cloud resources. Since the network resources are common, coordination to support spectrum sharing is easier.

The Role of R&D to Speed the Availability of Spectrum

I applaud rapid movement in the policy arena that has allowed for the introduction of new technologies and spectrum management techniques. However, good policy must be grounded within sound engineering principles and hence R&D should lead policy decisions. While I am very optimistic and encouraged by recent and rapid policy changes, we could be doing a better job in providing a solid technical foundation to support policy decisions.

The recent AWS-3 auction is an example where upfront R&D could have made the process better. Granted the auction did produce sizable revenue for the Treasury, which is surprising given technical uncertainties surrounding the transition. There was and still exists, a great amount of uncertainty of how the federal legacy users and commercial users will co-exist. Technical issues involving sharing spectrum with airborne platforms, and the aggregate interference levels to military systems caused by numerous wireless devices, are still unanswered. How well commercial systems, using their advanced interference rejection, will be able to contend with interference from military systems is not clear. These are fundamental questions that should have been addressed well before the auction, but one must wonder if the

federal government would have netted substantially more proceeds if these risk factors had been removed from the auction? Could a few million in R&D before the auction improved the value of that spectrum? Oddly, these R&D issues still have to be addressed, but now are being done after the auction.

The situation is similar for spectrum sharing in the 3.5 GHz band, where there was a fundamental lack of knowledge about the propagation characteristics of this band as the rule making progress began. The initial proposed rules for this band excluded large swaths of the country's population centers for shared spectrum use because of the lack of channel knowledge resulting in overly conservative interference protection zones (areas) in which commercial use of this band is excluded. Eventually this issue was resolved, for the most part, but this lack of technical data slowed the policy makers and hence slowed the transition of this band. The old adage "time is money" is certainly true for deployment of spectrum for commercial use and the economic benefits it brings.

These observations lead me to a set of specific recommendations given below.

Specific recommendations

1. *Prepare in detail for transition of bands, before any final decision is made for that transition.* Funds invested in this preparation are a small price to pay for speeding up the overall process of spectrum transition, even if that transition proves infeasible. For example, better preparation might have shaved a year off the transition of the AWS-3 band. The interest on $40B over a year would have dwarfed the small R&D costs needed to expedite that transition.
2. *Allow spectrum relocation funds to address the overall problem of transitioning federal spectrum, not just a specific band that has already been auctioned.* It is

counterproductive to everyone's best interest to narrowly constrain the use of these funds. It slows down the transition process for commercial use, and introduces unnecessary risk. For example, I understand that OMB has scored R&D funding for AWS-3 in a manner that is tightly constrained to only support AWS-3 transition. I don't know enough about the budgeting process to recommend fixes for this problem, but I do know that it is a pervasive issue preventing us from understanding the complete depth of transitioning users to other bands

3. *R&D incentives can help industry find solutions to government transition problems.* If companies are incentivized by R&D funds, they will use this knowledge to create products that will reduce risks of transition, and could even improve capabilities for the legacy spectrum users. If a government entity sees that the technology exists to supports their transition process, and that in the end the transition will give them better capabilities than before, then they will be much more likely to engage in the transition. In the end, industry can play an important role in transitioning spectrum to more productive use.
4. *Approach risk-assessment with realism.* Avoid falling into the trap that spectrum sharing techniques are not perfect and can in some instances cause interference to legacy users. No communication system has ever been immune to interference. Risks versus rewards need to be pragmatically assessed. Moreover, the ongoing improvements in cost, complexity and performance of wireless hardware and signal processing technologies enable the use of new methods for removing that interference. Many of these methods, developed by the defense and intelligence sectors over the past thirty years, change the paradigm of what's possible.
5. *Incentives can build support from the legacy spectrum users, but the "devil is in the details."* Thought needs to be given to metrics for assessing what and how much

incentives should be given for what [and how much] concessions. Furthermore, how those incentives are distributed within federal organizations make a difference in how cooperative the elements in those organizations will be with the transition. The organization's policies, and the benefits it receives from the transition, need to be clearly articulated throughout the organization.

6. *Build trust and transparency through collaboration between federal and commercial users, starting at early stages in the transition discussion.* If both federal and commercial users understand the problems resulting from the transition process, and how they have arisen, then they are more likely to work together to quickly solve those problems. Classification restrictions and export control issues of legacy federal systems are manageable though established processes and they should not be allowed to be a barrier that limits effective communication between federal and commercial sectors.

Conclusion

It is difficult to overstate the importance of good spectrum management on economic development. Establishing the right spectrum policies encourages innovation to happen here in the US, putting us in the leadership position to develop and deploy these new technologies. Policy changes should happen quickly to respond to demands of greater wireless traffic and to take advantage of new technology opportunities, but policies based on solid technical principles from upfront R&D are essential. This will require (1) continued research into spectrum sharing; (2) an R&D strategy that anticipates future needs more than we have seen in the past; and (3) active and frequent communication between all stake-holders including industry, researchers, policy makers, and incumbent spectrum users (both commercial and federal users).

Mr. WALDEN. Thank you, Dr. Reed. We appreciate your testimony, as well as that of your colleagues at the dais. It is very interesting, the suggestions you come up with, the work that you all have done to look at other spectrum.

And I guess the question I would have and some of you lay out some suggestions in your testimony, if you could give us some counsel on the specific bands we should be focused in on.

And I know, Mr. Roberson, in some of your research in Chicago, it is graphically evident what is in use and what is not because we have limited time and resource, too, and we have proven that we can bring agencies and private sector together and work out some of the differences.

I agree with Dr. Reed on the notion of R&D in advance. It gives you certainty before you go into the auction which could raise its value therefore. So that is something we will take a look at, too.

Can you give us some suggestions or can get back to us, Mr. Roberson?

Mr. ROBERSON. I would be delighted to. Actually, if we could bring up the screen that we had earlier?

Mr. WALDEN. We have enough spectrum capacity, I am sure we can do that.

Mr. ROBERSON. What you may have noted as I delivered my remarks——

Mr. WALDEN. Could you explain that?

Mr. ROBERSON. That is what I was going to do very quickly. I mentioned the world's first spectrum observatory in Chicago and what you are seeing is the live feed from that observatory. So this is the spectrum usage in Chicago at this minute.

Mr. WALDEN. Right there.

Mr. ROBERSON. Right there. And what you can clearly see, this is power versus spectrum. The spectrum starts at 30 megahertz which is just below the low end of the TV band and runs to six gigahertz which is just above the 5 megahertz part of the——

Mr. WALDEN. So for lay people, give me an idea. It kind of does the up and down there and then goes across kind of flat. Is that satellite band?

Mr. ROBERSON. Right. The flat parts are all the areas where to your earlier question where we should be investigating. I will apologize for the bit of a rise at 3 gigahertz. That is an artifact.

Mr. WALDEN. OK.

Mr. ROBERSON. But the elements that you see going up and you can see television and FM radio and the like and the cellular bands and so on, but you see large areas from 1 gigahertz to 1.7 gigahertz where there is very little activity. You can see other bands, 2.7 to 3.0 in the middle of the chart and I know that the numbers are so small you can't quite see them. But there is a blank area there. And as you go out, 4 gigahertz, particularly 4.2 to 4.4 I call out as areas where investigation would certainly yield——

Mr. WALDEN. And what would be on those bands today?

Mr. ROBERSON. The bands, there are a variety of things in 1 to 1.7, but there is satellite activities in those bands, some radar. In 2.7 to 2.9, this is the weather radar bands. In 4.2 to 4.4 is radar altimeters for airplanes which you would not normally think of as an opportunity band, but since those radars are only used during

landing and takeoff and we know where all the airports are and we know where the airplanes are, so the opportunity to utilize that spectrum carefully is another significant opportunity area. And there are others.

Mr. WALDEN. And given the issues with the latest hurricane and others and the discussion about adequate satellite coverage for weather event prediction, your point isn't that you blow all that off the airplanes?

Mr. ROBERSON. No, no, no.

Mr. WALDEN. Your point is that there is not much data coming up and down and we can actually share. Is that right?

Mr. ROBERSON. Exactly right. In all cases, I am really suggesting sharing, not to clear. And that is a huge opportunity. When you think about satellites that are operating in the vertical direction and terrestrial use which is orthogonal direction, you have an opportunity to share these bands, not in any way impacting——

Mr. WALDEN. Existing——

Mr. ROBERSON [continuing]. Existing uses.

Mr. WALDEN. I want to shift to one of my pet peeves and that is uh-oh, we just had a flood. We will get some help here. But meanwhile, receivers. What is it that you recommend could be done here to get better built, better engineered receivers? This has been a long-time problem. And we don't want to mandate standards per se, but boy, I would like to see more skin in the game on the receiver side than what we see today.

Mr. ROBERSON. Perhaps I could jump on that one since I called it out. My very good friend, Dale Hatfield, has been working on this problem for approaching 50 years which is incredible, but it has been a problem for a very, very long time.

The new elements that provide opportunity in this area are two. First, the opportunity for industry to take the lead and to self-govern itself, but place the requirement that industry do so. You rightly speak to the point that government should not, no one should dictate the way a receiver is designed. But dictating the requirement for having the industry itself self-govern is a good direction.

A second one that has actually come out the work in the Technological Advisory Council is something called the interference limits policy which establishes a harm's claim threshold where if you are, as a transmitter, if you are above that threshold the transmitter needs to fix itself.

Mr. WALDEN. Come back down. Right.

Mr. ROBERSON. If it is below that and the receiver is experiencing interference, the receiver has to be fixed. The beauty of this is it establishes a bar because today the debates are endless on what is harmful interference.

Mr. WALDEN. We went through this with Light Squared GPS. Is somebody listening in? Is it going to be too much power? Back and forth, back and forth. But you all are smart enough to figure out a——

Mr. ROBERSON. And there is no bar. And this would establish the bar.

Mr. WALDEN. Right.

Mr. ROBERSON. And with that bar and a measurable bar, you can now determine whether, who needs to remedy the situation.

Mr. WALDEN. Unfortunately, we have a bar and it is measurable and I have exceeded it by a minute and 37 seconds. So I thank my colleagues for the indulgence. We will go to the ranking member from California, Ms. Eshoo.

Ms. ESHOO. Thank you, Mr. Chairman. But it was worth the extra minute and 38 seconds in terms of what we just heard.

To each one of you, thank you for your excellent testimony. It is really highly instructive and it is most helpful to us when you target specific areas of recommendations to us. It really is most helpful to us in shaping a work product to address it.

Thank you, Mr. Berenbroick, for your attention to unlicensed spectrum. I don't think anyone has come here and given testimony concentrating so much on unlicensed and the importance of it. So I appreciate it very, very much.

One of the aspects that appears to be, I think, missing from the bills under consideration today is the role that the Spectrum Relocation Fund can play in promoting new research and development. And you raised R&D and placed a heavy emphasis on it. It is one of the most important undertakings regardless of what area we are in, but certainly as it applies to what we are talking about today, so it can play, I think, a really key role in promoting new—advancing more research and development.

In an August 31st letter, the OMB recommended removing some of the restrictions on this fund that prevent funds from being used for R&D, spectrum planning, and pilot projects. Do you agree that increased agency flexibility would enhance our efforts—I am teeing this up for you—would enhance our efforts to free up additional licensed and unlicensed spectrum and promote greater efficiency? That is to all of you.

Mr. REED. Well, maybe I can go ahead. I certainly agree with that recommendation. I know of no one who disagrees with that recommendation within the spectrum community. We should be focusing the funds on solving the problem, not associating with the specific interests. We made R&D funds available to the transition after the sale of the band. It is like buying your product and then deciding to do the R&D.

Ms. ESHOO. I understand. Do you know how much money is in this fund?

Mr. REED. I think it is around $500 million. It is quite a bit.

Ms. ESHOO. That is a good pot. Mr. Roberson?

Mr. ROBERSON. No, I also strongly agree with the points that Mr. Reed has made and believe that it is essential to do the work in advance and in fact, exploring taking off the testimony already provided, with the bands that can be identified through the ability to see the spectrum. Several members made the point that this is invisible spectrum. Well, it actually isn't invisible for those of us with instrumentation.

Ms. ESHOO. Yes, you showed that on the chart.

Mr. ROBERSON. Exactly. And we can use that to identify bands that have potential. But there is a need for funding for the researchers to then take the next steps and to really understand the parameters to allow that——

Ms. ESHOO. I don't know whether this belongs in the Matsui-Guthrie legislation or the other, but I think that this is something for us to pay attention to.

Mr. Berenbroick?

Mr. BERENBROICK. Thank you. Yes, I think we are all in agreement. We would like to see creative and innovative ways that make federal spectrum users more efficient. That way it can facilitate spectrum sharing or in ways to facilitate relocating those federal users to free up that spectrum for both licensed and unlicensed uses. That is one of the reasons why we support H.R. 1641 and we support the ideas you mentioned as well.

Ms. ESHOO. That is great. Mr. Roberson and Dr. Reed, you were both members of the PCAST, weren't you?

Mr. REED. Yes, we were.

Ms. ESHOO. Have we made any real progress in your view in implementing the recommendations? I thought it was an extraordinary report. I know you put and all the members put a great deal of time and effort into it. And we thank you for it. In some ways, I think it is under appreciated. But do you think that—tell us what you think we have not harvested from that that fits with what we are discussing today?

Mr. REED. Yes, I think we have made great progress since that report. The 3.5 gigahertz band, I think is a great example of that. The FCC pretty well followed the recommendations of the PCAST committee and how to structure it. I think we could have done it faster if we had known some basic principles. Here is the basic principle. If you have a transmitter over here with so much power, how well will that be received inside of a building some distance away? I mean that is pretty fundamental.

Ms. ESHOO. It is.

Mr. REED. But yet, at that band, there wasn't very much information on that. It should have been done beforehand.

Ms. ESHOO. Beforehand. Mr. Roberson?

Mr. ROBERSON. Yes. I would agree that there has been a great deal of progress in the PCAST report. Jeff and I had the opportunity to write a fair amount of that. So——

Ms. ESHOO. I read it. I read it all very carefully.

Mr. ROBERSON. Well, good. There are things though that have not yet been really touched, although they have been talked about. The wireless model city, the test city that was described in the report really has had discussions, but no action taken at this point.

The subject of the bill providing stronger incentives was another item in the policy proposal that has as yet although I am delighted to see the work going on here, it is a very intractable problem, but it still needs more work.

Ms. ESHOO. Thank you very much to each one of you.

Mr. WALDEN. I thank the gentlelady. Thank you, gentlemen. And let us go now to Mr. Latta, the vice chair of the Subcommittee on Communications and Technology. The floor is yours.

Mr. LATTA. Well, thank you, Mr. Chairman, and to our panelists, thanks very much for being here.

And Professor Roberson, if I could start with the questioning for you, a 2011 GAO report found several flaws in the spectrum management and use monitoring practices of the NTIA. At the time

GAO made three recommendations to improve NTIA's oversight of agency spectrum use, one of which remains open, the development of a strategic plan.

Do you believe that there are areas for improvement in the NTIA's practices?

Mr. ROBERSON. There are always areas of improvement for all of our practices, but particularly in this area. One of the things that is needed and I will really go back to the spectrum observatory capability, the practice out of NTIA is to solicit from the users of spectrum their usage models, then to correlate, collate those and thereby predict the usage across the country as opposed to independently assessing that use of spectrum. And that is a huge flaw. If you are asked are you using your spectrum? If the answer is no, I am going to take it from you, there is a pretty easy answer that comes back from that sort of assessment. And that is the difficulty in a very high contrast way with the approach that NTIA is able to use at this point.

Mr. LATTA. Let me follow up with how have the tools like their Federal Government spectrum compendium improved our ability to review and assess the spectrum use? Are you familiar with that?

Mr. ROBERSON. I couldn't——

Mr. LATTA. How have their tools like the Federal Government spectrum compendium improved our ability to review and assess the spectrum use?

Mr. ROBERSON. You are speaking to spectrum observatory data that we collect. I think that is what you are asking.

Mr. LATTA. OK.

Mr. ROBERSON. It has been actually enormously helpful because not only do we have the screen that you have seen, but we have kept the compendium that you are talking about. We have eight years' worth of data for Chicago, so we not only know how it is being used today, but we know how it has been used for the last eight years. We have begun to expand that and in fact, we have a spectrum observatory that is resident on Dr. Reed's campus, so we are able to observe the usage there and again, capture the data over an extended period of time. So that enables us to look at the spectrum, to identify the places where spectrum is ill-utilized and then begin the process of researching that spectrum and how it could be better utilized. And we are able to do that.

Often there are critics that say oh, yes, you looked at it this time, but if you had looked at it three months earlier, it was heavily utilized. Well, in our case, if you want to look at three months earlier, we will go back and look at three months earlier or any time in the last eight years we will look at how that spectrum was used. And that is a powerful tool in being able to really understand the spectrum opportunities that exist.

Mr. LATTA. Thank you. And this is a question to all panelists and so with my remaining minute and 45 here if you could answer briefly. Do you think federal agencies have the right incentive to utilize spectrum as efficiently as possible? And if not, what incentives motivate federal agencies to utilize spectrum more efficiently?

Mr. BERENBROICK. Thank you for the question. To touch on the question you just asked Mr. Roberson for just one second before I answer, Public Knowledge actually produced a white paper in 2010

on possible improvements to federal spectrum. I am happy to submit that for the record and we will do that after the hearing.

Mr. LATTA. Thank you.

Mr. BERENBROICK. On the question of incentives, right now I think it is TBD regarding whether agencies have the right incentives right now. I think we would like to see more incentives. We would like to see innovative incentives to help those agencies find ways to (a) use their spectrum more efficiently; and (b) find ways to consolidate their spectrum use. That way spectrum resources can be either reallocated for commercial use and unlicensed use or they can be shared using more efficient technologies in the band. That is why we are supportive—we mentioned the Spectrum Relocation Fund issue earlier with Ranking Member Eshoo. And we are supportive of the legislation H.R. 1641 and we support the FCC which the discussion draft would do. We support the FCC having the tools to take a look at bands and figure out how to make usage more efficient.

Mr. ROBERSON. The incentives are not there today. To me, in short form, probably one of the best incentives is to do the upfront research so that agencies can be assured that they can complete their mission in an alternative way.

Today, the real fear isn't that the agencies want to hoard spectrum or anything like that. They are simply trying to accomplish their mission. And without the upfront research to know how they can accomplish their mission in an alternative way with alternative spectrum, they loathe to give up that spectrum.

Mr. REED. Maybe I could comment on that one as well? I think that incentives can help and incentives may also be beneficial to flow to commercial companies. What bothers the agencies is they don't know how to proceed. They don't know what technology they can use to substitute for the technology that they have now. And if we do the upfront R&D, then industry will know, they will be able to develop the products so that the federal users won't fear transition. They will embrace it because they will see that in the end they will have a better system.

Mr. LATTA. Thank you, Mr. Chairman. My time has expired and I thank you for the indulgence.

Mr. WALDEN. You are more than welcome. We appreciate the comments from the witnesses and your questions.

We will now go to Mr. Pallone of New Jersey for 5 minutes.

Mr. PALLONE. Thank you, Mr. Chairman. The U.S. has led the world when it comes to fourth generation wireless technologies and as consumers start looking ahead to new fifth generation technologies, we need to ensure the U.S. continues to be a front runner.

So I wanted to ask both Dr. Reed and Mr. Berenbroick what we can do help the U.S. remain a leader in next generation wireless technology?

Mr. REED. Certainly to be out there in front we need to do the basic R&D. That is obvious. But perhaps less obvious is what we are doing here today. Actually, I think what you are doing is quite valuable for 5G because everyone that I know of within the research community is expecting that 5G will incorporate spectrum sharing. And because of the changes in policies that we have been

going through over the past few years, this is positioning us quite well. It is growth through good policy.

Mr. PALLONE. All right. Mr. Berenbroick?

Mr. BERENBROICK. So how to enable 5G to keep us ahead of the rest of world. First, I think as Dr. Reed mentioned, what this committee is doing is exactly what we should be doing which is to think about creative ways to find additional spectrum for both licensed and unlicensed uses and also to have conversations about how to improve spectrum efficiency and spectrum sharing. Like the transition from 3G to 4G, the transition from 4G to 5G will increase traffic on our wireless networks which will necessitate the need for more licensed spectrum.

Likewise, the more spectrum we have traveling on our licensed networks will result in more offload to our unlicensed networks to Wi-Fi. So we need more spectrum set aside for unlicensed use as well.

Mr. PALLONE. All right, thanks. And we have more and more consumer data traveling over unlicensed airways, but unlicensed spectrum is more than just a boon to consumers. It also drives innovation and significantly contributes to the U.S. economy. Some estimate that it gives a $220 billion boost to the economy every year.

Earlier this year, FCC Commissioner Jessica Rosenworcel proposed that Congress create a Wi-Fi dividend to account for these benefits.

And I wanted to ask Mr. Berenbroick, in your testimony you say that a Wi-Fi dividend may be a good idea. Can you explain more about this and the other options for increasing spectrum for unlicensed use?

Mr. BERENBROICK. Sure. So I referenced Commissioner Rosenworcel's testimony before a Senate Commerce Committee where she mentioned the idea of the Wi-Fi dividend. The idea there would be that when we look at spectrum to free up for licensed use, we also think about spectrum to free up for unlicensed use. The rationale is that the traffic that comes over licensed networks, much of that will eventually be offloaded on to unlicensed networks, and so you need those two systems to work together in concert.

I think you are exactly right when you mention the economic benefits of unlicensed spectrum. Like you mentioned, $220 billion in yearly economic activity. But that is only part of it. You are also talking about making a bet on the future with unlicensed. Unlicensed, we are looking at the internet of things.

We are looking at billions of devices connected to the network, the ability of anyone to plug in, the ability of anyone to plug in and to develop a device, develop a product at relatively low cost and to get it on to the network and to create a market for that product. So the economic benefits, I would imagine, are somewhat under estimated by the $220 billion, at least going forward in the future.

Mr. PALLONE. All right. I have one more question for you. Earlier this week, Politico had a story chronicling the difficulty we face in getting credit in the budget for revenue generated by spectrum auctions. I know you are not an expert in federal spectrum valuation, but can you elaborate on the value to consumers that comes from the reallocation of additional spectrum?

Mr. BERENBROICK. Yes. So I saw the same article that you referenced and let me preface, I am not an expert on budget policy or CBO scoring, but we were—the unlicensed community is disappointed to see that unlicensed spectrum and the economic benefits of unlicensed spectrum are not really considered by CBO. And so we would be happy to work with Congress, work with other stakeholders to figure out how to address that issue to make sure that allocating more spectrum for both licensed and unlicensed uses is made possible and that the CBO scoring issue doesn't continue to be a roadblock.

Mr. PALLONE. Thanks a lot. Thank you, Mr. Chairman.

Mr. WALDEN. Thank you, Mr. Pallone. We appreciate your questions. We will now go to Mr. Shimkus from Illinois and have at it.

Mr. SHIMKUS. Thank you, Mr. Chairman.

Mr. WALDEN. Welcome.

Mr. SHIMKUS. Doctor, you better be careful for claiming that we are going growth. There is growth through good policy. You are in Washington and really nothing good is happening here these days. So you may not—yes, yes. I will try to reiterate that. I don't know if my constituents will agree, but we appreciate those positive words. Thank you.

Besides— let me go where I want to go here. What are the benefits of a long term spectrum planning and a consistent pipeline? If we could just go from left to—my left, your right.

The business argument is that obviously to have to have consistency and you have got to be able to plan and execute, so what do you see the benefits of this?

Mr. BERENBROICK. This was mentioned in the opening statements by some of the other witnesses. The process by which we have typically allocated spectrum for commercial uses and for unlicensed uses has typically been a relatively slow process. We find a band that we want to relocate. We have to figure out how to move the user off of that band. We take the time to auction that band and then new services start to deploy.

And so I think some estimates, I think the PCAST report said it was about a decade from identification to deployment. That is slow. I think we would all like to see that process move faster. So that said, I think the discussion draft bill that the commission has put forward or that the subcommittee has put forward is actually very helpful. It asks the FCC to do that forward planning. And so finding that pipeline spectrum where we can figure out which bands and which uses go into those bands and to move forward with that quickly that is an incredible useful exercise. That way, all stakeholders can think about what is next, what do we need, what is coming?

Mr. SHIMKUS. Great. Mr. Roberson?

Mr. ROBERSON. Yes, the nature of spectrum use is a long game activity. It is measured in decades. Therefore, there is a need for a strategic plan that stretches out to an unprecedented length in the way business operates and even the way things operate in Washington where we are planning what we are going to do in spectrum 25 years from now.

So having the data, I keep hitting on that point, that would support our direction, and then putting together the strategic plan

that would position different spectrum usage even as it allows for innovation and new things that were not anticipated when the plan was put in place first is really critical and something that this body could do great service to the country by pushing it.

Mr. SHIMKUS. Thank you. Dr. Reed.

Mr. REED. I think it is very important to be consistent and forward looking in spectrum from a business perspective. Businesses, in fact, I have talked to VC about this. Sometimes VC don't want to hear it if it is a communications issue that requires some sort of regulatory aspect of it because there is so much uncertainty that is involved in it. If we have consistency in our spectrum policy, and with a plan, then businesses are more likely to be funded.

Mr. SHIMKUS. Great. Professor Roberson and Dr. Reed, you are both members of I think I pronounced this right, CSMAC or CMA or whatever it is called.

Mr. REED. Both of them.

Mr. SHIMKUS. A federal advisory committee comprised of spectrum experts that provide advice and recommendations to NTIA.

Mr. Berenbroick, your colleague at Public Knowledge is a member as well, I believe. He is back there hiding. Can you all discuss the current role that the committee and where you see it being most useful in the examination of federal spectrum use and are there ways to further and better take advantage of the expertise that is on this board?

Mr. ROBERSON. I guess I can take that one because I am actually the ranking member of this body on that particular committee. It is an excellent committee in terms of expertise, in terms of the multi-stakeholder nature of the group. Many ideas are brought to that committee. There are strong papers that are put forth. It is still a slow process though. And expediting that process, giving more problems to that body to sink their teeth into and to execute on is a very good thing. NTIA, Department of Commerce certainly do that, but I think they would be more than open to the questions that this body would have to be brought to them.

Mr. SHIMKUS. It sounds like governmental, slow and methodical. But I appreciate it. Thanks.

Mr. WALDEN. The gentleman's time has expired. We now go to a gentleman from Vermont. He is not here, Mr. Welch. Ms. DeGette is not here. Ms. Clarke, I believe you are next.

Ms. CLARKE. Thank you very much, Mr. Chairman. Dr. Reed, in your testimony you spoke of for the sake of efficiency it being necessary to invest in up front due diligence. Based on your experience, what is the main challenge when it comes to finding spectrum bands that could be reallocated?

Mr. REED. I think the main challenge is understanding how the new systems that would enter in that band would potentially interfere with the legacy users. And that involves getting an understanding of the nature of what we call the channel, the propagation channel, how well will the signal transmit.

It also means looking at the susceptibility of those systems to interference. And this requires studies, upfront R&D well beforehand in developing the planning tools. And in some cases there can be issues in terms of classification and ITAR as well when you deal with DOD systems. And sometimes that breaks down the commu-

nication between the commercial entrants and the legacy DOD users.

Ms. CLARKE. So having said that, how would you suggest that we move forward to keep up with consumer demand?

Mr. REED. Well, I think we need to get commercial entities talking very early with the Department of Defense. With these transitions, they will not go smoothly. There are always going to be things that come up that weren't expected and if we are transparent on both sides and collaborative on both sides, then we will be able to work together to solve those problems.

Ms. CLARKE. It would seem to me that those discussions should be underway as we speak, knowing what we know about the almost inevitability that these requests are coming down the pike.

Mr. REED. I agree with you.

Ms. CLARKE. Did you want to add something, Mr. Roberson?

Mr. ROBERSON. I am always delighted to add. But in this area, I think the key point is doing the work up front to the degree possible, as Dr. Reed has said. The other point that I would add though is that having an independent arbiter, if you will, technical arbiter, that can provide the input on whether a particular proposition is technically accurate or not is very, very important. Such an arbiter has been recently established under the Department of Commerce in Boulder. NASCTN is the acronym for the organization. And I think this organization can be extremely valuable in helping to sort through some of these issues and expeditiously and independently coming up with resolutions that will stand the test of time.

Ms. CLARKE. Very well, and after the incentive auction next year, the next major auction could be years down the road, so what are the next generation technology demands on spectrum? We have been able to understand what that is and what it looks like and that is open to the panel.

Mr. BERENBROICK. So in your opening statement, you referenced the internet of things. I think the internet of things is the next generation demand on that network. Billions of devices are going to connect to one another, largely through small cells using unlicensed spectrum. Additionally, as folks have mentioned on this panel, traffic over the licensed networks is going to continue to grow exponentially.

So the challenge here is to share spectrum as we have mentioned on this panel. The process of freeing up and reallocating spectrum is long and cumbersome and difficult. Sharing spectrum provides sort of a work around, if you will to use spectrum that is under utilized. So I think internet of things, finding a way to deal with increased mobile traffic and I think spectrum sharing is in the short term I think a great way to accomplish meeting those needs.

Mr. ROBERSON. We have an insatiable demand for spectrum. The demand for data, be it the internet of things or us communicating with one another or communicating to computers, deriving information from them or satisfying our entertainment needs, it is an insatiable demand right now. So moving to technologies that allow us to re-use that spectrum and use it very efficiently is absolutely critical and there are many, many things. I could spend a very long time on your question because it is a very rich question. But these

technologies must be explored and used in concert with one another and there are many technologies that have to come into play to even approach the satisfaction of our needs as a U.S. national organization.

Mr. REED. I think one thing that we need to be aware of is that the nature of wireless traffic could change over the coming years. And by that, today, we are receivers of information. We receive our email. We don't compose a lot of the email from our blackberries or iPhones. We download web pages. We watch movies. But in the future, we may be actually collectors of information and that traffic may flow from us into the network.

To be able to accommodate that that means we are going to have flexible spectrum policies going forward as we tend to do allocations based upon what direction the information flows.

Mr. WALDEN. Very interesting. We will have to pursue that another time with you because that is something we better be prepared for because we are in the multiples down versus singular up. We will go now to, I believe, Mr. Long is next in seniority based on the fall of the gavel.

So Mr. Long, you are up next.

Mr. LONG. Thank you, Mr. Chairman. Mr. Berenbroick, much has been made of the proper valuations of spectrum lately. There has been a lot of talk. And while it is difficult to predict, what do you view the potential dollar value of cleared spectrum and the bands considered best used for mobile broadband?

Mr. BERENBROICK. Thank you for the question. Unfortunately, I am not a spectrum valuation expert. I wish I had that information for you. I can follow up with you after the hearing.

Mr. LONG. I think that is very vital. I think that is something that I would like to learn from you if you could have your folks get back with me, I would appreciate it.

Mr. BERENBROICK. Sure, I am happy to follow up. Thank you.

Mr. LONG. OK, and Dr. Reed, how do you strike an appropriate balance between allowing industry to participate in the research and development phase, repurposing spectrum, and avoiding concerns of agency abuse of the process?

Mr. REED. Let me see if I understand your question. Are you saying——

Mr. LONG. How do you strike an appropriate balance between allowing industry to participate in the research and development phase, a repurposing spectrum, and avoiding concerns of the agency's abuse of the process?

Mr. REED. That phase "avoiding the agency's abuse of the process," I take that to be that sometimes there is a clash between legacy federal users and those that want to enter the band. And you know, it is understandable. It is human nature. We want to protect what we have.

I think what needs to be shown up front is that this is going to benefit the current users of that spectrum by doing this transition, that the commercial entities will help make that transition go smoother, although in the end potentially have even more capabilities through that collaborative activity. So we have to build trust and transparency.

Mr. LONG. OK. Thank you. And this is for you, Dr. Reed, and Mr. Roberson. Is it Roberson?

Mr. ROBERSON. Either is fine.

Mr. LONG. I will call you either then.

Mr. ROBERSON. I do that, too.

Mr. LONG. In seeking to maximize the value of spectrum to be auctioned, it seems to me that we need to do a few simple things like minimize impairments and provide potential bidders with as much information as possible about spectrum that they are bidding on. And being a former auctioneer for 30 years, I realize that the most information you can get to folks about what they are bidding on usually helps in the end result. Would you agree with that assessment?

Mr. REED. Oh, absolutely. The value will go up if we can do risk mitigation for those that are bidding on the spectrum.

Mr. ROBERSON. I definitely agree as well.

Mr. LONG. With respect to impairments or exclusion zone, do you agree that we should base our judgments on real world usage rather than worst case analysis that might assume more interference than is really realistic in the real world and thus reduce the value of the spectrum to potential bidders, Dr. Reed?

Mr. REED. That is so true. There has never been a communication system that has been able to get by without interference. And sometimes I see in FCC issues claims of interference, but it has to be significant interference. You just can't say it is going to interfere. You have to have a balance of risk with practicality.

Mr. LONG. OK.

Mr. ROBERSON. No, totally agree. Worst case analysis, when we had an abundance of spectrum, that was a wonderful thing to do. It protected everyone. We don't have an abundance of spectrum. So balancing risk is critical now and we have the tools to be able to do that. Many other agencies do use these kinds of tools way away from worst case to a practical case which is what your question was.

Mr. LONG. OK. Thank you. And Mr. Berenbroick, what opportunities are there for federal agencies to share spectrum with other agencies?

Mr. BERENBROICK. Well, I think there are numerous opportunities. I don't have examples at my fingertips for you. But as the other panelists have mentioned, there are opportunities for spectrum to gain more spectrum efficiency and for spectrum sharing. Technologies that we have access to and are yet to be developed will allow for that.

So there will be robust opportunities for agencies to share spectrum with one another, to share spectrum with unlicensed users and potentially to share spectrum with commercial users. That is why I think the discussion draft bill before the subcommittee is so important. It asked the FCC to ask and answer these questions.

Mr. LONG. Thank you. I am past my time and I yield back.

Mr. WALDEN. The gentleman yields back. The chair now recognizes the gentlelady from California, Ms. Matsui.

Ms. MATSUI. Thank you, Mr. Chairman. Congressman Guthrie and I have been working in a bipartisan manner on spectrum in close cooperation with the federal agencies. We co-chair a spectrum

working group and we are tasked to find solutions to meet our nation's growing commercial spectrum needs. I believe our collaborative oversight, and I do say collaborative, was critical to the success of the AWS–3 Auction which raised, as you know, more than $45 billion. And we worked to provide a reasonable path and that was really very important for the Department of Defense to relocate the 1755 to 1780 band in a responsible manner. And the AWS–3 was a huge win for consumers, innovation, and FirstNet, the public safety network that the auction will help pay for.

Dr. Reed, what lessons do you think we learned in the AWS–3 process?

Mr. REED. I think the lessons are yet to be learned. We are still in the process of doing this transition and there is still a number of unknowns. For instance, what will the interference be with a large number of consumer handsets? How will they impact military systems? How will the commercial systems respond to the interference that might be caused by DOD systems? How do we go about authorizing zones in which the commercial users can operate when and where? Those are details that have yet to be worked out. So far, so good. But I wish these details had been worked out earlier.

Ms. MATSUI. Right. I think we were making reasonable progress as we were trying to do and with our conversations with DOD trying to get to a point where we could have our discussion and move forward, knowing that there are details that we had to work on later.

Mr. REED. Yes, I would say don't slow it down.

Ms. MATSUI. No.

Mr. REED. I don't want to sound like we should slow this down and work out the issues.

Ms. MATSUI. I understand that.

Mr. REED. We just need to do more of the upfront R&D, have more people working on it beforehand.

Ms. MATSUI. Now Dr. Reed and Mr. Roberson, I know that you both serve on PCAST and that 2012 report from that group stated that federal agencies may have no incentive or authority to enhance their use of spectrum if the cost to police the budget available for the core mission.

My legislation with Representative Guthrie seeks to provide that incentive, encouraging federal agencies to be more efficient by allowing them to share in auction proceeds.

Mr. Berenbroick, do you agree that these financial incentives can be a game changer for federal agencies?

Mr. BERENBROICK. Yes. We do think they can be and we hope they are. Providing financial incentives for federal agencies to relocate and use spectrum more efficiently could be a useful tool in freeing up more spectrum to be repurposed for commercial and unlicensed uses. But we should also remember that those incentives might not be a silver bullet. That is why we also support sharing a federal spectrum.

And I also just want to point out if we are able to reallocate spectrum for commercial and licensed uses, we should think about competition as we reallocate that spectrum. And for these reasons this

is why we are supportive of the legislation that you and Congressman Guthrie sponsored, H.R. 1641.

Ms. MATSUI. As we are talking about reallocation of spectrum rights and reallocation of government users, typically, you have the priority when developing spectrum policy. The spectrum sharing also is an option as noted in Dr. Reed's testimony.

Dr. Reed, are there some services that are better suited to using shared spectrum than others?

Mr. REED. That is a good question. Certainly with shared spectrum, if you are a secondary user, your access may not be as reliable as with licensed spectrum, but there are certain types of traffic, for instance, video. And video is the big growth area in wireless communications right now. It is dominating the internet and is going to dominate wireless transmission. Those sort of applications are not real time sensitive because you can store it up during the times in which you don't have the link. You just deplete from your memory. So there are better applications. Some applications are better than others.

Ms. MATSUI. Well, can you think of scenarios in which spectrum clearing through reallocation may be preferred?

Mr. REED. Yes, I believe that there should be licensed spectrum. There should be unlicensed spectrum and there should be shared spectrum. Now where the boundaries lie, of course, that is going to be controversial. Licensed spectrum does have its benefits in terms of being able to guarantee the quality of service. But on the other hand, shared spectrum also has a role.

One of the use areas for shared spectrum is kind of like the overflow spectrum. If an operator's network is being impacted, they could always go to their shared spectrum reserve to help fill those needs.

Ms. MATSUI. That is the combination you are talking about?

Mr. REED. Yes, it is like with energy as well, where the power company can turn off your——

Ms. MATSUI. Right. I understand that my time is up. So thank you very much.

Mr. LATTA. The gentlelady's time has expired and the chair now recognizes the gentleman from Texas, the Chairman Emeritus of the full committee, Mr. Barton, for 5 minutes.

Mr. BARTON. Thank you. A lot of times at these kind of hearings we have to ask political questions and sometimes we have to ask "got you" questions. But sometimes we can actually ask fact-based questions and admit, at least in my case, I don't know anything. So I am going to ask some fact-based questions because I don't understand spectrum.

I made Ds in electrical engineering. I am an engineer. But I made Ds in electrical engineering. I made Cs and Bs in physics. I am old enough to remember the old radio dials. You had 600 on the low end or 500 and 1600 on the high end. I never understood the difference between AM and FM. But I am trying to get a handle on this spectrum and I understand we have two engineers here that know all there is to know about it.

So in this room, how much spectrum is there right now? Is there an infinite amount of spectrum? Or is there a finite amount of spectrum?

Mr. ROBERSON. I will grab that. There is definitely a finite amount of spectrum.

Mr. BARTON. Finite.

Mr. ROBERSON. Which is the challenge. It is divided up into frequencies, but it is very finite. It is temporal in that it is reusable, the spectrum that we have now, we have again now. So it is reusable.

Mr. BARTON. That confuses me.

Mr. ROBERSON. The spectrum is the thing. But its use is temporal. So if you are using it at one moment, it can be used again a few moments later.

Mr. BARTON. If we didn't have the FCC, would it make any difference how much spectrum was used in this room? I mean——

Mr. ROBERSON. It depends on its use. Yes, it would definitely make a difference in how much is used because of the spectrum being allocated for purposes like the AM radio that you were describing, that is a band of spectrum, a set of frequencies that are allocated for a specific purpose. There is another band allocated for—or several—for television, for FM, for cellular it has several bands. But this is the allocation——

Mr. BARTON. What I am trying to get at is why we need to worry about this? Is there at any given moment in time can only one broadcaster or user be using a specific, to use your term, band of spectrum?

Mr. ROBERSON. Yes, only one at any given time.

Mr. BARTON. OK. If I am on the 600 band spectrum in this room, can somebody in the next room also be on the 600 band of spectrum and in the next room?

Mr. ROBERSON. Yes. Under the right circumstances so that you don't have power that leaks across room boundaries.

Mr. BARTON. See, I don't understand that. What does that mean, "don't have power"?

Mr. ROBERSON. You do actually understand it.

Mr. BARTON. I am glad you think that.

Mr. ROBERSON. No, no, no. I will explain it very quickly as I do to my classes. If you throw a rock at a pond, it creates——

Mr. BARTON. I am not a college level student. I am a first grade level student.

Mr. ROBERSON. That is why I threw rocks in ponds.

Mr. BARTON. OK. I have thrown rocks in ponds.

Mr. ROBERSON. Yes. And when you throw a rock in the pond there was a big wave close to the rock, right?

Mr. BARTON. Yes, sir.

Mr. ROBERSON. And as you got out to the edge of the lake, there was almost no wave motion at all.

Mr. BARTON. I never saw that far, but I will take your word for it.

Mr. ROBERSON. The notion is there is a finite amount of energy that is inserted at a point.

Mr. BARTON. OK.

Mr. ROBERSON. As you expand, the incremental amount of energy seen at any point on the circumstance of that is diminished.

Mr. BARTON. OK.

Mr. ROBERSON. So in this room, you can have a finite amount of——

Mr. BARTON. So a one watt radio station wouldn't go very far. But a 100,000 watt radio station——

Mr. ROBERSON. I told you you knew a lot about it.

Mr. BARTON. Well, I do remember what a watt is. That is a measurement of power. So I got that. Some of my colleagues, they won't admit that they don't know either. They are nodding their heads.

Mr. ROBERSON. No, but you have hit a very important point. You really have hit an extremely important point. If you use low power, you can reuse that spectrum over and over again.

Mr. BARTON. Lots of people can do low power.

Mr. ROBERSON. Lots and lots of people as long as they are geographically separated.

Mr. BARTON. OK, now last question because my time is about to—is any of this spectrum better? I keep saying the premium spectrum. What makes spectrum better than other spectrum?

Mr. ROBERSON. This is the point that Dr. Reed made around propagation. Different spectrum at different points propagates better through the wall, for instance. Some spectrum will go right through the wall and not even see it. Other spectrum will be absolutely blocked by that wall.

Mr. BARTON. So best spectrum is more propagated, if that is a word?

Mr. ROBERSON. Depending on its purpose. It has to be fit for purpose.

Mr. BARTON. OK.

Mr. ROBERSON. For television, it propagates through walls.

Mr. BARTON. That is a good thing.

Mr. ROBERSON. Or if you want to keep the information enclosed in this room, you want to use a very high spectrum, high band of spectrum that doesn't propagate through the walls because you wish to contain the spectrum and you wish to reuse it. That is where the millimeter waves come in because they don't propagate well at all because water and oxygen absorb that energy.

Mr. BARTON. OK. I learned a little bit. Thank you for humoring me, but I really don't understand it and the only way to learn is to ask questions.

Ms. ESHOO. I give you enormous credit because around here people don't want to acknowledge that they don't know and there is nothing wrong with that.

Mr. BARTON. Well, if this were oil and gas, I wouldn't admit that.

Ms. ESHOO. I got you. I think it is very important what you said.

Mr. LATTA. We appreciate the gentleman's line of questions and his time has expired. The chair now recognizes the gentleman from Ohio, Mr. Johnson, for 5 minutes.

Mr. JOHNSON. Thank you, Mr. Chairman. And thank you to our panelists for joining us today.

You know, in August, the Office of Management and Budget made a variety of suggestions about the spectrum relocation including the idea that the FCC should be permitted to "charge modest licensing device or database administration fees" in order to "facilitate greater unlicensed access."

Now I support efforts to open additional and appropriate bands for unlicensed use, but I am firmly opposed to proposals to impose a tax on devices that use unlicensed spectrum. As the internet of things grows and more and more devices are connected, that could expand the tax man's reach to not just my phone, but my car, my refrigerator, my thermostat, and all sorts of other devices around the home that utilize spectrum. I think that is a terrible idea.

So for the panel, what are your views on the administration's proposal to tax devices that use unlicensed spectrum? And we can just go down the row there.

Mr. BERENBROICK. Thank you for the question. So Public Knowledge has not taken a position on that question specifically, but I might be speaking out of turn here. I would imagine that when we do take the position that we will not support taxes on devices, on unlicensed devices.

Mr. JOHNSON. Thank you. Dr. Roberson?

Mr. ROBERSON. I am not actually familiar with the proposal, but it doesn't sound like a very good idea to me in that you wish to keep the airways as open as you can and this would seem highly restrictive, especially with the billions of devices that are likely to be out there in the internet of things world. I don't even know how you would administer it.

Mr. REED. First of all, let me say why funds are needed. In the spectrum sharing regiment, it is like going to a library. You check out a library book and it can be recalled and it is a way to deconflicting and managing the spectrum. So there are costs.

Now that said, I really don't have an opinion on whether it should be a tax or not. There may be other ways to do that. But definitely there are expenses involved.

Mr. JOHNSON. I understand there are expenses. I certainly agree with that. But what I don't agree with, is that spectrum users in rural areas across the country that are increasingly dependent upon access through devices for connection to the internet, to the cloud, to services, are going to pay the lion's share of these kinds of costs.

Dr. Reed and Professor Roberson, in its progress reports, NTIA has identified 245 megahertz of spectrum they have repurposed in the last five years. However, when we examine that a little more closely, much of this spectrum was made available through changes in service rules or mandated by legislation. So do you believe that NTIA is making sufficient progress in independently identifying and repurposing bands of spectrum? And how can we help improve that process?

Mr. Roberson, do you want to go first?

Mr. ROBERSON. Sure. This is an enormously challenging area identifying the spectrum. I provided in my testimony some of the areas that can be pursued. I think this is something NTIA must provide leadership on and must put out effectively a funnel, as you would think of a sales funnel of much more spectrum that can be pursued and then per the conversation that we have been having, much more research is needed to choose the best of those spectrum options and then to rigorously pursue how to make those available.

Mr. REED. Actually, I visited NTIA as part of National Academy's evaluation of their lab facilities there, the folks who go out and

make those measurements. They are good technically, but the leadership until recently that is, they have new leadership now. The leadership wasn't all that great. And they were under funded and somewhat bureaucratic. So they have had their challenges.

That said, given the tools that they had, they did well. They just should have had more. They should have had more time and resources to do some of the upfront measurements at 3.5 gigahertz. In fact, I even asked them that question. Why didn't you guys do this? And they said we just didn't have the budget.

Mr. JOHNSON. Mr. Chairman, I yield back.

Mr. LATTA. The gentleman's time has expired and he yields back. The chair now recognizes the gentlelady from North Carolina for 5 minutes.

Mrs. ELLMERS. Thank you, Mr. Chairman. Thank you to our panelists for being here today on this issue.

Mr. Berenbroick, did I——

Mr. BERENBROICK. That is perfect.

Mrs. ELLMERS. OK, perfect. Thank you. Because it sounds just like it looks, so good. You mentioned in your testimony the importance of unlicensed spectrum. And in particular, the unlicensed underlay. Can you elaborate on this concept and why it would be a potential solution as a reform to spectrum policy?

Mr. BERENBROICK. Sure. And I have been saying that all my life that it looks like it sounds, so I am glad to be validated on the record.

So the idea of the unlicensed underlay, basically there is consensus that there is a need for more unlicensed spectrum with the internet of things coming with the amount of traffic that is being offloaded on to unlicensed networks. A federal underlay would allow for unlicensed use in bands where federal users reside. The idea would also be to make sure that critical federal functions, for instance, things like national security functions are protected, to take all interference mitigation steps that are necessary and also to ask the FCC to figure out how would this work? Is this workable? Is this possible? Which bands are right for spectrum sharing?

And doing that would potentially open up, Chairman Walden mentioned this at the start of the hearing, 18 percent of the best spectrum is allocated for federal use. It would allow for unlicensed use of that spectrum which, as the other panelists have mentioned, a lot of that spectrum sometimes is—I am not going to say it is unused, but it is used intermittently. And so it would put that spectrum to use more efficiently.

Mrs. ELLMERS. I have another question as we are moving towards the 5G and basically the interest from the American leadership on that, the question I have is, won't this require a great deal of the greenfield spectrum, otherwise bands that are not being used for 4G. And won't the spectrum need to be a mix of low, middle, and high frequencies? And what has been identified so far if there has been?

Mr. BERENBROICK. I can take the part of the question regarding the need for low, middle, high frequencies. I think these gentlemen might have more concrete thoughts on the specific bands that should be allocated. In the FCC's mobile competition report which came out in the summer, spring or summer of 2014, they identified

that for licensed networks to operate, the networks need a mix of low band and high band spectrum.

As Mr. Roberson mentioned earlier in his discussion about spectrum propagation characteristics, low band spectrum goes further distances. It goes through walls. With high band spectrum, it can carry more capacity. So for networks that operate in both rural and urban areas, for networks that have intensive uses for mobile broadband coverage, a mix of that spectrum is necessary.

Mrs. ELLMERS. Mr. Roberson and Dr. Reed, would you like to comment as well?

Mr. ROBERSON. Absolutely. And I would agree that you have to have the mix of spectrum. In my earlier testimony, I talked about milliliter wave which is brand new spectrum. It's high band spectrum, but it has tremendous limitations. So it has to be a mix of the two capacity of the higher bands, the coverage in the lower bands, and we will need to identify new spectrum in both those bands to achieve our goals for the fifth generation. And that is critical so that we maintain our U.S. position in that space.

Historically, as generations move first, second, third, the leadership has shifted from U.S. to Europe to Asia back to the U.S. now. It needs to stay in the U.S.

Mrs. ELLMERS. Dr. Reed.

Mr. REED. Yes, I think that we are not unique here in the U.S. in terms of facing this spectrum crunch. However, we have been a bit more innovative in the way that we approach this problem. So I don't think we are going to find much greenfield spectrum below 3 gigahertz. It is probably going to be shared mostly.

Mrs. ELLMERS. Thank you and I yield back the remainder of my time.

Mr. LATTA. The gentlelady yields back and the chair now recognizes the gentleman from Kentucky, Mr. Guthrie, for 5 minutes.

Mr. GUTHRIE. Thank you, Mr. Chairman. And I know that my friend from Missouri got to go earlier because he is here at the gavel, but I want to point—he took out Mr. Lance with a jug of water, so he should have been penalized for his order of the way to go.

Mr. LONG. I would have done that earlier if I had known I would get rid of him that easy.

Mr. GUTHRIE. I am working with Ms. Matsui, the sponsor of the bill, and I didn't know a lot about spectrum, still don't know a lot about spectrum, no more than I did. And the only way I knew the difference in AM and FM, my dad had a Pinto that only had AM radio. So that means if I was riding with him, we had to listen to country music. So it was just the way things were.

And Mr. Berenbroick, thanks for coming. I know you grew up in Radcliff which is the home of Fort Knox, so we always appreciate that. When people come to Kentucky they want to drive by and see the gold vault. What you can see from the scene from Goldfinger, you can see from the road. So it is an interesting place.

We started talking about—I know nobody talked about incentives. That is kind of where I wanted to go with it. But when we started on doing the bill, the question was we can pass a bill and say mandate that you release spectrum. You really have to have a willing—actually, we worked well with the Executive Branch on

this with Secretary Strickland. But you really have to—either somebody is going to be there managing the reports or you can incentivize. So we came up with the idea of incentivizing. In the bill is one percent.

Do you think that is adequate? Should incentives be based on the type of spectrum they move forward? Is one percent sufficient from what you would see? I mean how would you use the financial incentives?

Another thing, agencies came before us and said well, if it is just going to replace money we already have, we lose the incentive. So then we talked about does it go above— does it help them relieve some sequester issues by generating more money for the Treasury by relieving spectrum? So just kind of your thoughts on spectrum. And then I have one other question that I want to ask Mr. Berenbroick on how we incentivize these agencies to actually do it through financial incentives.

Mr. BERENBROICK. Sure. As I answered earlier, I do think the financial incentives can be a way to get those agencies to either relinquish spectrum in some cases or to figure out how to relocate and use other bands.

Mr. GUTHRIE. There is a lot of work to do. I just thought you just turned a dial. But it is not.

Mr. BERENBROICK. It is not.

Mr. GUTHRIE. I have learned that.

Mr. BERENBROICK. And so going to your question of how much incentive is enough, I think that question is going to be fact specific to each individual agency. I think different—some agencies might simply decide look, whatever the amount is, we are not going to move. Other agencies might decide for a specific amount, we would be interested in moving. So I think it is going to be agency specific and mission specific, because remember, we want to make sure that the agencies can continue to do their mission, but we also want to make sure that we are freeing up spectrum and using it in the most efficient way possible.

Mr. GUTHRIE. So I guess my question is so setting it at one percent, your suggesting it would have to be flexible because in order to get what we want out of the legislation, one percent may not incentivize someone, but it may incentivize someone else. Who do you think should do that, NTIA, OMB? Because unless we have to change the law every time we come up with this issue. That is how we——

Mr. BERENBROICK. I think NTIA and OMB are the agencies that come to mind, but there could be somebody else. I mean I would imagine the FCC would also want to think about what the best way to relocate those users is and what the use of that spectrum would be after relocation. I imagine it would be a conversation between the appropriate committees and those agencies.

Mr. GUTHRIE. I am going to go to my second question. So I had a semester of electrical engineering before I realized that wasn't for me. So I never could understand it. The right hand rules was about all I got out of it, but there is a big debate about sharing. So like you have emergency sharing, so to make an example simple, I said well, it is like this. We don't build highways for ambulances. We

build highways that people use and when ambulances use them, we get out of the way.

I was just in New York City and sometimes it gets crowded and I had to get out of the way and I almost got up on the sidewalk so an ambulance could get by. So I mean it is easier on I–65, we pull over and the ambulance goes by. Sometimes it gets crowded. Will sharing really work? That is the physics question or the electrical engineering question. And can people just get out of the way when emergencies need to use it or would it be too disruptive to share?

Mr. REED. Actually, I like to think of it in terms of E–Z Pass as well. Sometimes you really need to get to that location and you need to get there quickly and you are willing to pay that $5, who knows how much, just to get there. And the way that we have set up sharing is a prioritized basis and those who at least in the 3F gigahertz band who go to the auction and get primary access, they will have that freedom.

I think it is possible for us to manage spectrum and to be able to deconflict legacy users to get out of the way, for instance, of a military radar system or a satellite uplink when the time is needed.

Mr. GUTHRIE. Would you see a constant disruption like I am watching—well, everybody is OK if we have a battle or something is going on, but is it just little things will always be disrupting or something can be managed?

Mr. REED. It just depends upon the situation. I think at 3.5 gigahertz, I think there is going to be very little disruption. There are not that many federal systems out there. There are not that many ships that have that high-powered radar system, the SPY–1 or the SPIN–43 radar systems.

Mr. GUTHRIE. So even if like a hurricane is coming and emergency needs it, sometimes you need to just watch the broadcast because of the hurricane, watching the weather and the news on your device. So it kind of plays in it. I know I went over my time.

Mr. ROBERSON. If I could just very quickly, I think technology does solve this problem. The sophistication of the prioritization that exists today absolutely allows this sharing to take place and to take place very efficiently.

Mr. GUTHRIE. Thank you. I yield back.

Mr. LATTA. The chairman yields back and the chair now recognizes the gentleman from Texas, Mr. Olson, for 5 minutes.

Mr. OLSON. I thank the chair and welcome to all three witnesses. My first question is for Dr. Reed and Professor Roberson. What steps are federal agencies taking to improve spectrum efficiency particularly in the bands traditionally viewed as most viable for commercial use? Big question. Your thoughts, Dr. Reed?

Mr. REED. Well, in the case of the AWS–3 transition, they are moving some of those systems out and they are consolidating these federal systems together in a different band. So they will be more efficient users of the spectrum that they have. There will, however, still need to be some legacy systems that operate there because of the amount of time and money it takes to move those systems out. And there are some technologies that can help with this. Frankly, I don't think we know how well they will help at this point. Again,

it gets back to the R&D issue. But I think that we will be able to leverage some of the great properties of long-term evolution, LTE 4th Generation cellular. It is actually quite robust interference. So I am optimistic we will get good spectrum efficiencies.

Mr. OLSON. Thank you. Professor Roberson. Your thoughts, sir.

Mr. ROBERSON. Sure. There are a number of initiatives that are in the works, but these need to be expedited, so I will give you a balanced view. There are many things going on. Dr. Reed spoke to some number of them. But there is so much more that could be done. The way in which spectrum is managed within an organization like the Department of Defense is still very inefficient at this point. They know how to move from the inefficient approach, very human-centric approach to an approach that is much more richly supported by technology and by data. But they have not been able to move that. They have vast systems and they have increasing needs as well. But the opportunity is there. It just needs to happen and happen more quickly. And this would apply to many others than the Department of Defense.

Mr. OLSON. And to follow up on Mr. Guthrie's line of questioning for you, Dr. Reed, when evaluating potential bands to be repurposed whether through auction or sharing, what are the most important considerations for us to keep in mind? How can we help and how can we hurt?

Mr. REED. Good one. Certainly policy is going to make a huge impact. Being able to move quickly, but policy needs to be grounded in good engineering. And if we don't do our upfront engineering, then we could end up in a mess, granted.

The committee and the regulatory agencies have been moving remarkably fast compared to the historic performance and I applaud them for that and I think that that should continue. I think making sure that there is a lot of transparency in the overall process, that it is not DOD versus AT&T. We don't want to go there. They need to work as a team. So those are my thoughts.

Mr. ROBERSON. I think the biggest thing is the application of data, the application of technology. There is so much inertia in the rules and regulatory processes that we have today that overcome that and to move into the world that, where for instance, the spectrum observatory that we have put up at Illinois Tech. You can see the use of the spectrum. You have that data logged for years of time. Being able to apply data, real data, not theory, not worst case analysis, but real data to the problems and move things forward is really critical. And I think your part of this is to insist that conjecture not be the way in which decisions are made. It is rather based on absolutely solid research data that is available that concretely describes the situation and the opportunities that are in front of us.

Mr. OLSON. Thanks. I will have a question for the record, but one final informal poll. Houston Astros or Kansas City Royals. Any thoughts about that, guys?

Mr. BERENBROICK. St. Louis Cardinals.

Mr. OLSON. Thank you. I yield back.

Mr. LATTA. The gentleman's time has expired. Really expired. And he yields back. And on behalf of Chairman Walden and also for the gentlelady, the ranking member from California and myself,

we thank you very much for your testimony today. And seeing no further business to come before the committee, we stand adjourned.

[Whereupon, at 12:11 p.m., the subcommittee was adjourned.]

[Material submitted for inclusion in the record follows:]

PREPARED STATEMENT OF HON. FRED UPTON

There's no question that freeing up additional spectrum for commercial use is a vital step in ensuring America's continued leadership in technology and innovation. Congress, the administration, industry, and public interest groups are all in agreement that there is a need for a great deal more spectrum to meet demand for important services and technologies.

Our federal agencies are the biggest single user of spectrum, much of which is devoted to important work and operations. But surely there are ways to invest in our agencies and improve systems to ensure that they are using spectrum in the most efficient way and with the best equipment. Getting agencies to make these changes can be difficult. It requires federal users to take on additional work without compromising their core missions—a difficult sell. One way to encourage agencies to make this kind of investment of time and resources is to provide them with a financial incentive for relinquishing unused or unneeded spectrum. Reimbursement for the spectrum they give up can help to further their mission in other ways. The bill put forward by Representatives Guthrie and Matsui will be an important step in this process.

The committee is also considering a discussion draft of a bill to identify additional bands of spectrum that could be made available for consumer use. Spectrum has helped transform the daily lives of folks in Michigan and across the country—giving us the ability to stay connected with personal devices today that were once unimaginable just a decade ago. While we have done a great deal through hearings, whitepapers, and legislation to promote the availability of spectrum, there must be a consistent and predictable supply to fuel competition and innovation to pave the way for continued advancement. NTIA and the FCC have done a great deal of work to identify potential sources for spectrum to be reassigned. I am optimistic that we can do our part in crafting legislation to provide additional structure to this process and give these agencies the tools needed to succeed.