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Transcript

2021 Spectrum Policy Initiative Conference
Frontiers in Spectrum Sharing

September 9 – 10, 2021

Silicon Flatirons Center for Law, Policy, and Entrepreneurship
University of Colorado Law School | Wolf Law Building | 2450 Kittredge Loop DR | Boulder, CO 80309

Day One Intro & Keynote

https://www.youtube.com/watch?v=Z6TTBByvkT0&list=PLTAvIPZGMUXNWmcqlTXSrvUmWJ0RfSL9K&index=1

[00:00:00.51] AMIE STEPANOVICH: Both to the folks here in the room joining us in person, back at Colorado Law School, I'm really excited to be [AUDIO OUT] human bodies, as well as all of you across the country, across the world, who are joining us virtually. My name is Amie Stepanovich. I'm the executive director of Silicon Flatirons, and we're excited to be hosting this year's spectrum policy conference on Frontiers in Spectrum Sharing.

[00:00:27.72] Before we begin, I want to acknowledge that wherever we are, we are meeting on the land's First Nations people. And the traditional owners of the land here in Boulder are the Cheyenne, or Arapaho, and Utah nations. And I'd like to pay particular respects to the elders, past, present, and emerging, who lead these communities.

[00:00:47.34] In just a moment, I'm going to introduce Keith Gremban to the stage, and do a more-- who will do a more formal introduction of today's conference. Before that, I want to say a thanks to the Silicon Flatirons and the law school staff who have made today's event possible, for their hard work getting everything up and They were kind of running two separate events today for the people in person and virtually. It's added a whole new component to what we do. And I hope that we are successful.

[00:01:15.84] But please do look for that feedback form after the event's over. Let us know what we can do better, let us know what's worked. We'd love hearing back from you on what is great, and how to better serve our community. In particular, I want to also thank our student volunteers, all of our students who are going to see in the room and over the live stream over the next couple of days, and to the individuals and the organizations who support Silicon Flatirons, and make these conversations and all of the work that we do possible day in and day out.

[00:01:48.00] That's why we can catalyze conversations and help to develop who we believe are going to be the next generation of professionals leading in tech community. And I have one more really exciting announcement before I turn things over. Starting with this conference, I get to announce that Dr. Keith Gremban will be joining Silicon Flatirons as the new co-director of our spectrum policy initiative, alongside Dale Hatfield. I could not be more excited to welcome Keith.

[00:02:22.35] Keith Gremban has long and illustrious resume, which I urge you to check out if you have not previously done so. Including 30 years of the defense industry as a software architect and systems engineer, where he has led research and engineering efforts in robotics, command and control systems and tactical communications. This of course, means that Pierre de Vries will be stepping down, though he will be continuing on with the Silicon Flatirons family as a distinguished advisor and director emeritus. And we're excited also to continue to support his work as well.

[00:02:59.22] With that, I'll go ahead and introduce Dr. Gremban into the stage. Welcome more formally to the Silicon Flatiron's family, and allow you to introduce our first keynote. Thank you so much.

[00:03:16.56] KEITH GREMBAN: Logistics are a little more complicated nowadays. That's better. Thank you. They got the wave from the back. I thought I turned it on. So we apply the no acronym rule. So remember that audience and panelists may not be from your community. So a string of letters is not going to mean much to anybody. Make sure you define the acronym before you use it.

[00:03:49.42] So it's now my honor and privilege to introduce this afternoon's keynote speaker, Ambassador Grace Koh. And as many of you know, Grace Koh was the former ambassador to the International Telecommunication Union's World Radiocommunications Conference that was held in Sharm El Sheikh, Egypt, in 2019. In that role, she managed the interagency discussions to formulate the US policy positions and the strategies leading up to the conference. She then led the 125 member delegation in negotiating successful outcomes for both the US government and US private sector interests.

[00:04:27.30] So Grace came to the role as the ambassador very well prepared. She previously served as the special assistant to the president for technology, telecom and cybersecurity policy in the White House, and was also the deputy chief counsel to the subcommittee on Communications and Technology of the Energy and Commerce Committee in the US House of Representatives. You can find additional information on Ambassador Koh's background in the program.

[00:04:52.02] What's interesting now is her current role as vice president of Legislative Affairs at Nokia. Not only does she have to deal with terrestrial and satellite spectrum management issues, which we'll be discussing today, but potential interference in spectrum management is sharing issues in space. And this is because the National Aeronautics and Space Administration, or NASA-- see no acronym rule-- selected Nokia as our partner for building the first ever 4G LTE communication system in space. And that will help pave the way for long-term human presence on the moon. So let's welcome Ambassador Koh. Thank you.

[00:05:30.18] [CLAPPING]

[00:05:34.85] GRACE KOH: Well, congratulations Dr. Gremban. It's great to see Silicon Flatirons continuing to have such great leadership. I'm sure that they're really excited to have you, and it'll be great to see you leading our discussions in the future. And thanks very much for the kind intro. Really glad to be here with you all today on the 42nd day of May 2020.

[00:05:59.81] Like most of you, I'm pretty sure I've lost track of time and reality during this awful pandemic, and it's just been a hard slog trying to keep moving forward. But I'm glad to see that you all hear at Silicon Flatiron to start, or you're still moving forward. You're still bringing together discussions, thoughtful perspectives, fresh ideas, getting a debate going, and new lines of research.

[00:06:21.71] I really do miss this real face to face dialogue during this period of social distancing, and even I miss more the after-session beer that you get to have with the panelists.

[00:06:35.03] But we're all moving forward. We're all trying to move forward. It's not actually May, 2020. We're already actually in the fourth quarter of 2021. And I think looking around--

[00:06:46.25] So I thought I'd talk less about, specifically about the spectrum-sharing, and less about maybe what Nokia is doing on the moon. Although I'm happy to answer questions about that later. But I just thought I'd talk a little bit about macro changes in the past few years and how views on globalization have changed and the rise of populism and activism. And ultimately, how that's further accelerated by the pandemic.

[00:07:10.77] And then I was going to talk a little bit about how it impacts the world we inhabit on spectrum innovation in technology, and what it means for spectrum sharing. It seemed better suited to my wheelhouse, as I'm not really an engineer. I don't even play one on TV.

[00:07:28.74] So let's say that we go through cycles of populism every so often. My friend, Bruce Mehlman, estimates that every 60 odd years, a wave of populism and then subsequent reforms sort of

recurs throughout the American history. And you see it in the Civil unrest of the 1960s. It happened during the end of the Gilded Age with the calls to end the gold standard in the late 1890s into the early 20th century. And you might even argue that the American Revolution could be considered the first American populist movement.

[00:07:58.14] And these past few years have definitely borne witness to some of the most shockingly clear articulation of populism. The election and departure of President Trump, the pro-Brexit vote, the yellow vest demonstrations in France, or just think about any country in South America in 2017 or 2019. And much of this popular sentiment appears to be due to globalization shocks. In short, it feels like the world is experiencing a giant sort of collective hangover from policies that have been supporting globalization.

[00:08:41.09] So globalization, the notion of free movement of goods, labor, tech, across borders under liberal agreements, really took off I guess in the 1990s when we saw the end of the Cold War, the economic liberalization of India and China, as well as former Soviet satellites. We saw the creation of big multilateral institutions like the WTO and the EU. And don't forget that this is when the internet was born and our ability to communicate across borders accelerated; it expanded exponentially.

[00:09:12.76] So globalization has had a lot of positive effects. Generally speaking, we saw at first what we expected to see; a massive increase in the global middle class and fewer people living below the poverty line. And just so you know, folks at the White House used to call me globalist freeze. And not in a friendly way. I'm not trying to defend or criticize any of the trends. I'm just trying to give you my interpretation of events at this point.

[00:09:39.09] The upshot was though that we came to realize that globalization didn't make everyone a winner. For example, during this time, the 1980s on, and 1990s, saw the gap between the rich and the poor was really started to increase. Experts argue about whether globalization really contributed to income inequality. But the fact remains that the gap increased during the heyday of globalist policies. CBO estimates that from 1979 to 2018, income per household grew about 33% for the lower 80% of Americans, but for the top 20%, income grew 99%. For the top 1%, It was 218%.

[00:10:20.36] Other trends probably fueled the perception of being left behind in globalization. So rising trade pressure resulting from increased free trade, the financial crises like the one that the US and most of the world experienced in 2008, 2009, or the fiscal austerity that's related to foreign debt exposure in many other countries. Labor competition through increased immigration, which is perceived or otherwise. These have all contributed to a sense of economic insecurity that perhaps has fed populism and activism, not just here, but also across the globe.

[00:10:58.36] So let's also remember that the work that we do as technologists, engineers, and scientists, have also contributed to this period of anxiety. Faster real time communications, increased automation, greater computing power, have all contributed to the efficiency gains that have also increased the pressure on the middle class livelihood, the gig economy and part time work accelerated with the advent of the app economy.

[00:11:24.11] This all came through at the same time. De-unionization and scarcity of the traditional pension-backed benefits late in full time jobs, came with those developments. These are all again factors contributing to that sense of economic security that has now fed a populist and protectionist backlash. And it's increasingly in the mainstream.

[00:11:46.95] And if globalization shocks and technological advancements were already pushing us toward a protectionist populist agenda, I'd argue that the pandemic sealed the deal. The shutdown of borders gave the world a flash cut to a disconnected international economy and exposed vulnerable

supply chains in all areas. People realize that the globalized world built for highly leveraged deficiency was ill prepared to take on a crisis of this kind. And after all, resiliency and preparedness are ultimately at odds with efficiency.

[00:12:16.86] A backup communications band is just spectrum lying fallow, right? As one general explained to me, I don't know if I want to have to use it, but I sure as hell don't want to be without in case shit goes south. Can you believe that?

[00:12:32.50] I haven't mentioned China really explicitly yet. And that's primarily because in one way, the anti-China sentiment is just shorthand for the anti-globalist view. China's rise coincides with the world's push toward globalization. China's accession to the WTO during the heyday of globalization had many experts claiming that China would become a liberal economy by 2015, maybe even a democracy. I think we know better now.

[00:12:55.03] American businesses and governments have-- and liberal governments have faced the reality of continued trade deficits, state-owned enterprises, forced technology transfers, and the steadfast refusal to open the market to foreign enterprise. We saw a stronger, more aggressive China take advantage of enforcement free agreements to expand and grow.

[00:13:14.47] And it's true. It is important to realize that China has emerged as a major rival to the United States. But I also still think it's useful to remember that this is about the reality of globalization. After all, globalization was fine when it really meant Americanization, as many people outside of the United States have pointed out. We might have a harder time with the concept of globalization if it actually means certification.

[00:13:40.24] And it's been interesting to see that policymakers at this point are not interested in changing China, but co-existing with China. The end game appears to be defensive and more containment oriented to pull a Cold War term. When I ask experts what our goal should be vis-a-vis China, one person who works at the New America Foundation or Institute said America has to get used to living with a powerful China. Another person, actually a US Senator, actually said that-- he said to me we need to prevent China from winning.

[00:14:18.85] That's a very different sentiment from saying that the US needs to win or that we will ultimately persuade China to become a liberal democracy and a market economy. And if this is all true that countries need to turn inward and focus on resilience and preparedness in order to be able to continue to fight off, I think, perceived threats from climate, from exposed supply chains, from pandemics, from adversarial threats, countries need to figure out what actions policymakers should take.

[00:14:55.76] And we're seeing in the States that both parties are realigning around a populist agenda. Leaders on both sides of the aisle are preaching that we need to regulate big tech, big banks, big companies, generally. That we need to buy American, that we need to control our borders, and that we need to invest in domestic industry and domestic technology.

[00:15:15.52] That is sort of what this is coming to. Policymakers are looking to the role of technology and global leadership. And government wants in. Government wants a bigger role in technology and innovation.

[00:15:28.72] By the way, I fully realize the incongruity of saying this, even though we still haven't seen the nominations for an FCC chair or NTIA administrator. Just saying. But the government wants a role in tech, and not just the tech and innovation that's used typically by the government for the military or for scientific research, but in the technology that's used in the commercial world.

[00:15:50.83] I think what we're worried about to some degree is tech imperialism. The notion that a country can spread its influence there, its dominance in commercial technology. Maybe in the way that America has been able to be a significant leader in that respect for the past several years.

[00:16:07.73] And in spectrum, tech imperialism particularly matters. You might have to come up with a better term than that. But no matter how hard any country turns inward spectrum flows across borders, and international cooperation is always going to be necessary.

[00:16:20.11] And without the cross country dialogue, we risk interference at the borders and we risk losing economic opportunity. How many f-16s or wireless routers can we sell if the rest of the world doesn't agree with our frequency allocations? This is just another example of how commercial tech is being co-opted into the realm of national security.

[00:16:40.62] Government is continuing to make inroads into how it would like to oversee, monitor, influence big tech or tech generally. You're seeing calls for increased antitrust scrutiny or efforts to look deeper into supply chains, efforts to collaborate more closely with the private and public sectors, like a new mechanisms for monitoring progress like the Cybersecurity Safety Board established in the recent Cybersecurity EU, or greater review of research facilities and who is actually staffing them. More explicit guidance on permissible and impermissible components and equipment, and just think greater information sharing or spying.

[00:17:25.02] On the plus side, there is the government checkbook. The US Innovation and Competition Act still in draft of the house after its passage by the Senate, captures very well the US desire to secure technology, leadership and industry here. So much so it runs I think to the tune of $200 billion.

[00:17:42.82] The bill focuses on the so-called strategic sectors, semiconductors, drones, wireless, broadband, and artificial intelligence, and it seeks to do everything from educating a tech forward workforce to creating funds to counter Chinese investment in other countries.

[00:17:57.66] But I did want to point out the word spectrum appears twice in this nearly 1,450 page bill. And one of the times it's really to talk about the full spectrum of issues. So I think that one doesn't count. It's a little troubling.

[00:18:17.58] And while the United States generally has never conducted explicit industrial policy, it's no longer a completely unthinkable. It is the time for big changes.

[00:18:27.81] After the 50s and 60s, came the Civil Rights Act. And after the unrest-- at the end of the Gilded Age, came the progressive era. And the glory days of labor unions and active antitrust enforcement. And if the US goes into industrial policy, we'll see the rest of the world do even more of it.

[00:18:46.67] But then again, you all work in spectrum. And very possibly, spectrum policy has been one area where the US has come closest to ever having an industrial policy, despite its absence in the Senate draft. We all know the mantra, right? Spectrum is a scarce public resource, and the government has a compelling interest in ensuring its highest and best use. Highest and best use.

[00:19:15.08] Well, here's a secret I think you all know. There is no highest and best use. Well, not a full level that you all work at. JPS is just as important as weather forecasting, is just as important as missile radars, is just as important as mobile communications, is just as important as research into the Big Bang. New and innovative services are absolutely necessary for growth. But incumbent services are also absolutely necessary for stability.

[00:19:45.29] And each of these priorities are important to a functioning society. Sure, sometimes we shift them, but there's never going to be a point where the choices are easy or that we'll able to be really-- we'll choose a winner or a loser.

[00:19:58.94] Today it seems that policymakers will seek efforts that will move the US toward self-sufficiency and preparedness. And there is very little margin. Against that policy backdrop it becomes much harder to repurpose federal spectrum for commercial use. Plus we've made all of the easy decisions on spectrum already in that instance. Although I think David read along very strictly would not say that AWS [INAUDIBLE] was easy. Sorry.

[00:20:22.61] This is why essentially, the spectrum memorandum in 2018 requires the NTIA to develop a sustainable strategy for spectrum usage with a particular emphasis on advancing spectrum efficiency sharing. At least that was the goal when I first started working on it in 2017. The point of the memorandum was to take the focus off repurposing spectrum from federal bands and move the ball on advancing sharing technologies.

[00:20:50.87] It was a recognition that more spectrum was not likely to come. Instead I've really wanted us to think differently about solving the problem. What is our desired end state? Ultimately, we should be able to take out that device, phone, radar, automobile, tiny little moisture sensor by the soybean plant, and have it connect to whatever spectrum is available and work flawlessly. OK.

[00:21:15.01] So that is a pipe dream, but this is the time for big ideas. It's just as important now as it was in 2018, 2017 to set us on the path toward determining how to make spectrum as abundant as possible. And the memo was intended to turn us toward passing up our research into new spectrum sharing technologies, whether it's sensing and forming, coordinated sharing. We wanted to know how coordination could be improved, information could be better exchanged, maybe with a little less knowledge, among other things.

[00:21:45.49] Examining older technologies used by the government or the commercial sector and how they can be phased out and the spectrum could be reformed. And of course, by us, I meant really NTIA-- so sorry, all of you from NTIA who are here, you did have a ton of work-- I would have tried to get you longer than nine months to write up national spectrum strategy though, but sorry, I left government.

[00:22:11.20] It would have been ideal to have NTIA lead a process to develop a strategy to increase the efficiency of spectrum usage and allocation for all of American society, not just government. Ideally, I would have liked to have seen a strategy outlining several work streams, including review of government to use his understanding, what technologies might be prime for upgrades out into different technologies, cooperative review, maybe with the FCC of underutilized bands, even in the commercial area, and possibilities for phase out and reforming spectrum there.

[00:22:41.23] Review of redundancy and government services, possible technologies and candidate bands for sharing in both federal and commercial events. And which spectrum sharing technologies might be good protocols to implement. Maybe also policy and technology measures to help coordinating those spectrum allocations instead. So I'm listing all of that. I'm sure NTIA is really glad that somebody else finished the memo instead.

[00:23:06.14] I would have liked to have seen a review of engineering efforts, for example, to make transmission more efficient or a plan to make-- to plant here a few engineering efforts. But with the cooperation of folks like you here at Silicon Flatirons or academic for our standards groups, I would have hoped to see a section maybe on cognitive radio and how it may help satellite systems use

spectrum more efficiently. I would have liked to see a reprisal maybe of the receiver standard question in this document.

[00:23:35.54] I know that the industry appeared to just sort of heave this giant collective shudder when the question was asked the last time around back in 2012, but I am kind of glad to see Commissioner Simon to bring the issue back to the surface in such a thoughtful and deliberative way. It's a question worth exploring, particularly as the margins get tighter. And like I've been saying, it's time for big ideas.

[00:23:57.68] And speaking about big ideas, maybe it's time to revisit current thresholds. What do our product cycles look like now? I mean, with NGSS and shorter life cycles for [INAUDIBLE] Do we think we can implement evolving harm thresholds to get more used?

[00:24:11.72] I might have also imagined that the memo would have included a review of possible improvements to spectrum access systems for tiered access bands like the CBRS and I have tier it or guess warn a little. I think it's obligatory. Nokia has done a great deal of work in developing the radios and sharing architecture for use of the 3.5 gap band.

[00:24:31.94] And using this architecture, I think you're seeing some budding success with the deployment of multiple environment-- the deployment of networks in multiple environments like airports and oilfields and congestion zones. We can probably think of ways to improve SAS, and different sort of modes in which we can implement the sort of shared information.

[00:24:57.33] So looking, for example, at the new incumbent and forming capability system for 3.45/3.55. It allows for submitted information which probably takes sort of the sensing capability question out of it. But coordination with any system always introduces a clutch factor, and I would have loved to have seen NTIA talk a little bit about the clutch factor and figure out how to automate processes. Maybe even talk about maybe how to use AI in determining and possibly predicting patterns of use.

[00:25:37.46] Everyone likes to bring up AI I suppose. I did mention AI in spectrum sharing to the House of Representatives staff on the Science Committee as they were drafting their upcoming list re-authorization. Just so you know who to blame if that does come up again.

[00:25:54.05] I would have liked to have seen suggestions generally for increased collaboration between developers of different services. This is something that Mike Markus and I have talked about it in looking at the spectrum above 95 gigahertz. I sort of have to mention 6G and that it's just-- and I know some of you were throwing up a little bit in your mouth.

[00:26:15.18] But as researchers are beginning to work on this next generation of commercial mobile communications, it seems to be the perfect time to understand the characteristics of the services that coexist within the same radio frequency and actually try to design for coexistence.

[00:26:30.02] That's one of the good things coming out of this current discussion on radio altimeters and the c-band, at least in my opinion. RTCA has reached out to understand better what 5G characteristics are, so they can so they can take those characteristics into consideration as they draft the next standard for the next generation of radio altimeters.

[00:26:50.39] And certainly, the government's convening power could help produce that dialogue. So I'm not really sure what the National spectrum strategy will hold, actually, but with the amount of attention paid to the last rather spectacular spectrum battles, I suspect that sharing methods will be

top of mind. And I hope there are big ideas in this strategy to shake up the world a bit and meet the challenges posed by times of crisis.

[00:27:20.02] In the end though, I think the single most important thing to bring back to the spectrum allocation process is trust, however. Without information exchange between the potentially coexisting services, sharing becomes impossible. And without sharing, it will be impossible to meet the challenges of the day.

[00:27:36.48] It is hard for one agency to make a call and determine what's going to happen for all of these incredibly important equities. What really does need to happen is for people to, actually, without drama and fanfare, have the conversation of what is actually needed and what might be accomplished together.

[00:27:57.33] And that chaos of conversation could yield to really, really good spectrum usage improvements in sharing. And that is ultimately one of the things that hopefully the government will turn its attention to in trying to figure out how to produce that kind of environment. I would highly recommend that they do this maybe over a beer.

[00:28:23.50] So thanks for listening to me over-- thanks for listening to my whole survey of thoughts over some of the development of the times in the past few years and how that I think it might impact the work that you all do. I appreciate your time.

[00:28:44.74] KEITH GREMBAN: I think we've got time for one question. And I had my microphone off earlier, when I said we followed the Phil Weiser rule where the student gets to ask the first question. And our student is Jonathan Stokely. So if you'd come up to the podium.

[00:29:09.81] JONATHAN STOKELY: Thank you, ambassador. I was very insightful to hear your words. And I'm usually not one to be without a question. So I kind of have to struggle. So I'm going to keep it fairly straightforward as much as possible.

[00:29:21.82] But what advice could give to a second year master's of business administration student, MBA for short, as they launched their second half of their career and helping to both shape commercialization, but then as well as leverage spectrum to help narrow the poverty gap and help trying to make more equitable world, so we can all grow forth and prosper as a global economy?

[00:29:51.65] - Wow, that's a good question. Thanks Jonathan. I think one of the harder things to do, actually, has been-- I mean, one of the more appealing things about shared spectrum generally, is that the cost is not going to be nearly as much, right? That you're not going to have to invest billions of dollars in licenses. I think this term for a chair, it may mean that spectrum becomes a little more accessible to entrepreneurs and folks who can find ways to make equipment better. It's actually going to be a little cheaper.

[00:30:22.20] But a little cheaper means that it can be more widely deployed and used by people of different incomes, whether it is a user-consumer device or if it's a device that's an IoT sensor, that helps to grow crops. That allow people to eat because the farming is more efficient. Or if it's a device that allows you to back investments right to the money safely, as opposed to anywhere else.

[00:30:51.14] So I think there are all sorts of areas where you can go into this. Use spectrum in a way that actually improves the lives of the general population. It will obviously be your choice, but it's great that you're thinking about it.

[00:31:09.53] - Thank you. I appreciate that.

[00:31:17.91] - Thank you, ambassador. I think that's all the time we've got for questions. We're going to have to move on to our next panel. But thank you very much. We appreciate your time and thoughts.

[00:31:30.01] - Thank you.

[00:31:31.49] - Very enjoyable having you. So next. So our first panel addresses spectrum sharing in space. The moderator for this panel is Scott Palo. Scott is a professor of aerospace engineering at the University of Colorado Boulder and the associate director of SpectrumX. You can find a full biography of Scott on the conference website page. So Scott, over to you and your panel. Thank you.

[00:32:02.04] - Great. Thanks, Keith. I just want to make sure we can hear OK, get a tech check.

Sharing at the Final Frontier — Spectrum in Space

https://www.youtube.com/watch?v=wOHKtMFWl9g&list=PLTAvIPZGMUXNWmcqlTXSrvUmWJ0RfSL9K&index=2

[00:00:00.46] KEITH GREMBAN: Panel addresses spectrum sharing in space. The moderator for this panel is Scott Palo. Scott is a Professor of Aerospace Engineering at the University of Colorado Boulder, and the Associate Director of SpectrumX. You can find a full biography of Scott on the conference website page. So Scott, over to you and your panel. Thank you.

[00:00:22.28] SCOTT PALO: Great. Thanks, Keith. I just want to make sure we can hear OK, get a tech check. Great. And looks like we have our panelists coming on. If the panelists are available to turn on their cameras to join us. Great. Well, looks like we have all the panelists here and have their cameras on. So I wanted to thank the ambassador for a great overview and background as we set up here for our first panel discussion, entitled "Sharing at the final frontier, spectrum in space."

[00:01:12.78] And we're going to focus on issues associated with spectrum management of space-based systems, and touch on a number of topics related to space-based systems and spectrum. I wanted to take a moment to introduce our panelists really briefly. Their full bios are available on online. But to give you some insight to the power, and background, and intellectual knowledge of the problem that we have here and on the panel.

[00:01:42.76] So our first panelist is Alexandre Vallet. He is the Chief of the Space Services Department and the Radio Communications Bureau at the International Telecommunications Union. And prior to that, he was head of regulatory affairs and spectrum orbit resources department at the French agency in charge of radio spectrum management. So thanks for joining us.

[00:02:05.25] Second, we have David Goldman. David is Director of Satellite Policy for SpaceX. He was the Chief Counsel for the communications and technology subcommittee. And before that, he served as senior legal advisor for FCC then Commissioner Jessica Rosenworcel.

[00:02:26.81] We have Ashley VanderLey. And Ashley is the Senior Advisor for Facilities in the Division of Astronomical Sciences in the Directorate of Mathematical and Physical Sciences at the National Science Foundation. Ashley represents NSF on the NTIA Interagency Radio Advisory Council, IRAC, and its subcommittees, and serves as US Head of Delegation on behalf of the State Department to the Radio Astronomy Working Party 7b of the International Telecommunications Union.

[00:02:59.69] And we have Peter Tenhula. Peter recently retired with 25 years service at the National Telecommunications and Information Administration as a Deputy Associate Administrator in NTIA's Office of Spectrum Management. And Peter also chaired the inter-departmental radio advisory committee for IRAC. So thank you all for joining. And we'll go ahead and get started with some questions. The first question I want to address to Peter.

[00:03:32.48] And so, Peter, there are a wide range of ongoing space and terrestrial spectrum challenges, the most notable being the GPS Ligado conflict that regularly shows up in the news. Others include spectrum frontiers and the use of spectrum bands above 24 gigahertz for mobile radio services. From your prior NTIA experience, can you comment on the most relevant domestic spectrum challenges with respect to sharing spectrum between space and terrestrial users?

[00:04:06.63] PETER TENHULA: Sure, Scott. Thank you. Thanks for having me. I'm coming to you from the moon. Coming to you from the moon. Actually, I'm in a conference room here at the law school at Silicon Flatirons. On your question, a couple things come in to mind in addition to the ones you

mentioned. About four current battles going on between the challenges involving domestic and space-based services.

[00:04:36.48] And they typically-- just to generalize a little bit-- is that you look at them as-- are you talking about new entrants versus incumbents, or you talking about a new entrant in a new entrants, and other new entrants, that are trying to develop spectrum-- some on Earth and some in space. Because technology is changing all the time. And Grace mentioned that in her talk, about how technology is probably faster than what's a regulation.

[00:05:06.76] So when I was at the NTIA, we came across all kinds of conflicts. And when I was at the FCC as well, all kinds of various conflicts between the terrestrial side and the satellite side. And the dynamics varied. And there were sometimes distortions in the way that you had to deal with these battles. Grace mentioned, what is the highest and best value use of a particular piece of spectrum, and how do you pick between-- choose between winners and losers in that. And sometimes you're talking about inside a band, and pick your band, and sometimes you're talking about adjacent band. But let me just run through a few examples.

[00:05:53.79] Start with the obvious one, is the L-band, which is GPS and Ligato. And there, you've got players with different postures. You got a lot of government users and non-government users of GPS. I know we're all central arbiter or representative of them to deal with that. So you got FCC and NTIA representing the various interests. And NTIA and FCC did not agree on the outcome of that. And that involves a new entrant coming in to want to provide terrestrial service, and what are the potential effects to the satellite service and adjacent bands. And you have different dynamics involving the players there. And it's not unlike terrestrial other battles in just the terrestrial space.

[00:06:54.42] In the C-band, you had a little more, I think, cooperation. Because that was an in-band situation. And that involved incumbent new terrestrial mobile versus [INAUDIBLE] satellite. And that seemed to work out well. I mean, there's obviously folks that were disappointed. But there were some meetings of the mind. The decisions moved pretty quickly. There's still some issues above 4.2 gigahertz in that band with the aviation side of things. I'll call that space, since it's up in the air. But the satellite folks had been there a long time with their stations. And they realized that they could probably be more efficient in using that spectrum and could make room for the terrestrial mobile.

[00:07:46.95] In 12 gigahertz, there's an ongoing battle. I'll call than an in-band battle-- between new entrants on the terrestrial side who want to provide mobile service and the incumbents being the direct broadcast satellite. And there's also a new entrant component to that. So in these cases, they require the technical folks to have meetings of the mind.

[00:08:17.85] And like Grace said, some level of trust, so that the information, the studies that are being provided to the regulators who are often not very technically savvy are understandable and have credibility. Grace was involved-- I don't think she mentioned the 24 gigahertz one, but that ended up getting resolved on an international stage. Lots of conflict internally within the US. And it's a subject of a recent GAO report about how the conflict was handled or was not handled domestically.

[00:09:04.65] So we need a way to figure out to develop trust-- especially on the technical side. And that's a challenge. And also to make it understandable to various levels, especially on the political side. Because all of the times, there's distortions in these battles when the political folks get involved, because you need to explain things to them. It's important to bring, I think, multidisciplinary group together and negotiate in good faith in the basic engineering terms, and what are the assumptions that you're making. So that's the biggest challenge I see. Did I hit all my examples? I think I did.

[00:10:03.96] SCOTT PALO: Yeah, no, that's great. Thanks. Thanks for that. And so, I want to ask [COUGHS] excuse ME-- if any of the panelists wanted to follow up or have any additional comments on that? Just go ahead and raise your hand on the Raise Hand button down at the bottom. Or as we're going through any of the discussions, if you want to chime in, absolutely I'll call on you, and we can have a discussion. I think it's a little bit more challenging to manage the discussions here in the remote environment. So with that respect, did anybody have any additional comments to follow up on what Peter mentioned with regards to the ongoing sharing-- you would say, domestic sharing. Yeah, Alexandre?

[00:10:51.58] ALEXANDRE VALLET: Yes. Thank you, Scott. Just to add that the 12 gigahertz issue that Peter mentioned was specifically interesting, because it's not simply a new entrant on the terrestrial side versus an incumbent in the [INAUDIBLE] market. And it's also that there is a further new entrant, which are the NGSO constellations, which also use these bands. And which, in fact, add another layer, and another kind of service, in addition to the traditional [INAUDIBLE] service. So it is really, in fact, three actors on this field. And this makes, in my view, this case very interesting. Because there will be-- I'm not so sure that it's possible to share between the three of them. Probably two of them can coexist, but three of them, it's maybe a little bit difficult. So the proceeding will certainly be interesting from this point of view. Thanks.

[00:11:53.51] SCOTT PALO: Thanks. I guess, and also wanted for the [INAUDIBLE] audience to explain that NGSO, for those that are not familiar, is a non-geostationary orbiting spacecraft. So these are spacecraft that orbit the Earth every 90 minutes, versus geosynchronous spacecraft, that largely sit in one location geographically above the Earth. So the non-geosynchronous, or NGSO aircrafts are far more dynamic with that respect. Yes, David.

[00:12:31.04] DAVID GOLDMAN: Yeah. Thank you. Oh, so first, let me thank you for including me and inviting me. This is great. I'm really excited about it. I feel like I have to speak up now as one of the NGSOs that's using the 12 gigahertz band. I think that's why Peter raised it, was just to bait me to get involved in it. But yeah. And just real quick, so I work at SpaceX. And we operate one of the NGSOs.

[00:12:58.70] And so really, one of the key difference is, just to expand a little bit more on that issue, is that geostationary satellites, it turns out that the movement of the satellite actually has to do with the altitude you're at. So in order to be geostationary and stay at one point relative to where you are over the Earth, you have to be really, really far from the Earth. And if you move closer to the Earth, there's a lot of advantages to that, because you can get lower latency. And so, you speed things up. But the problem is, you need a lot more satellites in order to be able to do it. Because as you move closer to the Earth, the satellites move across the sky relative to the Earth. So it becomes much more dynamic and there's a lot more issues to it.

[00:13:40.40] In the 12 gigahertz band, it actually is an intensively shared band already. Because there is not only-- one of the things that I think gets lost a lot when we talk about spectrum is, people are very used to terrestrial spectrum and terrestrial spectrum assignments, which tend to be exclusive. For satellite uses, it is all shared. Satellite bands-- I can't say that every satellite band is, but at least a bulk of the ones, and certainly the NGSO ones are all shared among different operators.

[00:14:09.48] So this band is shared. 12 gigahertz is already shared across three different technologies, different services. So there's already a terrestrial service called MVDDS. There's the geosynchronous satellites, so the ones that are really far from the Earth. And they're doing satellite television. And then, there's several NGSOs in there already. So this band is already shared across three different industries-- and within each of those industries, a number of different operators.

[00:14:38.96] And so, what the dynamic is there is, the terrestrial operators are asking to expand their rights. So this is a shared band, where we actually-- instead of going towards sharing, the discussion is, do we move away from sharing, and do we expand the rights of the terrestrial operators in there. Whereas, I will tell you from our perspective, we operate below the noise floor. In order to be able to share and accommodate, the rules are already so tight in this band, that we have to operate at such low power. That if you increase the power of other systems, that it necessarily basically breaks our link. And so, you can't connect anymore.

[00:15:13.68] And so, the discussion in 12 gigahertz-- I'm not sure it's exactly the way that Peter described it. And again, he's probably just baiting me anyway. But because this is a band where you have a ton of different operators doing different technologies, different services. And the question is, can we give more rights to one of them, and how much harm do then we cause to the other services in order to be able to do that. And yeah, I mean, we shouldn't take it over on that. But I think, that one has a particularly-- I actually don't think this one fits cleanly into the dynamics of other bands, where it is necessarily a new entrant versus an incumbent. I think there's a lot moving in this one.

[00:15:56.38] SCOTT PALO: Yeah. And I will say, that I'm coming from a technical side in engineering and learning a lot more about policy over time. And the more I peel back the onion, I keep finding there's more moving in all these places. And I anticipate the complexity, just I always find surprising as I learn more about the issues. Ashley, did you want to comment on that? I do have a question for you. So I'll move into my question after you make your comment.

[00:16:28.65] ASHLEY VANDERLEY: Yes. A very brief comment. I wanted to add one angle of complication to this as we talk about incumbents. And there's a little bit of a difference here between rights of protection to transmit, and the idea of rights of transmission. And I bring this up, because the original space-based system is actually nature. So I did want to highlight for those folks who think about it, that nature is always transmitting. The sun is transmitting at all kinds of frequencies. Stars and satellites are, and galaxies, the atmosphere is. And these transmissions don't require a FCC license to be able to transmit. They're always going to be transmitting, whether or not we want them to.

[00:17:07.56] And so, that's something I wanted to highlight. That scientists have rights of protection so to speak, and certain bands that have been identified to be the most important for science. But irregardless of that, scientists are always looking to glean information. And so, it's also important to just note, kind of across the frequency bands, that scientists are going to be looking to glean as much information as they can, where nature is choosing to transmit. So that's something to keep in the back of your mind all the time. And this is especially important as we think about things like solar flares that can have an impact on our commercial space system. So I did want to just raise that point.

[00:17:42.57] SCOTT PALO: Well, that's a great lead-in. So I wanted to ask, Ashley, you've been involved in the scientific use of radio spectrum for many years as an astronomer, more recently as a Senior Advisor at the National Science Foundation. The radio spectrum is critical for a myriad of scientific applications, including weather forecasting and scientific exploration such as radio astronomy. I wanted to ask, from your perspective, what is the rapid growth of commercial space systems on scientific users? And also, what do you see is the opportunity and challenges for sharing as these systems evolve and expand?

[00:18:27.22] ASHLEY VANDERLEY: Yeah. That's a great question, Scott. And I think as Grace mentioned in her keynote, advanced sharing technologies and really driving on the research and development in innovation is going to be the key as we move forward. And that's part of what's motivated NSF to establish the Spectrum Innovation Initiative, and really try to drive research dollars towards that. The question if there's an impact, hopefully I can describe very quickly, yes, there's an

impact. But it's not necessarily all negative. And it really depends on what angle you're coming from. As Grace mentioned, what is the highest and best use? It really depends what your mission is.

[00:19:02.98] So I wanted to emphasize the fact that, here, we really all are on the same team. So we're trying to-- at least from the scientific perspective-- glean that knowledge that it's going to be useful to benefit even commercial systems. So Scott, you're really familiar with CubeSats. So this is a great example of a research area that NSF has funded. And so, NSF CubeSats in low-Earth orbit, one of their main missions is to understand the space environment. So they make in-situ measurements. They do remote sensing to better understand the atmosphere.

[00:19:32.72] And this is going to lead to an understanding of propagation that's coming from the broadband signals being transmitted-- either at that same orbital altitude or higher-- and things like drag, that are going to be important for recommendations like the 25 [INAUDIBLE] orbit. So that research and information is really helpful to contribute back. And so, this is where science is not really just the purview of scientists. This should be knowledge and information that all of us are learning and sharing with each other, which is the scientific process.

[00:20:01.58] The other point I wanted to make related to impact is highlighting that there are different needs, different tensions, and stakeholders. And so, this can really complicate how you evaluate and how you make decisions. And you really want to do it thoughtfully and carefully. So two quick examples there. I think one, atmospheric water vapor is a great example. If you think about radio astronomy from the ground, they actually choose bands to observe atmospheric and effects in the universe based on where there's not water vapor.

[00:20:36.14] And so, for example, 86 to 115 gigahertz is a very transparent window. When you get above 116 gigahertz, you have a water vapor line. So it's not really a useful band, per se, for most ground-based astronomy, unless you're on a very high mountain without a lot of atmosphere above you. Same with 24 gigahertz. But those bands are very valuable, as you know, for atmospheric scientists. They're going to use that for climate and weather modeling. So you see even in the science perspective, there's not a common view on what band matters the most. It really depends what you're trying to study.

[00:21:09.07] Another example, I was really glad that Peter brought up on the global navigation system and GPS-- global positioning system that the US runs. Because I think this is just another example to really illustrate impacts of commercial systems, and the fact that there's this very dynamic system. So when GPS was launched, around 1,500 megahertz, 1,200 megahertz-- huge impact-- negative impact to radio astronomy. So they do a lot of observations from 1 to 2 gigahertz-- only protection in a couple of little bands that are the most critical. But wherever these GPS signals are, it's not possible to glean that really faint information from the universe anymore-- from a distant galaxy.

[00:21:48.67] So astronomers have to just cut that piece of the band out of their data, and they can't glean that information. So a negative impact, you would say, to scientists' ability to study the universe. At the same time however though, radio astronomy provides really useful information to global navigation by providing the most precise Earth orientation. So the Earth is constantly moving. Stars are moving. And so, we need to know where the Earth is and where the satellites are for things like traffic management.

[00:22:16.24] And so, radio astronomy-- by observing very distant galaxies and quasars-- can provide that information that is very useful for the commercial space sector. So you see the positive and negative coming from the radio astronomy service and this. Add on to that a layer that atmospheric scientists actually use these really bright signals to look at radio occultation. And they're able to do

profiles through the atmosphere. And this is really great information for climate change, weather monitoring, et cetera. So something that has caused a negative impact to radio astronomy has led to creative and beneficial scientific studies by atmospheric scientists.

[00:22:54.07] So I just bring this up to say, as we work moving into the future with these new mega constellations of satellites, lots of challenges. We've been working very hard with SpaceX and other companies to find ways of mitigating challenges to certain science cases. But there's also potential opportunities as well. And so, this is where I think this open dialogue and conversation about what is it you're trying to accomplish. How can we work together.

[00:23:20.71] And then, as Grace mentioned, really thinking about where do we want to be 50 years from now. And how can we fund the research and innovation that we need to get there is really going to be the best approach. Because there is great good that comes from all of these different services. And so, we just have to understand each other and try to work through that. So those are just two quick examples. But yeah, great question, and really complicated.

[00:23:46.07] SCOTT PALO: I think that follows up on a point that Peter made, was understanding each other and developing trust. I mean, that's part of the challenge here in managing some of these use cases. I guess I wanted to ask David-- I know Ashley had mentioned coordination and collaboration between the scientific community and SpaceX. Can you provide any insights into that, and how that process works, or lessons learned for the folks listening?

[00:24:24.13] DAVID GOLDMAN: Yeah. That was great. And Ashley, if you ever are teaching a class on this stuff, I would gladly sign up. That is so interesting. But yeah. We do a number of things. So the spectrum that we're allowed to use actually is adjacent to a radio spectrum band in the 10, 11 gigahertz range. And so, one of the things that we did right off before we ever even started operating is, we made an arrangement with the radio astronomers who were using that band, where we have essentially 250 megahertz of our adjacent band that is theoretically under our license that we have access to, we've essentially used as a guard band.

[00:25:08.89] And we just don't use that band in order to be able to-- because the radio astronomy readings that they're doing in that band are so sensitive, that if we're operating immediately next to it, that there could be bleed-over. So in order to avoid any of the bleed-over, we gave up 250 of the megahertz in order to be able to give enough space to be able to have that. And we're constantly in discussions with the radio astronomers. One of the things that also resonated to me about what Ashley was saying is, you say, radio astronomers. There's not one group. There's all over the world, a lot of different interests, a lot of different use cases. All of this is heterogeneous.

[00:25:45.31] And so, there's a lot of different discussions, and it's constantly ongoing. Because we're constantly evolving our technology. But also, on the radio astronomy side, the technology is constantly evolving. So you can't just strike one deal and say, you're done. This has to be an ongoing conversation. And we're constantly learning from each other. And as our services are evolving, we're having the conversation.

[00:26:06.83] We're trying to be as transparent as we can about what we're doing, and try to learn as much as we can about what's evolving on the radio astronomy side, in order to be able to make sure that the arrangement we have is always putting-- I mean, with a 250 megahertz guard band, that's great, and that protects the service. But that also means that there's now a huge chunk of spectrum that's basically going unused. So is there a way to think about, again, to the highest and best use. Is there a way to think about that as we look ahead going forward. And the only way to do that, as Peter said, is to continue to talk and learn.

[00:26:34.96] The other one that got a lot of attention-- we got surprised, actually, on our first launch, that our satellites went up. And they're reflective. And it means that we are so low, we operate so low and so close to the atmosphere, that you could see them. And we didn't know that that was coming. And so, that was troubling. I think that the first couple of launches wasn't such a big deal and could be worked around by the optical astronomers. So not the radio astronomers, but the optical astronomers. But we saw what was coming.

[00:27:08.89] And so, we got heavily, heavily engaged in a lot of discussions with optical astronomy groups to learn what works and what doesn't. What do they need. What are their use cases. And what can we do. And we've taken a number of steps to mitigate how we operate now. And so, for example, our satellites, we essentially turn them on their side when we first deploy them so they don't reflect in the same way. For a little while, we were putting visors on them to block the sun to prevent reflectivity. But this is also an ongoing discussion. Because the optical astronomy-- the technologies on that side and what they're trying to do on that side is constantly evolving as well.

[00:27:43.64] And so, and as we're developing our new systems and our new satellites, we went from bolt on new ideas and figure out how to go, that as we're moving forward, we have this in mind. And so, we have reflectivity mitigation by design, as opposed to a bolt on idea at the end. But nobody knew this was coming. You can look through all the discussion ahead of our launch. Nobody said anything that this was a possibility. And so, this is one of those things, that we have to learn from experience.

[00:28:14.17] And because we're essentially first movers in a lot of this, we are spending as much time as we can and as much engagement as we can to try to learn-- and potentially, we hope, set best practices. Another thing that we've learned, actually, that was kind of counterintuitive, is that lowering your satellites closer to the Earth actually is better for astronomers for optical astronomy. Because when you're further up, you're moving across the range of the sky-- you're view with the sky much slower. The closer you get, the quicker you move. So actually lowering your satellites is actually much better.

[00:28:46.91] It's not something you necessarily would have thought of. But as we started working on it, it's one of the things that together with the astronomical community, that we were able to discover this. And we've been lowering our satellites for a number of reasons. But that's one of the benefits that we've been getting from it. And again, we're hoping that these learnings, we try to make them public. We try to publish what we're learning, and help all the other operators learn as well as we go forward.

[00:29:10.36] SCOTT PALO: Yeah. That's great. It goes again, back to that model of trying to understand both sides, trying to develop trust relationships, which are critical when it comes to developing-- sharing approaches. I want to take a minute and pivot now-- talk a little bit about the international domain. And so, Alexandre, in your position as Chief of the Space Services Department in the Radio Communications Bureau of the International Telecommunications Union or ITU in Geneva, you are acutely aware of emerging global challenges with respect to spectrum.

[00:29:47.01] Clearly, the growth of NGSO's satellites which orbit the globe every 90 minutes create new challenges but also new opportunities to explore new solutions. I wanted to ask if you could provide your perspective from the ITU, what you see evolving internationally, and with regards to the opportunities and challenges for sharing spectrum with regards to space.

[00:30:12.75] ALEXANDRE VALLET: Yeah, sure. Thank you, Scott, and thank you for the invitation. Well, what we see is the four main trends. Some of them are very well known. Some of those are maybe a little bit less known from the general public. So the first main trend that we see, of course, is the advent

of what we call the megaconstellations-- these large systems of non-GSO satellites that are going to provide broadband internet. So these megaconstellation, in terms of sharing spectrum, I'm not so sure, in fact, that they create so many challenges, in the sense that there are currently many projects.

[00:30:58.75] But let's be clear. In my view, it will be more the market than the access to spectrum that will decide who is successful. And I'm not so sure that the market will allow all projects to be successful. But at the end, I don't really think it will be a spectrum access that will decide on who will be successful. I really believe this will be the quality of the service offering-- and as often, the end user and the customers that will be determine that. The impact, however, on sharing from these megaconstellations is that, definitely they need more sophisticated tools to develop methodology and get results out to share between themselves.

[00:31:45.48] However, and this is understandable, because in the time of the geostationary satellites, in fact, sharing was very easy in a way. An Excel spreadsheet was enough to make the computations to share. Now, it's not the case. You need to simulate the constellations to check the percentage of time of interference, and so on. But again, this is a question of improving the tools. And as you know, we are also living in a period where a number of improvement in the software industry is coming. And so, I don't really believe it will have a major impact.

[00:32:28.80] The second big trend that we see is, of course-- and is also well-known-- the surge in small sats. But this time, not really in constellations. More sats that are launched by small companies, one or two at a time, maybe sometimes a small group, a small group of four or five. So these kind of systems are certainly emerging, providing a lot of different solutions from Earth observations to IoT but also signal intelligence. And Ashley was mentioning, you can even use it for scientific purposes. You have seen probably that NASA has launch a small sat to a company a probe on Mars to check the health of the probe.

[00:33:17.71] So there are many, many solutions. Here again, I don't really believe that sharing is really an issue, because there are quite a lot of bands available. The spectrum requirements of these systems are not so high. It's not like the constellation that want to provide broadband internet. Very often, this small sat needs smaller bandwidth to get their mission done. And very often as well, these small sat rely in fact on the transmission of data that they collect from the space. They're not necessarily designed for communications.

[00:33:58.20] The third trend that we see and that is a little bit less known is a surge in national small geostationary satellites. So a number of countries are now considering the importance of space industry for their development-- for their economic development. And they want to launch a national project, a national program, of satellites based on a GSO. As you may have seen in the market, there are now small GSOs that are available for about half to one third of the price of a GSO. And this becomes very interesting for these countries.

[00:34:43.86] This is a little bit more challenging, because the GSO orbit is quite crowded. And some area, it's almost close to full. And the point also is that, these national programs are not really based on economic reasoning. They are not necessarily economically viable, because they are designed as a strategic asset or as a development of national capacity for the economy. So they may prosper, or they may even be launched, without necessarily an economic-- I would say-- an economic business plan behind it. So it means that these number of projects may also have a kind of difficulty to get access to the GSO spectrum. So depending on the area where they want [INAUDIBLE], they may get some difficulties. And we may have to see how to make some room for them.

[00:35:48.33] The last one is quite well-known in the-- well, it's making the headlines, but it's still a nascent one. It's really the commercial space exploration. So up to now, space exploration was mainly the realm of space agencies. Now, we are seeing more and more commercial companies entering into this field. Even if it is still, I would say, under the umbrella, under the auspices of the space agencies. Because still, governments are leading the space exploration. But most of the governments are willing to offer a room for commercial industries in the new space exploration.

[00:36:29.35] So you have companies willing to go to the moon, together with the, I would say, under the auspices of the Artemis Project. And also, you have now some companies planning to mine asteroids or to go to Mars. And you have even some companies that we have seen looking for spectrum to develop, I would say, a kind of GPS, but around other celestial bodies. So this is a little bit of science fiction, I must say.

[00:37:05.76] This is probably not going to happen very, very quickly. But there are ideas like that. So for that, I would say, in terms of sharing and of spectrum access, there may be an issue if this becomes really a flourishing market. So we don't know yet, because this is very nascent. But if really there is a lot of commercial development for space exploration, then we will have to probably to identify new spectrums through the traditional means of having new allocations through the Wave Radio Conference.

[00:37:42.84] Because currently, all the spectrum allocated for this space exploration was done on the basis of the requirements of the space agencies. And they were very, I would say, cautious to use their spectrum very efficiently and to minimize the spectrum requirements as much as possible. I feel that if there is really a development of the space exploration, especially if there is a development of the mining industry in the outer space, there will be a growing need of additional communication links-- and therefore, additional spectrum requirements. But that is more on the longer term, probably the next 8 to 10 years. So in summary, that's the four trends that we see.

[00:38:30.69] SCOTT PALO: Well, it looks like you got some interest here from the other panelists. And I'll go to David here. And I suspect that Ashley is going to have a comment about the radio quiets done in the lunar environment-- the shield zone of the moon. But wanted to hear David's thoughts first.

[00:38:50.01] DAVID GOLDMAN: Hey, yeah. And I will try to be quick. I want to hear what Ashley has to say too. The breadth of what Alexandre was talking about is a little overwhelming. So I just wanted to zero in on something at the very beginning, talking about whether or not there's enough spectrum for all the different operations that are coming in. And I think, Alexandre is right. I think that's right, that there is enough spectrum for everybody, if we all get along. And I think the, if we all get along, is really, really the important part.

[00:39:18.10] And when we think about policy, the way that it works for the kind of spectrum that we're using for our next generation satellite systems, as I was mentioning earlier, it's all shared. Basically the rule-- the requirement is, that we need to negotiate amongst ourselves on how to resolve any interference problems. That means, that all of our policy as we think about our policy is setting the stage for those negotiations. It's setting the table for when you're starting to talk operator to operator of, how can we get our systems to work together. And the regulations then drive what are the incentives, and who has an incentive to concede anything, or how do you work together.

[00:39:58.05] And as Alexandre was saying, there's technologies that's evolving, that's making it easier and easier to be able to coordinate. Or I shouldn't say easier, but possible to coordinate in new ways. But those cost money. And they cost money in R&D. They cost money in time, makes your satellites more complicated. And so, you need to have policies that drive operators to want to invest in getting

along. And so, I just think Alexandre is right, that there is enough spectrum for everybody, and that it can be driven by the market. But that is contingent on that the policies actually encourage all operators-- everybody-- to sit down at the table and work together, and to actually invest in improving their systems in order to be able to share.

[00:40:40.83] Because otherwise, the incentives go the other direction. Because otherwise, in a shared environment, your incentives are actually to build a system that can't share well, because then you can bump out all your competitors by having a bad system. And it saves you money by doing so. So I think, that's the key. To get this to work, you have to be thinking out what are the incentives, and how we're driving operators to do the right thing.

[00:41:03.15] SCOTT PALO: I want to circle back to that question in just a moment to you, David, about incentives, and the challenges, and efficiency. But I did want to give Ashley a chance to respond here.

[00:41:16.62] ASHLEY VANDERLEY: The shielded zone of the moon is really interesting. But I was actually going to comment on something similar to what David said. I was really happy to hear what Alex commented on, that the computer models are really improving. But one of the challenges I think we've seen with sharing is the impact of aggregate emission. So that's kind of what David was referring to. How do multiple different systems all contribute together to an aggregate level of interference or an aggregate signal.

[00:41:43.86] And so, just a concrete example of this is the steps that he described for the SpaceX system to actually meet the radio astronomy recommendations does permit about 2% of observations from a single operator to cause interference 2% of the time. Because they say that, no one's perfect. We permit about 2%. And so, you can have two operators each causing 2% of the time interference. But the international recommendation says, the aggregate of all operators should be 5%.

[00:42:14.42] So then, you can do the math. And you get right to the point David was making. What happens when the third operator comes in, when two of them are already providing 2% interference, what is that aggregate interference? And that really needs to be included in our model. So that's a very important line of effort to make sure that models include that aggregate. But then also, what David was mentioning, about incentives. So just wanted to add that point in.

[00:42:42.20] SCOTT PALO: Great. So thanks, Ashley. So David, back to your comment about the rules and sharing. I have heard that building of efficient systems is a way to-- inefficient systems is potentially a way to game the system. And you were sort of leaning on that a minute ago. Could you provide some more insights about what you mean there, and how we can get to a place where we have incentivized through policy or other mechanisms to build efficient systems so that we can get the best and highest use from the spectrum?

[00:43:25.88] DAVID GOLDMAN: Yeah, sure. I guess, since this is in a law school, I will use a torts example. Is what I think about a lot of times is that, when you're developing these systems, you may have an incentive to become the-- if it's shared spectrum, and everybody is using essentially the same plot of land, we're all in the same place, and we all have to get along. I may have an incentive to build as much as I can, but then become the eggshell plaintiff. Be as sensitive as I possibly can to interference. So that way, if anybody else comes later, or even somebody is coming at the same time as me, that I come in, and I'm able to turn around, and then scream and yell that, oh my gosh, they're causing me interference.

[00:44:11.01] Now, the question is-- and this, I think, should be a question that's not just in space. Actually, I think that it's spectrum across every facet of this-- the question should always be, when someone's saying that they can't share, or they're specifically subject to interference, is the question

because the physics requires that? And a lot of times, it is because of the physics. If you're operating like we do, referencing earlier the 12 gigahertz, we're operating at such low power that there's physics there. That it's just, we get interference just if there's higher power, we're at such low power, it just does it. But is the question always physics, or is it the technology? And is it that you didn't invest in the technology that allows you to be able to coexist.

[00:44:50.75] And I think that's one of the things that policymakers need to be able to suss out when they're looking at these issues that are coming up, is are the people who are complaining about interference, and they're saying that they can't share, or they can't co-exist-- is it because of physics? And sometimes it is. Or is it because I built a system-- and there's two reasons. Now, I may have built a system because I just didn't want to spend the money on one that can share. But I may have built a system intentionally sensitive to interference, because in a shared environment, the more sensitive I make myself, and the more I make it that I'm not able to get along with anyone, the more that I will be able to claim the territory for myself.

[00:45:33.20] If all the rule says is, you guys all negotiate amongst yourselves and figure this thing out, and then the regulators are going to step back, and we're only going to come in if there's interference, my incentive is now, build a system that claims as much territory for myself as I can. And so, one of the things that I think policymakers can do-- and we actually have a petition in front of the FCC on this-- is actually reward operators who meet some level of efficiency. And I know there could be a fight over what efficiency means.

[00:46:02.27] And putting that aside-- and we can fight over what efficiency means-- but come up with some sort of metric of what efficiency is, and reward the operators with more spectrum, or there's different ways to do it. But reward the operators who are actually investing in the systems that meet the metrics for efficiency that we decide on. And then, you can flip the incentives around. Instead of a race to the bottom, where everyone wants to build the least efficient system to claim territory for yourself, that everybody now actually wants to build the most efficient system in order to be able to reap the regulatory rewards that are put in front of you. So you can have carrots and sticks put in there.

[00:46:38.70] SCOTT PALO: Great. And I saw, Peter, you were you were nodding your head as David was talking. Do you have thoughts there? And I guess also, are there other incentives for sharing that we might consider to help move forward?

[00:46:55.77] PETER TENHULA: Well, David had raised very good points. And I just wanted to make sure-- I couldn't put that emoti-- emotion to clap, or cheer dramatically for his very thoughtful thoughts. But what brought to mind is, there's actually language in the spectrum pipeline act from a few years ago that has a prize authority for the Department of Commerce to award prizes for spectrum efficiency. And this seems like a great area to do that. Problem is, it's not funded. And one of the requirements for that prize to kick in is for the FCC to come up with a definition of efficiency. And so, it might create an incentive to be efficient that way by putting in some-- wave some money.

[00:47:54.30] But really, I mean it's all comes down to cost, and what is their cost calculations. And so, if there's transparency requirements, or negotiation requirements, and I think, if the regulators step back and only say, well, we'll come in if there's a dispute. But if there is a dispute, the question is, who has the burden to show that when my model is correct and their model is not correct. And how do you balance the interests there. So none of those processes have ever been established. It's basically ad hoc, case by case, a mess. And like I said, in the C-band, it seemed to work relatively well-- comparatively well-- because more interests were aligned than not. And they seem to get along.

[00:48:55.59] But if the regulators just say, we don't know, ex-ante before the fact, a lot of this stuff. And really, the problems are going to come up ex-post. We'll be there ex-post. And when it does happen, here's the burden on the various parties. The person who says that they're being interfered with will have to show that they've built, for example, the best state of the art receiver in their system and are not wasting spectrum with sloppy receivers. That would be an example. But I don't know. David makes a lot of great points. That's why I shake my head vehemently. Up and down.

[00:49:43.29] SCOTT PALO: As we talk about this, yeah, Alexandre.

[00:49:48.50] ALEXANDRE VALLET: Yeah. Just maybe two points. In my view, in the C-band things, where is by the fact that there were a lot of financial incentives to repack the spectrum from the satellite point of view. I mean, the idea whether the satellite industry was not simply, I would say, cold to improve their spectral efficiency. They were clearly rewarded to do so by quite a lot of money-- about $9 billion. So this is a major incentive. And generally, many people get more agreeable to think about such things when they see such an incentive. Especially for the satellite industry. If you look at what is the turnover of a satellite operator, the money that was engaged was really appealing.

[00:50:44.57] The second part is that, at least on the international side, there is a kind of balance between the right of the, I would say, sensitive incumbents and the newcomers, or the more efficient newcomers. That indeed, the newcomers have to protect the incumbents. But not at all costs. There are limits to which the protection is due. But also, when there are disputes on the level of interference, ultimately this is the incumbent that has to be able to prove that it is interfered. And it has to be able to produce measurements to show the actual interference.

[00:51:29.75] So if your job-- if your interest is simply to increase your sensitivity, be sure that you have the means of measuring it. Because if you try simply to block a competitor using the technical regulation, then it may not be so easy. Because you will need to spend a lot of money building a lot of detailed monitoring stations just to ultimately maybe try to block new entrants, which probably you will not even succeed in.

[00:52:06.53] So this balance was established in order to avoid the kind of difficulties that have been explained by David. For which I agree. Then what David is proposing is a step further. Not only trying to have a balance between both incumbents, but also rewarding the most efficient one. And I think it's a great idea. The main difficulty up to now is that, I think collectively the community has never been able to define what is the most efficient use, or the most efficient system in a certain band. And this is the main missing point, in my view. Thank you.

[00:52:54.91] SCOTT PALO: Great. So we've been getting a number of questions coming in. So I'm going to move into the open Q&A time here. I want to encourage the panelists, if you click on the Q&A button, you can see the questions that have come in. Feel free. I saw Alexandre has answered in a text response. But what I will do is give you the opportunity, if there's a question in there you would like to answer specifically, rather than me deciding, feel free to raise your hand, and we can do that. And of, course following the wiser rule here is that we start with a student question. And so, I understand that we have a CU student, Taylor Hartley on hand, to ask the first question. And it looks like Keith is up at the podium. So I think we'll have Taylor coming in.

[00:53:56.39] AUDIENCE: All right. Hello. There was so much fun. Thank you so much. My name is Taylor Hartley. I am an MBA student here. And I have a background in intelligence, surveillance, and reconnaissance. So my big question is, what does security look like in these non-terrestrial networks and a shared spectrum? Are there more concerns, less, and what's happening?

[00:54:24.44] SCOTT PALO: A great question. And there's definitely lots of discussion about cybersecurity with regards to space systems. Alexandre, you want to comment on that?

[00:54:40.58] ALEXANDRE VALLET: Yes, thank you. Maybe the first answer is that, very often the weak point of the satellite systems are in fact the terrestrial part of the satellite system. So the ground segment of the satellite system is the most vulnerable to cyber attacks, simply because it is also the easiest one to get access to. Well, cyberattacking a satellite system-- the satellite itself in space-- this is certainly possible. But currently, it requires a lot of technology that is not really available to, I would say, a large number of entities or governments. Where it is much easier is indeed to hack the ground system-- the transmitting stations throughout the satellite. And then, use it as a backdoor to the entire system. Of course, this calls for more security on this part of these satellite systems. I would say, the satellites themselves, they are quite well protected to now.

[00:56:00.36] SCOTT PALO: Ashley?

[00:56:03.06] ASHLEY VANDERLEY: Yeah. I just wanted to highlight, I think this is a fantastic question. And so, this is something that NSF, the Directorate for Engineering, has been investing in a lot. And it's not just for the areas you mentioned in terms of reconnaissance and intelligence. But also, just as we think about keeping our data secure. Whether it's your stock market portfolio, or your banking, or personal communications you have with family members.

[00:56:28.90] So I wanted to highlight one program at NSF called Secure and Trustworthy Cyberspace. And this is definitely looking to fund research to address those challenging scientific and engineering problems. And they highlight that there's many components of that system that you have to consider for the security and privacy. And so, this is an active area of research. So I mean, I think what you highlight is very important.

[00:56:53.40] And it's going to just become an increasing area of research as we have more and more wireless devices, you have to worry with backward compatibility, with things like the internet of things, making sure that the old devices are actually not easier to get hacked, and then get into other devices in your house, for example. So this secure space-- very active area of research. So I mean, fantastic question. And happy to point you to a number of the research grants that we funded in this portfolio, or get more information. But just wanted to say, great question and very active area.

[00:57:30.01] SCOTT PALO: Yeah. I think there's also an interesting ongoing challenge, at least for a lot of the new entrants who are getting into small satellites. They oftentimes are the ones that maybe aren't as secure. And there's a push with the challenges in space debris to have maneuverability on orbit. So to be able to have propulsion so that you can change your orbit or avoid a potential collision. However, now that once you put propulsion on spacecraft, you can change your orbit and do other things that may be more nefarious.

[00:58:14.04] So it creates an interesting challenge with regards to having the capabilities to maneuver, but also requiring sufficient security so that those spacecraft can't use for nefarious purposes. I didn't know-- David, operating-- oh wait, David just disappeared here. Oh, there he is. Yeah, you put your head up. That's why. You moved when you put your hand up. I was going to comment, as an operator of the largest satellite constellation, what are your thoughts in regards to I would guess, both cybersecurity, and then also the increasing challenges for orbital debris?

[00:58:58.83] DAVID GOLDMAN: Oh, with the debris also. Yeah, so I guess, addressing security first. And I don't want to claim to be a security or cybersecurity expert. I have some passing knowledge, probably enough to be dangerous, so I should be careful. But one of the things that just to add one additional point to it is, these systems are global. And so, unlike even geostationary satellite systems

that could be operating in a specific region, when you're non-geosynchronous, almost by definition-- not all of them, but most of them-- have some sort of global reach.

[00:59:30.96] So you're dealing with a lot of different countries. You're landing your data in a lot of different countries. And these different countries can have different laws, and can have different policies, and different approaches. And so, just think about if you're landing in one country that is very privacy focused and says, everything needs to be encrypted end to end completely, and locked down, and you can't even access it yourself. And the country next door says, you better make sure that you have the key to decrypt, it because our law enforcement is going to want to be able to see it all whenever they want. And this is one network.

[01:00:04.40] And so, I think you don't have the political boundaries that you have necessarily-- or you don't build the network with the different kind of geographic boundaries into it. So by being international, you have a new complication to it, and a new layer of complexity in how you're thinking about it. We fortunately, we have a team of security experts who are working and thinking about these things all the time. I'm not one of them. So I can't really speak to it. But I do know that just looking at-- because I deal with the policy and looking at the policy across different countries-- there is definitely trend lines moving in privacy that conflict with the trend lines that are moving in lawful intercept data security. And I think that down the road, I think there could be tensions there that will need to be thought through and worked out.

[01:00:53.30] Pivoting to the space debris question. Yeah, we spend-- actually, a lot of this ends up having very similar discussion to what happens with spectrum. How do you make sure that people have the right incentives? And how do you make sure that people are investing? It is more expensive. As you said, Scott, that everyone wants to have propulsion now, or should have propulsion. How do we make sure that everybody does put propulsion on their system? It's cheaper to not put propulsion onto your system.

[01:01:21.87] And so, but at the same time, by requiring everyone to do that, you're definitely raising the barrier of entry. So what are we trying to accomplish? And so, there's that. One of the things that we spend a lot of time on, that we think is-- I guess there's two main points that I would hit on debris. And then, because I know there's a lot of other topics too.

[01:01:44.12] One is, time in orbit really, really matters. I think Ashley mentioned it earlier, of the global standard of satellites to come 25 years after they're done. I think there's almost uniform agreement that 25 years is too long. I think as more satellites are being put up, and as we're trying to use space more and more intensively, 25 years is probably too long. And we should be driving it to try to get that number down lower. How do we get people to bring down satellites or get rid of their satellites when they're done with them as quickly as possible.

[01:02:15.69] And I think, the other component to that is altitude. The higher you are, the longer your satellite-- if you have a failed satellite or you have a satellite without propulsion, the longer it takes to come down. So under 600 kilometers, it'll come down within 10 years. And so, even if you have a problem, basically within a decade, that problem is gone. Once you get higher than that, it quickly becomes centuries or millennia. So as you get up to say, 1,000 kilometers, you could have a satellite that if its propulsion fails, it's coming down over 800 years. And through some of the highest densest orbits you have with small debris. And so, you almost have a bowling ball crashing through junk. And you're just waiting for something to happen.

[01:02:59.61] And so, I think what we do is, we try to push our satellites as low as we can down to the atmosphere. Because that way, if you have issues, they go away much, much quicker. That to us is the

best way to solve it. But I mean, this is really going to be an issue that we need to be thinking about as we go forward. Oh, sorry, I said that I was going to have two points. And I don't want to be one of those people who says two points and then says one. Just knowledge-- one of the things, and I think this is something that maybe NSF can help us with too is-- knowledge of where satellites are and where objects in space are, but where they're going to be. It's actually, because where we operate is essentially still at the highest reaches of the atmosphere. So we're still affected by the atmosphere.

[01:03:42.35] And so, that means that it's the uncertainty of where satellites are going is high. It's really hard to predict. And you would think you could map it out really easily. But we just don't have the technology right now. Mankind does not have the technology right now to have really accurate predictions of where things are going to be. So one of the things that we really should be thinking a lot about in order to make sure that space is sustainable, and we can use it as intensively as we can for commercial but also for scientific exploration, is better understandings of where things are and where they're going to be. When we know where they're going to be, you can avoid it. It's the uncertainty of where something's going to be that really raises the risk.

[01:04:23.87] SCOTT PALO: Absolutely. So we got about a little under 10 minutes here left in our discussion. And I wanted to give the panelists an opportunity, if there's something pressing that we haven't discussed, something that you think is important for the audience to hear about. If you'd like to bring that up for a final discussion. Otherwise, I can throw out one or two more questions. Probably only about one. Ashley.

[01:04:55.80] ASHLEY VANDERLEY: I just wanted to quickly address a question that came up by an anonymous attendee to ask about experiences-- practicing radio astronomy as a female scientist. And what I wanted to just remark on is that, I always felt very supported and that my gender had nothing to do with ability and was very much encouraged as an undergrad, in high school, even in graduate school. And the reason I wanted to just mention this briefly is, I think one of the things that's really important for us to consider is looking to broaden participation in spectrum management.

[01:05:27.75] So we want to have a group of technically trained from science engineering law that understand the international policy that really reflects the diversity of our nation. And so, that's something important to think about how we can move towards a workforce. There's lots of challenges that I think we see moving forward that we're not going to have the workforce that we need for all of these challenges that we've described it in the past hour. So I just wanted to mention that as something that is really important. And won't say anything else now, because we're running short on time. But I thought that was important.

[01:06:06.74] SCOTT PALO: Well, thanks for those insights. And I think, thinking about the workforce development, and how do we develop the spectrum managers of the future, and what are the required skill sets, and the problem-solving abilities. And as we see, it is evolving. The technology is evolving quickly. And trying to manage those challenges. So maybe to wrap up, would be to hear what everybody thinks, or as we have time, about what are the skill sets for the spectrum managers of the future, and how do we attract talented people into this area? David.

[01:06:53.32] DAVID GOLDMAN: Yeah. I mostly just really wanted to-- what Ashley said is great and right on. And I just know for people who are not familiar with these topics, this can be a lot to take in. And probably, every other thing any of us said was some new issue that people hadn't thought about. And it can seem like a lot and intimidating. This is all developing. These are all new things. Nobody has years of experience on all of these different issues.

[01:07:22.07] I just want to encourage-- I know we've got a lot of students listening to this. And we really do want to bring a wealth of different backgrounds. And it doesn't necessarily have to be that you have expertise in spectrum, or that something special about satellites, or space, or any of these particular issues. Enthusiasm, smarts, excitement about the issues-- we can figure it out.

[01:07:43.51] I mean, whatever we're talking about in two years is not going to be the same thing we're talking about this year anyway. And so, we really do-- bringing in more diverse viewpoints across every version of diverse-- really, all the students who are listening, I can't encourage that more. And I just hope this all seemed accessible, and I hope there's nothing that intimidated anybody out of doing this. Because I really think that this is something that is fun to get into. And you'll be at the bleeding edge of new technology and new policies.

[01:08:18.62] SCOTT PALO: Great. So Peter, with your 25 years of experience at NTIA, any thoughts for the students? Nuggets of wisdom going forward and getting engaged in spectrum?

[01:08:34.70] PETER TENHULA: Well, I used to think it was not rocket science. But oh, guess it is for some areas. It is not rocket science. You fall into this, like most of us, accidentally. In my case, it happened to be the person in the office next door got a new job, so I just picked up her spectrum portfolio. And that's the way most people I know get into these things, is accidentally. But if you just want to get into telecom generally in the satellite stuff, I mean, I've seen this stuff back in the late '90s-- a lot of the stuff in the NGOs is deja vu all over again for me.

[01:09:17.48] And like Alexandre is talking about, it's going to be the market deciding these things. So I know young kids these days-- because I got three of them-- and one of them just yanked me out earlier, and I apologize for that-- didn't know the time difference. But young kids these days, they don't decide that they're going to do something for 25 years. And this is going to be my career. They want to jump from one thing to another.

[01:09:51.06] So it's try, try, try. Try all kinds of different things. If you got an opportunity to work with SpaceX sweeping floors, I'd take it. And even working for David. No, I'm just kidding. I would definitely want to work for David someday, if I were young. But the opportunities, I think, are endless. It just takes a lot of networking, unfortunately, to find these little creases. Because the entrepreneurship in this space-- no pun intended-- is incredible. I'm surprised every day.

[01:10:37.47] SCOTT PALO: Absolutely. I think the excitement, and the entrepreneurship, and the buzz is there on a daily basis. I want to give Alexandre the last word. I also want to thank him for staying late with the time zone change, coming to us from Geneva. So any final comments with regards to workforce or other items you wanted to mention before we wrap?

[01:11:06.62] ALEXANDRE VALLET: Well, no. I think I can simply echo the previous comments. What is really interesting in my view in this field, that it's really a mix. It's at the crossroads of values field. So you can come in this field with from various background. You can be a lawyer, you can be a policy analyst, you can be also an engineer, or even a scientist. We need all of that. And nobody is too much, I would say. So we really need a diverse background to make a good use of spectrum for our fellow citizens. So without sound spectrum engineering, without sound scientific research on the use of radio spectrum, we cannot build progressive policies that will benefit the society.

[01:11:55.55] But similarly, if we stop at the level of spectrum engineering, if we do not transfer this information and the wealth of information to the political level, and to the people that will decide the best value that we can use on spectrum, then we cannot neither reach the entire components of our societies. So really, every field is called to act in the spectrum policy domain. And this is even-- well, this is increasing and increasing, because more and more applications now of our daily life relies on

radio. They are less and less activities where you can say, there is no radio involved in this activity. So yeah, I think everybody should consider making a contribution to it. And certainly, this would be very welcome. Thank you very much.

[01:13:00.80] SCOTT PALO: Thank you. And I want to thank all of our panelists for the time and effort they put in their thoughtful comments and participation here, and making this an excellent opportunity to have some discussions about ongoing and emerging trends. So with that, I think we're wrapping up the panel. And I'll turn it back to Keith and the Law School.

[01:13:31.16] [APPLAUSE]

Frontiers in Coexistence Engineering

https://www.youtube.com/watch?v=oqYxRysBPGE&list=PLTAvIPZGMUXNWmcqlTXSrvUmWJ0RfSL9K&index=3

watch?v=oqYxRysBPGE

[00:00:00.12] KEITH GREMBAN: Nomi is a senior executive at Advance, where her mission is to seek out, identify and invest in companies that help diversify and grow their Advance portfolio. Of course, you can find a full bio of Nomi on the conference website page. So Nomi, over to you.

[00:00:21.17] NOMI BERGMAN: Thank you so much, Keith. Let me first just thank by besides in addition to thanking you and to thanking so many of our colleagues and somebody that we're all a big fan of here, Dell Hatfield for inviting me to join you today. I think so much of my interest in technology is because of learning from Dell during some of the early years of my career. And I'm really forever grateful to him for his crisp explanations and thoughtful questions.

[00:00:48.48] So let me start by welcoming my incredible panelists. I'll start with Mariam Sorond. I'm going to just say a few brief words about each panelist. And again, their full bios are in our materials. Mariam joins us today from CableLabs, where she's senior vise president and chief research and development officer involved with execution and adoption of new technologies for CableLabs members and the cable industry.

[00:01:14.79] I also want to welcome Dr. John Chapin who has a new role at NSF, a dual role where he's special advisor for spectrum. A role in which he serves as program officer in the electromagnetic spectrum unit in the Division of Astronomical Sciences. And also he's an advisor on strategic spectrum issues to NSF leadership.

[00:01:37.67] And next, Petri Mahonen, professor and head of institute, the Institute for Network Systems of RWTC Aachen University in Germany. And Jonathan Ashdown whom I learned has lived right down the road from me. I'm here in Syracuse, New York and Jonathan's in Rome, New York where he is a senior electronics engineer and information directorate at the Air Force Research Laboratory. Thank you to my panelists. I'm so glad you're all here with me today.

[00:02:09.45] So we're going to talk today about frontiers in the coexistence of engineering and spectrum sharing from a standpoint of-- in particular of discussing-- we're going to discuss sharing across service boundaries. And I think it's important that we maybe start off with technology descriptions as to how we should define spectrum sharing.

[00:02:35.30] So I'll actually toss this out to any of the panelists to begin with. Just if you could share some thoughts on how you define spectrum sharing. And probably just because we've been tasked with it specifically spectrum sharing across service boundaries.

[00:02:53.67] JOHN CHAPIN: Well, OK I'll get started. John Chapin here. So nice to speak to everyone. I just need to say that everything I'm saying is on behalf of myself and not on behalf of-- does not represent NSF or the government's position. So I think we should use a definition that tries to capture the general meaning of the word as it's been used by the technical community over the last 20 years.

[00:03:15.97] And to me what that means is spectrum sharing is the operation of independent systems close enough together that dynamic mechanisms are required to prevent interference. Independent systems are those that are controlled by entities that are distinct from the perspective of the regulator. So really, I'm focusing operationally on the use of these dynamic mechanisms as distinct from the more traditional static separation and frequency space or time.

[00:03:45.86] MARIAM SOROND: I could weigh in also. So I think if we wanted to step back, it is very hard and there is no single definition of spectrum sharing. It really depends on the context and the parties involved in the discussion and that's where it drives a different definition. Currently you can claim spectrums being shared one way or the other, whether it's through a partitioning it a technology a database or regulation, right?

[00:04:12.77] This means that we really need to clarify which part of this is are we talking about. And that's going to be hard in every conversation. Are we talking about two different regulatory bodies that allow different operations in the same band? Or two different licensees using unlicensed and licensed spectrum? Or are we talking about two different technologies using the same spectrum?

[00:04:36.26] It's like I may call a turquoise blue and someone else may call it green, really. But I think one thing that perhaps we can agree on and talk about is that one of the most complex sharing scenarios is the sharing between government and commercial entities whose spectrum are regulated by different agencies.

[00:05:01.91] JONATHAN ASHDOWN: And from my perspective, I share a similar perspective. It's obviously very complicated when you talk about spectrum sharing, even within a homogeneous body such as the DOD. But you have all the various intricacies of the various service, whether you're talking Air Force, Army, Navy, Marine Corps, Coast Guard et cetera, and all their different mission sets right

[00:05:27.22] but if they're geographically co-located, currently there are different systems that each service has to manage spectrum. And that utilization of spectrum really needs to-- and the DOD is moving in this direction to be able to share assignments across the services.

[00:05:47.86] But it gets even more complicated as just mentioned when you're dealing with DOD or federal and commercial spectrum sharing. Because of not only a heterogeneous set of spectrum dependent systems, but also a heterogeneous web of authorities that manage the utilization of those spectrum dependent systems.

[00:06:10.06] So I mean, I think that's why we're here today to discuss it but I agree on-- one other thing I wanted to mention was that if you look at the FCC table of allocations, you see a highly suboptimal solution to spectrum sharing.

[00:06:26.80] It's like a static frequency assignment type of approach, very Marconi in nature. First transatlantic telegraph in the late 1800s where a certain spectrum dependent system was allocated a certain frequency band and add infinitum for we don't really take the amount of time that maybe a certain spectrum independent system needs to do its thing or maybe it's a temporary license.

[00:06:58.09] But we need to think about how to be smarter about solving this multi objective optimization problem in a more optimal way rather than the suboptimal solutions that currently exist where in large cities throughout the US even on the commercial side you're talking under 50% utilization of spectrum.

[00:07:23.14] So we can no longer afford to do that. And I really enjoyed the previous panel where they're talking about having working together and having these conversations, because that's really the only way that we'll be able to get toward coming up with the more optimal solution.

[00:07:42.14] NOMI BERGMAN: Thank you. Go ahead. Go ahead.

[00:07:44.40] PETRI MAHONEN: Maybe from my side, emphasizing what the John was saying that I like to adding a word operational or sometimes in a technical community where we're putting a dynamic spectrum sharing. But I agree with Mariam also that there are many different ways to call it.

[00:08:08.28] The main danger is that whenever we are writing white papers or having our fights as a policy domain, we are careful enough to define what we mean actually, we are talking about. Because the confusion which can come up if we don't have an agreement what we are talking about can be a huge.

[00:08:32.29] And one is definitely that when we have an engineers talking about operational spectrum sharing, there is a highly different view when more policy people or regulators are talking about spectrum sharing policies. So in a perfect world, we would be anchoring our terminology and fix them. But then I'm a pessimist enough that I think there will be always a little bit of the loose ends and we have to be careful on that.

[00:09:07.43] And adding maybe a little bit of the European way that where I am seeing in this side of the Atlantic problems, is that partially because of the loose terminology, sometimes in a Europe it's not even clear, even in the policy domain that who actually has the power.

[00:09:28.27] Is it the European Union? Is it nation states or the standardizing bodies for making certain sharing decisions? And it can become a very acronyms battle. And then in the end of the day, you fight two years and you'll find out that everybody was fighting on the different thing. So we have to be careful with the terminology.

[00:09:54.27] NOMI BERGMAN: Thank you, all. Thank you so much. And just maybe one follow up question on that and then I want to move to another topic about scarcity. Petri, in our prep calls, one of the things you talked about which really struck a chord with me was you warned us of the dangers of placing complexity on complexity. And I thought that fits well with what you were just sharing about engineers talking about the operational aspects. I wondered if you care to comment on that here.

[00:10:25.44] PETRI MAHONEN: Yes. I mean, my complexity comments are in a two domains, in fact. So adding complexity over the complexity is I think it generally we have to be careful in our operational spectrum sharing or even sharing policies. So there's almost inherent danger with us as an engineers for adding more and more things because it's a fun and it shows that we are intellectually very powerful. We are adding things.

[00:10:57.82] But once we increase a complexity, it's not only that we have a problem with increasing costs of the system but more complex systems are also more fragile. And this of course, comes if we consider for example, the National Security or DOD aspect. So we have to be careful that even if we are able to do some very smart things, if it increases a complexity or variety, let's say an undefined boundary, we might have a problem we would not like to have.

[00:11:33.09] And another problem of course in purely in a technological area is that I have been starting to feel that the increase in talk about that we need an email and because we have a so complex system is this just hype or is it the desperation that we are not any more able to handle the engineering system we are developing?

[00:11:59.82] Because again, when it's a critical system, we actually would like to understand. We would not like to leave it for Black box neural network decide whatever. But it goes again a little bit of this kind of cost and benefits and danger, trying all what we have to be careful for considering.

[00:12:22.83] NOMI BERGMAN: Thank you. I'll just give panelists a chance in case they want to comment on the comments there. I know we'll talk more about AI little bit later, but anybody or else I'll move on? OK.

[00:12:35.75] JOHN CHAPIN: Just a quick comment.

[00:12:37.71] JONATHAN ASHDOWN: Go ahead, Dr. Chapin.

[00:12:39.22] JOHN CHAPIN: All right, I should raise my hand. I think what Petri is talking about links to a common theme that we've heard from Scott Pallo many times and from the others, which is the really critical importance of trust. If we're going to move forward in this space at all, the various stakeholders have to trust that their equities will be protected and that their be able to predict the return on investment depending on where you sit. And the more complexity we have, the harder it is to trust. And that's a really interesting challenge in order to move forward effectively. Thank you.

[00:13:11.34] NOMI BERGMAN: Jonathan, go ahead. Thank you, John.

[00:13:14.07] JONATHAN ASHDOWN: Yeah, and another aspect and I know you said we're going to get into the AI conversation a little bit more as it relates to spectrum sharing. But one concern that I have and that we've seen is that even if you were to get to pretty good solutions in terms of the optimality of sharing the spectrum with these techniques, there's a lack of traceability in terms of figuring out.

[00:13:42.75] So say there is an interference event between two parties sharing a certain spectrum band. It's difficult again, with the black box neural network that Petri mentioned to really trace back what caused that. So was it the system itself disobeying some policy or rule set that was put in place? Was it a derived policy that was pulled from a regulatory document? Was it a spectrum manager who is actually in charge of allowing those systems to access that spectrum?

[00:14:24.31] So the provenance piece being able to trace things back to their roots the source lacks there. So really what is needed is more of an electromagnetic spectrum ontology, like an ontological framework where you have that traceability aspect.

[00:14:43.93] NOMI BERGMAN: Thank you, Jonathan. And we are definitely coming back to identifiers as well. Maybe just before we do, just to finish setting the forum, thank you so much to all of you. And thank you John Chapin for making the comment about trust. I think now we've heard that in each panel, which is-- and from the ambassador. So it's a great line throughout this.

[00:15:03.79] I want to get to asking all the panelists how real is scarcity. Maybe just before I do, just to acknowledge Martin Cooper recently published his autobiography, Cutting the Cord. And in it, he said there has never in the history of radio been a scarcity of radio spectrum and there will never need be a scarcity in the future. Since radio's invention, technologists have created new spectrum faster than uses for that spectrum has been intended. Technological advances and spectrum use and efficiency have continuously kept ahead of ever rising demand.

[00:15:38.14] I guess, I'm wondering how our panelists, how my great panelists feel about Marty's-- you don't have to comment on Marty's comment specifically. But just mostly how real do you feel the scarcity is. And then and then we'll next get into some needy more technology issues.

[00:16:02.52] PETRI MAHONEN: Maybe I'll start for hopefully increasing a controversy in our panel. So in one sense, the scarcity is there. I mean, everybody has been seeing this everything is allocated maps. So maybe in the policy domain we have some issues.

[00:16:24.06] But if we consider pure physics or let's say on engineering, I tend to be a little bit more in the Marty's scan. And it comes to the point that what we mean with the scarcity. The one way is to say that so can we pack more systems? So let's forget the cost. We forget the business consideration. I don't think that we have a scarcity.

[00:16:53.62] Actually, at Marty himself has been sometimes solving a very beautiful map where he has been actually showing that almost all, I'm a little bit exaggerating, but almost all the extra area bandwidth, what we have been getting is not coming for us to making a massive MIMO or better modulation. It has been coming from making a smaller and smaller cells.

[00:17:22.44] And obviously, there are some physics limit how small cells we can make it but we are very, very far away from how small cells we could generate. That doesn't mean that it would be economically possible, but kind of fundamental since there's lots of spectrum to be used, especially if we go then to millimeter wave patterns or terahertz band where we have a small narrow beam with things that we can really make geographical packing very strong.

[00:17:58.29] I think a more research question is that where is the boundary between economically viable engineering and an availability of the spectrum? I'm still more in, let's say the positive side as an engineer that there's not really a spectrum scarcity. We still are getting wonderful new technologies coming in.

[00:18:22.08] You might then ask that why everybody's speaks about scarcity. And this is maybe my controversial part that I have not been seen too much even an academic community pointing out that there are also reasons for claiming that there's a spectrum scarcity while there is no spectrum scarcity.

[00:18:45.33] And that's when we are talking about, especially the cellular operators. You have to remember that they have in one sense economical incentives to hog spectrum and keep new entrants out. So the whole point is that that's why I think we need more and more very level field discussion and hopefully independent people looking for issue. It's not so easy then just listening to a couple of CTOs or CEOs telling that please we are lacking again a spectrum, we need more.

[00:19:24.28] NOMI BERGMAN: That's a very interesting answer, Petri. I see Mariam was raising her hand. Mariam, and in your answer I know you're going to reply to Petri's good comment. I'm wondering if you can tie it in at all to David's comments in the prior panel where he talked about a carrot and stick approach of creating incentives. To me some of what Patrick is saying there about getting to smaller cells is a bit of-- is moving towards it's capitalizing on an incentive in a sense of using the spectrum and operator has. I don't know. You answer however you'd like, but I'm wondering if your answer might tie that in.

[00:20:04.09] MARIAM SOROND: Yeah, absolutely. Well, first of all, thank you Petri for bringing that controversial point that creates a very interesting discussion. I think that and I'm going to put-- I used to be a mobile operator. So maybe I can just add some color to how at least, typically mobile operators view this and how it's hard that they would create the scarcity. That argument is a tough one, and here's why.

[00:20:34.99] First of all, I think mobile operators typically look at spectrum needs based on their capacity forecasts. They do this years in advance. Because if they await for the capacity crunch to come, it would be too late. So when they start talking about needing spectrum, it's way in advance due to these forecasts.

[00:20:56.83] Additionally, it's important to highlight that their lead times involve from one spectrum assigned to when it can be deployed for public use. So sometimes this may look like somebody sitting on a spectrum, but ecosystem development, widespread deployment takes time.

[00:21:18.55] And the other aspect I think it's important is that if you look at traffic demand, traffic demand is not uniform and it peaks during different hours at different locations. The aggregate

demand when averaged over hours and days and geography looks low, that's for sure. But you know but it's true that spectrum really is there to meet the peak hours and the population. OK.

[00:21:49.69] So in some cases therefore, that spectrum is underutilized in other areas but the point is that it needs to be more targeted. Now when all of these things line up, sometimes again, if everything lines up, you do get an example of this year where there was an earlier auction this year on C-band and you have an operator already deploying 70,000 C-band sites this year. But that's the little bit of the stars aligning with the development and things like that.

[00:22:20.74] So I just wanted to say you know it's an interesting discussion but I think just from a mobile operator perspective, I'm not sure if they're trying to create scarcity. And Nomi, to the point about the small cells, I apologize that I missed the last panel. I didn't hear the point. I'm going to pass on commenting on that.

[00:22:44.72] NOMI BERGMAN: No problem at all, that was a great answer. John, Jonathan, do you want to comment on the scarcity?

[00:22:53.20] JOHN CHAPIN: Sure. I actually have of course, tremendous respect for Marty and I believe his technical point is well founded. But I would say that whether or not there is scarcity from a technical point of view is sort of irrelevant to what we're dealing with here.

[00:23:11.15] And the reason is that there are long established regulatory structures that make it difficult and expensive to launch a new service or expand the service. And there's long established business structures that are assumed, and maybe in some cases derive value from the fact that spectrum access is a barrier to entry.

[00:23:29.90] So we, by definition have scarcity because of the system that we live in and the conditions that create that are not going to change on timescales less than decades. Certainly at the NSF, we are investing in the fundamental research and the basic and applied understanding that can help to change that situation. But we really do need to make all of our short and medium term spectrum related decisions understanding that scarcity is a reality.

[00:24:00.99] JONATHAN ASHDOWN: Yeah, and I would agree with Dr. Chapin on that. I think it's not necessarily a scarcity issue. I mean, if you look at sub 6 gigahertz, there is plenty of congestion in the current regulatory structure. I'm just talking commercial side, similar on the federal and DOD side as well. But that congestion is really a byproduct of the regulatory structures that have been in place to regulate our spectrum for many, many years and we'll likely continue that way.

[00:24:36.69] Now it goes back to what I said earlier about from a technical perspective of course, you could come up with a more optimal solution to the optimization problem. That's not the hard part. What's the hard part is basically affecting material change in the way our spectrum is essentially managed and regulated. And that will allow for more innovative approaches in the utilization of that spectrum.

[00:25:12.42] We've heard about cognitive radio for many, many years now, like decades. There's been many compelling demonstrations over the years on being able to maneuver through interference in a shared spectrum band with technology. In my opinion, it's a matter of catching the policy up with where the state of the art of the technology is. Of course, you have millimeter wave up to terahertz as was mentioned. There's plenty of available spectrum up there, it's not really a scarcity issue.

[00:25:50.98] NOMI BERGMAN: Thank you so much. Those were fantastic answers. Thank you. Well, moving on now to like a bit more deeper into the technology. I'd love to talk a little bit about and hear everybody's thoughts on what we can learn from historic efforts to share spectrum. We've always had various systems for reusing the airwaves across frequency space and time. And it's also been nearly a decade since the PCAST issued influential reports declaring that the norm for spectrum should be sharing.

[00:26:23.65] And certainly we started with sharing with static regulatory separations, and then move to the coordinated sharing effort of the AWS-3 band. I would love-- We sent around amongst our panelists a list of various developments. If I can ask you about them specifically or I'll let you just speak to them, would one of you care to start just to share your thoughts on one of the historical developments, be it AWS-3 or really our largest real world experiment in spectrum sharing to date, the CBRS experiment.

[00:27:08.31] MARIAM SOROND: Sure, I can share a little bit about maybe AWS-3 thinkers as a part of that. I mean, it was through was a really good example of several things I thought. There's definitely there was a concept of again, talk about misuse of terms and confusing everyone by dynamic spectrum sharing. Because that term gets coined in different ways.

[00:27:33.54] But in this way, it was dynamic sharing in the sense that basically with respect at least to one of the sections where there were whether operations and actually uplink services with mobile. There was not only sort of analysis done with coordination zones, but also real time systems, something called an RFM was created over there that tried to accommodate more use of the spectrum through measurements.

[00:28:11.64] And so that was an interesting first application and basically, it looked at what Noel was doing particularly and a few other agencies were looking at basically how this RFM system looks at early deployments to later deployments and how they can balance this act. Because when you deploy mobile networks in a band that's newly allocated, you don't all of a sudden have 300 million users day one. You basically start with ramping up and mobile users are transient.

[00:28:50.24] So I thought that was a very interesting learning that when that gets implemented, that we could look at some real time measurements done by sort of the orphan system and then in addition to some of the coordination zones that was created. And I think with CBRS, that's also another example of a dynamic sharing where there's the sensing and basically there's also multiple licensees in the band.

[00:29:26.23] And I think there's definitely the deployments are coming along. It was auctioned last year and I think looking at that band and looking at the deployments in the future is going to give us a lot more learnings again, as we ramp up because no spectrum gets turned up day one all of a sudden together. So very, very good learnings over there also to look at as more deployments are made.

[00:29:55.82] NOMI BERGMAN: Thank you, Mariam. John?

[00:29:59.41] JOHN CHAPIN: Sure. OK. Well, I'll answer the question by turning it backwards. I'm going to take some answers-- I'm going to state some lessons that I think I've learned and then maybe just give one example for each of the kind of historical sharing experience that it comes from. So three lessons.

[00:30:14.87] The first one is that having some form of ex-post enforcement is really an absolutely necessary complement to the designed ex-ante sharing mechanisms. One example that among several that supports that is what happened in the 5 gigahertz DFS band. Where the very carefully

designed sharing mechanisms ended up not working the way they were planned in the field in part because of user action. And it took quite a lot of effort to solve that, and we still have some ongoing interference issues as a result.

[00:30:46.49] The second lesson is that sensing based approaches inherently limit both your spectral efficiency and the evolvability of the system over time. And really information sharing between the spectrum users is critical. And so there we've seen this learning happening in the 3.5 gigahertz CBRS band where there's recognition that we need to evolve from the environmental sensing capability to some kind of incumbent in forming capability.

[00:31:15.70] And the third one lesson I would draw is that access level agreements are critical. That's a term I came up with. Maybe there's a better one floating around in the community. But by analogy to service level agreements in telecommunications, an access level agreement is something that specifies the quantitative thresholds that define when harmful interference occurs. And those may be time-based or power-based or something else.

[00:31:43.12] We really need that because dynamic spectrum sharing rests on having some form of automated or at least prespecified spectrum management. And you have to have quantitative targets. We can't rely on the old approach of just sort of I know it when I see it harmful interference. So we've got multiple experiences, whether that's the TD white space or the 5 gigahertz DFS, or the cross-border issues between the US and our neighboring countries where we can see the importance of having these quantitative targets. Everybody can plan if they've got them.

[00:32:17.54] We also note that if the regulator has to establish those targets through a proceeding, it is a long and painful process. The 5 gigahertz DFS took three years of negotiations and still didn't get it right. So really the future has got to be acceptable agreements as contracts between the spectrum users themselves. And that everybody can agree to and then plan for in the future. So those are my three lessons. Thank you.

[00:32:48.87] JONATHAN ASHDOWN: All right. So yeah, I can share some lessons learned from over the years. I'm glad you brought up the PCAST report. I encourage anyone who is interested in spectrum sharing to reference that document. I saw something in the chat about-- it sort of like highways where we plan our road infrastructure for the maximum traffic.

[00:33:12.51] If it's a middle of the night, cars only need to would only really need to use one lane. But at peak times they would have to use all the lanes and then some.

[00:33:23.15] So spectrum does have some similarities. The Obama administration had drawn that exact analogy in the PCAST report. I believe Press the Marshal, who I think currently still works for Google had been on that advisory board for the president who I bring him up because we worked on a the wind forum which helped set the standards for the CBRS, Citizens Broadband Radio Service.

[00:33:55.77] Of course, that's 3.5 gigahertz. But spectrum sharing with Navy radar and commercial systems, so that's a neat lesson learned for some current work we're doing, which is to basically come up with a spectrum coexistence and sharing system to allow for commercial 5G network that's being deployed at Hill Air Force base.

[00:34:19.26] It's a standalone private 5G network and Nokia is the prime on that where they're deploying a network that will be manipulated by a spectrum coexistence and sharing system to be able to maneuver through incumbent interference presented by various DOD spectrum dependent, systems such as the airborne warning and control system, or C13 station keeping plumbing et cetera.

[00:34:43.36] But I guess one of the interesting things we've done and I did this through the AWS-3 bands experimentation as well. I was part of a committee called the spectrum sharing test and demonstration steering committee, is actually led by the Defense Information Systems Agency. And as part of that, the DNCIA was involved in ITS, which is based actually out your way mountain time out near Boulder. It's the Institute for Telecommunication Sciences.

[00:35:17.46] They did several data collection measurement campaigns to really figure out what the thresholds would be for interference to allow for spectrum sharing between the commercial and the federal spectrum dependent systems.

[00:35:34.38] More recently, they've been helping us on a big program that we're working on dealing with dynamic spectrum sharing and utilization between, again commercial 5G and those various spectrum dependent systems on the side. We've been doing flyovers and data collection measurement campaigns at Table Mountain, which is a radio quiet zone just North of Boulder, Colorado. So we're working with Frank Sanders and the team at ITS to really figure out what is needed to be able to effectively share the spectrum.

[00:36:12.87] The other thing too is worth bringing up is radar altimeters aboard both commercial and military aircraft. There's concern about how 5G will affect those globally. So we're also part of an effort called JIFRACO, which is the joint interagency 5G radar altimeter interference program.

[00:36:34.14] And I am not the lead for that one, but I do head up a sub working group that's really looking to do flyovers and set up this 5G network to be able to do test and collect measurement campaigns to really figure out what is needed to be able to effectively coexist. And what those harmful interference thresholds are.

[00:37:03.63] PETRI MAHONEN: Maybe from my side, the one thing I'll start from the again from the trust point of view that a both in a US and European based projects I haven't been involved in, especially if you have an actual operators or defense forces involved in, you very rapidly in an issue of the trust that what's going on. We share but is everybody actually following a sharing rules. And this is now entering even with licensed spectrum access to commercial domain.

[00:37:43.74] So John was pointing out quite well that in order to have enough trust, you have some kind of ex-post enforcement. To the point that you have to be able also to prove that something happened and somebody is not crying wolf or whatever.

[00:38:00.13] So be related to this is that I think one of the surprises if we think about is at DSA community is that everybody was first believing that we just make dynamic spectrum measurements, and then we go to the white spaces. And I think we more or less have been proving that this is not an approach to call.

[00:38:22.21] But if I have to guess we probably will have a renaissance on the spectrum measurements. Not so maybe sensitive ones, but exactly for having enforcement, the probability that the spectrum is shared properly. Because otherwise, I don't think that we are able to build a trust, at least in some areas where there might be a local scarcity or local very high level sharing.

[00:38:51.52] Another thing which I think I have learned is that yet there's still a little bit some pockets at least in an academic community who are thinking that it's enough for defining a primary user, so to say and then you have a spectrum sharing. But this is not obviously a case.

[00:39:13.54] Actually, you have to define who are the sharing entities in a technological sense. Because the whole point is that how quickly they can release spectrum again, what kind of aggregate

interference they can generate. And indeed actually, whether it is for these secondary users commercially viable to use, shared spectrum depends very highly what kind of system you are putting there to share. So we should be careful to define all the sharing entities technologically.

[00:39:49.18] And the third probably coming from all of my career, which would start somewhere around the second generation is kind of piece of warning, which I would hope that Mariam is especially agreeing is that things tend to evolve differently than what we expect.

[00:40:10.85] So even if you are a cellular device manufacturer, of course you are doing lots of tests, you deploy test networks, you do things. But once the real heavy duty commercial networks are there, people are starting to use it, you'll find it in a few years that oh no, we didn't think about that. Or we didn't think that the users could actually come this kind of applications.

[00:40:38.48] I mean, a good example is that in the beginning of the two gene, nobody thought about that you would like to put a TCP/IP traffic to the cellular network. It would have been laughed in some research centers telling that we have to worry about data traffic because everybody knew it's a voice traffic, find a peak time, dime in the network, done. And then people found that actually even a low rate data can be extremely valuable.

[00:41:10.56] So this is of course, which is making this whole game very difficult because we have to leave a little bit of tolerance on our board regulation and the technology development for unknown unknowns so to say. Things really-- In my 30 years in this business, things tend to evolve completely differently what the best-- Best purpose put off in the planning is showing.

[00:41:42.38] But that's also of course, the reason for increasing our capability for dynamic sharing and sharing systems because that would give us a capability to evolve much more faster. Because really the problem is that the regulation is too slow. The technology itself is not mainly a slowness. It's that if the service is everybody is fixed too tightly, then we start to have a problems, kind of artificial scarcity problems.

[00:42:15.91] NOMI BERGMAN: Yeah, absolutely fantastic answers. Let's move into the technologies. But if you want to come back to some of these historical examples as we're talking through some of the technologies, please feel free. I'd love to hear our panelists talk about some of the technologies that offer promise for inter-service sharing.

[00:42:34.87] I'd like to spend most of the rest of our time here. And I can ask you about specific ones, but I know I did send around a few from our preparatory discussions. So you could pick any of them and speak to their promise. And why don't we also fit the-- certainly the discussion of AI fits here. But also I know we talked about this in the challenges section, but please feel free to also to comment here about the importance of requiring that all transmitters use a unique identifier. And if we don't get to that here, I'll call it out later, specifically later.

[00:43:13.15] But for now, yeah I'd love if you maybe pick one of the technologies we talked about that offer promise and talk a little bit about how they might help in managing increasingly complex multidimensional interference environments or again, our desire for service sharing which offers its own complexities. So if you could each maybe pick a technology and speak to it, that would be great.

[00:43:41.25] MARIAM SOROND: Sure. I'll pick two if that's OK. One of them is AIML. I wanted to clarify that one a little bit more about what I mean, because I think it's different than what the context of AIML that was used earlier. And then the second one is I think, Convergence. I saw someone in the Q&A talk about Convergence. So I think it's important to talk about that as well.

[00:44:05.38] Let me just hit AIML first, but I think first of all, I mean, currently sharing is centered around developed technology. OK. So instead, I think technology should be developed to embrace sharing. So I think we should think ahead this time. So just picking on 6G here for example, for a second they should consider how future aspects of how cognitive radios will use AI and ML technologies and deep neural networks.

[00:44:39.24] I mean, this is about the technology doing it. I'm not talking about AIML to manage interference. That's not it. It's the technology itself actually having cognitive abilities and using these things to be able to do many different ways of coexistence with other technologies and manage interference. So I think it's an opportunity right now to look at this while future technologies are looked at. And I think it's important to incorporate and would love to hear their thoughts on it.

[00:45:14.91] The second one I want to hit on is convergence also, because if we could talk about that it's important. Because we have to talk about our future networks and how connectivity will evolve in the future. When we were talking about connectivity, we have wired and wireless networks.

[00:45:31.08] So right now there's new technology enablers that are creating a dynamic where we're getting an opportunity to converge multiple access schemes between wired and wireless technologies. And so once you do that, a couple of things happen that become make it very interesting.

[00:45:51.34] First of all just looking at the wireless side through convergence, we can certainly bond different spectrum bands, including license, unlicense. If a portion of spectrum becomes temporarily unavailable, operator can deliver the same user experience that's expected somewhere else.

[00:46:08.37] OK. So that's one thing that convergence brings. Convergence also allows multiple operators to provide a consistent and seamless user experience through their service boundaries via open standardized applications, APIs and things like that. So that's an enabler too.

[00:46:31.80] I think that what happens is whether through the use of common platforms or APIs or both, convergence promotes better interworking and information flow with various network elements. So that's a key ingredient for enabling effective spectrum sharing.

[00:46:51.16] So for example, one of the projects we're looking at CableLabs is something that allows traffic steering splitting and bonding among various wireless networks using real time network data to drive the optimal traffic management decisions. This could play a role also in sharing. So there's definitely an opportunity there for convergence and using these new technologies.

[00:47:29.53] NOMI BERGMAN: Thank you. Thank you so much. That was a fantastic answer. Thank you. Those were very practical examples. Others?

[00:47:41.74] JOHN CHAPIN: I don't know if Jonathan is being quiet for the same reason I'm being quiet. But being at NSF, people write proposals to us all the time and I really can't bias those by picking winners and saying certain technologies are more important than others. I would just highlight that NSF has a program running on technologies for promoting spectrum coexistence. It's called Swift.

[00:48:03.69] We've given two years of support out. If you type Swift into the NSF award search, you will find dozens of really interesting technologies that were judged worthy of pursuing, that fall into a bunch of different categories. And so I just really need to leave it at that. Thank you.

[00:48:26.69] NOMI BERGMAN: I understand.

[00:48:27.92] JONATHAN ASHDOWN: I'm in limbo as Dr. Chapin and that is the reason I was holding back. But I will say that there are a lot of key enabling technologies. I won't necessarily hone in on any just one, but I think it's inevitable that AI and ML will play a part in the future spectrum sharing. I will point some folks to the DARPA spectrum collaboration challenge, which was a program that actually did utilize AI and ML successfully to allow for on the management side. So this side.

[00:49:06.74] So I know the device side was also mentioned, which I agree that that will most likely be in the future. But the thing to just bear in mind is that traceability aspect, I think there are other options. I think a whole electromagnetic spectrum ontology is really what's needed to be able to again, when there's an interference event to be able to trace back who was at fault.

[00:49:34.32] And that enforcement that was talked about earlier by several of my panelist colleagues that would potentially enable them to be able to figure out why something occurred and be able to follow up appropriately. I will say there's a lot of 5G enabling technologies which are extremely interesting. Several of which various vendors are utilizing on an active program under the 5G initiative led by the Office of the Undersecretary of Defense Research and Engineering Division. Essentially, you have everything.

[00:50:16.58] I mean, what about like massive MIMO, right? So to be able to-- and a multi-user context, being able to steer the beams, essentially the electromagnetic energy in the direction so as to allow various users the bandwidth or the essentially that they need to perform certain tasks. So it would be a different allocation say for someone, but it would be a different-- you take in the spatial domain into account rather than just the frequency, right?

[00:50:54.05] So assuming they're in a shared frequency band, someone streaming Netflix could get a certain amount of coverage at first as someone just checking an email or a text would get a smaller allocation. Or essentially, you're taking in not only the frequency part but also the time and also the space. So you have all three dimensions, which isn't currently captured in the current regulatory structure.

[00:51:25.45] NOMI BERGMAN: John?

[00:51:25.78] PETRI MAHONEN: Yeah.

[00:51:26.88] NOMI BERGMAN: Go ahead, Petri.

[00:51:27.97] PETRI MAHONEN: Maybe from my side, it's difficult to pick the winners but why it is so difficult is also that it depends whether you are in a short term, mid-term commercially viable or foreseeable techno economics. Or then just dreaming some very academic but not knowing whether you are able to do it or whether it's too expensive.

[00:51:58.13] But kind of low hanging fruit, I would agree with Jonathan is that and nearly everything in a massive MIMO or lately in academic research, there has been lots of talk about cell free MIMO or cell free massive MIMO. That's interesting. It's related is, of course, using a millimeter wave bands because definitely go with the fast on the nine arrays with very, very narrow beams which means that you have a huge space for reuse.

[00:52:31.82] Now all of these technologies the one point is still that there are still lots of question marks. I could hype it as much as I want. But in all reality trying to be honest, we still have a even an academic question marks how well you can make various points to work. But we get also to the point that what service do you want to do it.

[00:52:55.83] I think the millimeter wave is a good example because I think we are seeing a little bit of the hype curve going down. Because if we were believing all hype, we did solve all the spectrum scarcity, let's say for normal operator business. There's so much spectrum there that at least in the mid-term. Everything is solved especially because the spatially so well reused.

[00:53:23.28] But the point was, of course that if you need to support high mobility or long link distances, then you have a problem. You actually still need this low or sub 6 gigahertz band. So we are again in a situation that even in a technology [INAUDIBLE], we have to little bit think about what service we want to do with.

[00:53:46.30] Very long term we have to remember that where we would like to go is of course, to having a more and more fiber. I mean, that's ultimately what we would like to have it. And we have to remember this when we are talking about 20 years, 30 years. That's where we still want to get because fiber is also a good friend of tented small cell wireless.

[00:54:10.27] And in one sense, this might be a crazy coming from the major legal wireless research there are few technology is fiber. We just have to wait quite long to get it there, but we should not forget that depending on AIML, I have to say that I probably started to look that just after being an examiner of audit show meterles pieces and that's about 2000, 2001.

[00:54:39.13] So I have been kind of 20 years getting enough hit with reality. So I hadn't become a little bit skeptic. This is not to say that we should not research AIML. I also believe that it has a place, but I don't think it's going to be as big game changers as people believe.

[00:55:03.38] But one area where I believe it is a game changer, I have to also say that I'm biased because that's one of my research areas is indeed that it's less on a radio level or spectrum level. It's more like indeed traffic shaping or moving traffic for the different frequencies or between fiber and the wireless.

[00:55:30.20] I think there, the machine learning can really give us a huge gains, and there are two reasons for that. The time scale is such that we can learn. We really can learn and we have a better understanding that why various machine learning algorithms are giving us results what they give.

[00:55:53.15] The second reason is that we have such a huge amount of data there to actually teach, even a very deep neural networks. Well, I'm a little bit more skeptical how much the academics can do there. Well, we can do some things but my eyes are more indeed in the places like the cable apps, Google and sites because you need to have an operational network data. You really need to have a massive amount of raw operational network data, otherwise it's again you are just making a toy models which don't prove anything.

[00:56:31.54] But what little I have had an access for operational data, I'm quite gung-ho that that's where the ML at least in the short term, is going to make a difference. Not for inventing a new modulation schemes or rapidly jumping between white space. It's a little bit higher in a protocol stack, and it's really hands of the operational companies.

[00:56:59.55] NOMI BERGMAN: Thank you. Fascinating answer. Mariam, were you going to say something or?

[00:57:04.32] MARIAM SOROND: Yeah. No, I was going to just definitely wildly agree with Petri here because he's absolutely right. There's definitely challenges around AI and ML that need to be sorted out and the data aspect of it and the data availability of it is one thing. Access to the data in order to be able to do this is one thing. And also the amount of data.

[00:57:24.61] Let's talk about how processor intensive this could get when we're talking about real time dynamic spectrum sharing. So that also is something that is a challenge today. So definitely very future looking, and I'm definitely hoping that as we evolve that these challenges will be solved. But I think the time to think about it is right now.

[00:57:51.15] Because if we don't do that, I mean, again these opportunities of these new developers will come and pass by us and then it will be hard to change because they'll be commercial networks. They'll be live networks. They'll be in people's phones and homes and everywhere else and that it becomes even more difficult.

[00:58:13.49] NOMI BERGMAN: Thank you. I really, really enjoyed all of those answers. One of the things that we've kind of talked about or at least touched on a little bit is trust identification enforcement. I was wondering if I could ask the panelists and any one of you to talk a little bit about those issues.

[00:58:32.77] In particular, I know there's been work being done that the NTIA seismic to-- how could the NTIA and the FCC equipment authorization rules be modified to require that all transmitters use unique identifier? Since that will be such an important part of enforcement, we're enforcement to also evolve as the technology solutions evolve. If you wouldn't mind just to talk a little bit about that both as a promising new development and possibly to touch on it some of the barriers.

[00:59:15.02] MARIAM SOROND: I'll try to go first to make it short because I would love to hear the other people's ideas. I was the chair of that-- co-chair of that subcommittee and my partner in crime is missing, Brian Tremont. So actually the two of us really did put effort around trying to really go across the industry and the various entities to ask their view of unique identifiers.

[00:59:44.33] And it became a very interesting perspective. I'll share some highlights because there's definitely opportunities with unique identifiers. I'll share the challenges and then would love to hear other's perspective. One of them was privacy and security. I mean, that became a very big concern that if you do put unique identifiers and every transmitter and every sort of, what will that do to privacy and security.

[01:00:12.80] And the second one became a cost perspective. On the cost of these things, especially in when you're going to these low cost IOT type solutions and things like that, what happens when you do that. So some of the challenges were there, but with lots of good stuff in there. I would love to hear the other panelists perspective.

[01:00:40.20] JOHN CHAPIN: OK. I'll speak to this at a couple of levels. With regard to the cost of the UIDs, the cost becomes very difficult when you're transmitting them say, in every packet header. But if they are transmitted probabilistically, and maybe that probability can be adjusted over time if then you might be able to deal with the cost.

[01:01:03.91] So if there was some mechanism where if there's an interference problem in a given area or in a given band, then someone with authority can come in and turn up the dial on how much IDs happen temporarily in that place in that band. And there you would have perhaps enough information to help find the source of the interference. So we should be looking at those kind of adaptive mechanisms instead of a one size fits all mechanism.

[01:01:30.69] With regard to the privacy side, [INAUDIBLE] had a very interesting comment on this years ago where he pointed out that even if it's a completely opaque license plate a random 64-bit ID, just by correlating that information say to two or three places that a person visits in the course of their day, you can identify them-- deanonymize them very, very easily.

[01:01:58.03] So you need to use modern technologies like encrypted sequences so that someone can't correlate it over time without having the secret key that again, they would need a warrant or some kind of appropriate authorization to get a hold of. So I think there are many, many dimensions to this problem of unique IDs.

[01:02:19.26] I just want to quick take a step onto the other problem that Nomi talked about, the broader question of enforcement. Let's say that we could figure out that it was a certain make and model of device that was causing an interference problem in a given band. What do we do then if there are thousands or millions of them out in operation?

[01:02:39.72] And I want to give a shout out to a paper that Bill Lehr and I did many years ago now called Time Limited Leases that offers a solution to this. Let's turn the problem on its head let's say that every device that goes out into the market in one of these shared bans, after some period of time like several months will stop operating, will stop transmitting. Unless it receives a key through some authorized channel that lets it keep going.

[01:03:07.48] And so then even if something is completely causing a huge problem, all you do is wait a little while. And even if you have no communication with those devices, they will stop transmitting. And that might be a way that we could give ourselves a little bit of a lever to stand on to keep the spectrum less polluted over time. Over.

[01:03:30.70] NOMI BERGMAN: Thank you. Thank you, John. Thank you, Mariam. You know what, I'm going to hold Petri and Jonathan for a second and just ask because I guess I see we're getting nearing to the end and I just want to make sure we fit in that-- I understand we have CU student, Taylor Hartley. I know she asked a question to the last panel and you're on hand to ask a first question from the audience to our panel. Thank you.

[01:04:07.58] TAYLOR HARTLEY: All right. Hello again. So a question for this one. Talking about AI and ML, that's super hot right now. All the companies want it. They want to incorporate it into their business model somehow. So that means there's going to be fewer and fewer data scientists and engineers to spread around.

[01:04:29.87] And that got me thinking about how 5G really hurt the spectrum community between misinformation and conspiracies. And so I wanted to know, is that reflective in your hiring pool? Have you seen a loss of interest in wireless? I know space is probably boosting it back up. But I just want to know what that kind of looks like right now.

[01:05:02.09] MARIAM SOROND: I'll try to answer. And thank you for your question. In general, I'll tell you there's definitely the hiring space is getting tougher and tougher because it was just simply new technology, emerging technology, virtualization, colliding of multiple domains together. And you mentioned 5G, which is an interesting one.

[01:05:25.88] And whether some of that was due to the misinformation that was spread with respect to some radio waves being harmful or creating some other things in the industry. It could be, but that's being grouped up in the general challenge with finding folks that are ready for the next wave of technology and ready for some of the changes that we try to see or incorporate in the industry given all the new enablers.

[01:06:02.30] I mean, right now you're looking at a world where you're moving from having a radio traditionally bill to pulling it apart, putting a lot of it in software and using just common hardware to do things. So those are bringing different expertise levels that are required to the table. You have to mix sort of an RF engineer with somebody who understands the IT side. So that created a big challenge in

the industry as well with two worlds meeting each other. So really good question, but I'm not sure if I've seen statistics with respect to the misinformation.

[01:06:51.43] JOHN CHAPIN: If I could just jump in and say that the question about the workforce needed for growth in this area to future spectrum professionals, that's recognized as a major challenge by multiple entities within the federal government. And certainly we at NSF, have made workforce development one of the four main thrusts within our Spectrum Innovation Initiative. And it was a listed as a key part of the program solicitation that we put out earlier this year for a large center scale activity in spectrum.

[01:07:25.13] So I think the question about making sure there's enough workforce out there is really recognized as an important one. The big open question which may be folks in this entire conference can help with is what does that future workforce need to look like. Where is the need? What types of skills are required? And I really do hope that the community can come together and provide input on that. Thank you.

[01:07:52.21] NOMI BERGMAN: Thank you. I'm just going to read a couple-- There's two to open questions. I think the others are common questions here. There's one from Hassan. In what ways can we incorporate factors of protecting privacy and limiting the data collected about locations within the specification of technology?

[01:08:11.35] This is in context of the small cells and the increased spatial density of cells deployed by the operator. How do we account for the fact that the systems can increase the risk of surveillance at the cost of privacy of individuals? I know we spoke to this some, but could any panelists care to elaborate further on that point? I know we did cover it some, right? We did.

[01:08:39.20] JONATHAN ASHDOWN: So I'll speak to it briefly.

[01:08:42.50] NOMI BERGMAN: Thank you.

[01:08:42.65] JONATHAN ASHDOWN: Could point with the ultra-densification and the small cells getting to those cells, et cetera. But I will say that one thing having been familiar with 4G LTE and the evolution to 5G, I will say that in the 3GPP standards. And even within the ORAN alliance, which is the open radio access network alliance, there have been provisions put into the standards to enhance security of bits and packets going over the network as well as for the individual user.

[01:09:20.04] For instance, with 4G LTE, one reason the DOD really couldn't use it because there's this concept of better buying 3.0 where the DOD would like to leverage the billions of dollars of commercial investment where possible of course, but there wasn't the appropriate and cyber hardening.

[01:09:42.95] There wasn't required encryption of the IMSI channel right so the international mobile subscriber identity. So then there's well documented. You Google it, you'll find things called IMSI catchers and for $1,200 in the US RPA graduate student could create one of these things that could spoof your [INAUDIBLE] or your phone essentially to send routed its traffic through that device therefore stealing very private information that's linked to your IMSI.

[01:10:15.71] In the 5G standards, again the further evolution of 3GPP, the third generation partnership project. You see provisions made for the end to end encryption of the GMSI channel. They call it the Global Mobile Subscriber Identity in that case. So I get what you're saying there's more granularity with the ultra-densification piece, but there are provisions in the standards being put forth to ensure security on the personal level.

[01:10:51.14] NOMI BERGMAN: Thank you, Jonathan. Let's just take-- Let's go to Darcy's question real quick. Hopefully it's OK to run just a few moments over, because then we'll have gotten to all the questions. If I can ask the panelists to look with me, but I'll just read it real quick.

[01:11:05.27] Darcy says she appreciates John Chapin's remark about considering an expost enforcement up front in any spectrum sharing solution. She'd be interested in hearing a bit more about our thoughts on automated expost enforcement in any ongoing initiatives or emerging technical solutions focused on that part of the problem. Can I ask if any of the panelists would like to answer that?

[01:11:32.04] PETRI MAHONEN: Maybe I can start with the partial answer. So the one kind of-- certain kind of exposed enforcement is indeed if we are putting commonly used spectrum sensing devices around this is still relatively general term that what they are sensing aren't they just sensing that what kind of modulation is going on there or whether we have an IDs or whatever. But generally, that could solve the many problems.

[01:12:10.55] I think we have a lot of technological ideas how we could use a common spectrum sensing network for that. The bigger question is that who's going to pay it and who is going to operate it. So it's again, more an economical side where it's a little bit harder to see that who should do it. There are lots of ideas that at least one could start to do on a test scale that.

[01:12:39.14] I think that there's some economic or regulatory benefits on that because I'm flagging up again, accelerate the relatively old paper and suggestion from Pius Debris, which was saying that maybe we should not aim at 200% guarantees that there are no interference. But we should put a risk limit. So we would call the probabilistic regulation.

[01:13:05.12] It's a wonderful idea but if you go to that kind of probabilistic regulation, then we are immediately in an issue with that how we enforce it, how we know that these probabilities are not getting too high. But that's something I would like to see a research community and of course, the companies starting to look a little bit more that what kind of sensing capability we would need it and can we make it economically viable. It probably would need to be some kind of public private partnership to make it viable.

[01:13:43.85] NOMI BERGMAN: Thank you. Thank you. With that, I know we are out of time. I think we kind of got to all the questions. There's three left here, which I think were more comments than questions I'm thinking. So I want to thank my esteemed panelists and thank all of you for your incredible comments. And thank the audience as well for their questions. So thank you so much everybody, and I'll turn things back over to Keith.

[01:14:10.31]

[01:14:23.79] KEITH: Thank you, that was a great panel. That's it for today. I don't know about everybody else, but I.

Day Two Intro & Keynote

https://www.youtube.com/watch?v=jTUTG5_mYXA&list=PLTAvIPZGMUXNWmcqlTXSrvUmWJ0RfSL9K&index=4

[00:00:01.89] KEITH GREMBAN: Day two of Silicon Flatirons conference on Frontiers and Spectrum Sharing. I'm glad to have everybody back again. And I think we've got another great day of discussions as we continue to explore spectrum sharing. So today we'll be discussing governance and incentives and then close off with a wrap up-- OK, I'm told I'm not coming through on the--

[00:00:26.84] [INAUDIBLE]

[00:00:27.68] OK. So we will be discussing governance and incentives and then close off with a discussion of the key takeaways and next steps and to go. So a couple of reminders, again, to moderators and panelists-- so again, we follow the Phil Weiser rule that students get to ask the first questions. I guess I wasn't audible yesterday, but Phil Weiser was the founder of Silicon Flatirons, and is currently the Colorado Attorney General.

[00:00:55.29] And again, a reminder to remember the no-acronym rule. We're not all from the same community. So define your acronyms on first use. And with that, I'm going to introduce Dale Hatfield.

[00:01:07.07] I think most everybody here knows Dale or knows about him. He's currently a distinguished advisor at Silicon Flatirons and co-director of the Spectrum Initiative. Now, with me. Dale has over 50 years of experience in telecommunications and spectrum management. So over to you, Dale, to introduce our keynote speaker.

[00:01:36.63] DALE HATFIELD: Thank you, Keith. Welcome. Good morning. It's my honor and privilege to introduce this morning's keynote speaker, FCC commissioner, Nathan Simington. President Donald J Trump nominated him to serve as a commissioner of the FCC, and he was confirmed in that position by the Senate in 2020.

[00:02:01.56] Commissioner Simington brought both private and public sector experience to the commission. Previously, he served as a senior advisor at the National Telecommunications and Information Administration, NTIA. In that role, he worked on many aspects of communications policy including spectrum allocation and planning, broadband access, and the US government's role in the internet.

[00:02:29.13] Prior to joining the commission, he was a senior counsel in Brightstar Corporation, an international mobile devices services company. In that capacity, he led and negotiated telecommunications equipment device services transactions in over 20 countries. Prior to joining Brightstar, he worked as an attorney in private practice.

[00:02:58.09] Now, on a more personal level, for the past several months, I have had the opportunity to brief Commissioner Simington and his staff on technical aspects of spectrum management. In doing so, I found commissioner Simington to be particularly adept at asking very in-depth questions, very penetrating questions about the technical facts and then figuring out profound inferences from those facts and other information that he and the commission staff had assembled.

[00:03:39.48] Finally, as someone who has worked been involved in spectrum management issues at the national level for something over 50 years now and under both political parties, I have also been especially impressed by his willingness to reach across the aisle in search of technical and other solutions to our nation's most pressing spectrum sharing issues. Please join me in welcoming Commissioner Simington to the virtual podium.

[00:04:11.16] [APPLAUSE]

[00:04:12.12]

[00:04:17.42] NATHAN SIMINGTON: Good morning. Dale, I greatly appreciate your kind introduction. I'm delighted to have this chance to speak to you all today about spectrum sharing, an issue that will surely define the future of spectrum policy.

[00:04:30.71] People often say that spectrum is congested. In my view, this is a good problem to have. It means that spectrum is desirable and heavily used. As such, we have a spectrum congestion problem that we didn't have when we were last developed and lack the ability to exploit spectrum as thoroughly as we do today.

[00:04:47.36] Within living memory, Silicon Valley was farmland and spectrum, likewise, was so abundant that the easiest way to connect spectrum to services was just to give every service its own bound. And just as we needed new planning and land use regimes as cities and became more sophisticated, the question of how to handle new demands on spectrum suggests new spectrum use regimes.

[00:05:08.70] Spectrum congestion for 5G mid-band is often in the news. But as important an issue as this undeniably is, it is just one example of the new demands on spectrum. I'm going to discuss a few specific bands and challenges today, but I'm also going to mention general concepts of sharing in some current and proposed regimes, technologies relevant to sharing, and factors tending to cut against sharing. And I hope you'll indulge me if I return now and then to land sharing is an extended metaphor because spectrum is like land. They just aren't making any more of it.

[00:05:38.50] There's a recent report taking stock of spectrum sharing by John Leibovitz and Ruth Milkman that I would encourage everyone to read. I don't think it's possible to provide a more lucid thoughtful account of the theory and practice of spectrum sharing, so I'm not even going to try it. Instead, I'm going to adopt much of its vocabulary and framing today.

[00:05:55.88] Leibovitz and Milkman make the familiar point that use of spectrum is restricted in frequency, space, and time. And maybe the more subtle point that it's also through signal. Through the use of protocols and techniques permitting the massively scaled coexistence in a single banded service. So under the existing framework, the Table of Frequency Allocations or TFA is a sharing system by frequency under which licenses distinguish on space and time. the TFA is static at any given time and only dynamic in that it can be gradually revised.

[00:06:26.68] They also furnish a helpful definition of a sharing policy and as one permitting multiple overlapping types of spectrum use in a single bound in geography. And that makes the point that after all spectrum is in some sense shared, but we want to have a specific definition of spectrum policy to oppose the existing exclusive use regime.

[00:06:49.51] Automatic sharing regimes promise to go further than the TFA in fulfillment of this definition. Any static system is going to exclude almost all uses. And whenever it's not in use, the spectrum is [? fallow. ?] Or if it's used to transmit only a limited amount of information, likewise, we ask the question of whether it's being adequately exploited.

[00:07:07.63] And automatic sharing regime proposes almost the opposite to enable diverse uses by permitting time and frequencies to be used by multiple services in a coordinated fashion. Leibovitz and Milkman categorized such regimes with two sets of parameters-- our regime can be first

coordinated informing, forming, or sensing, and then second, decentralized or decentralized. In a coordinated regime, multiple radio systems plan their coexistence in advance.

[00:07:31.09] In an informing regime, one service tells another to be quiet so it can talk. In a sensing regime, services detect when others are talking and pull back. Likewise, in a centralized regime, there are one or more central agents running the regime, whereas in a decentralized one, the users themselves coordinate. So coordinating, informing, and sensing regimes will have their places, whether centralized or decentralized.

[00:07:52.81] This diversity of conceptual tools is not done about finding a single ideal approach. Like frequency allocations, regimes should be tailored to anticipated uses, the priorities of users, the physical characteristics of the frequencies at issue, and a mix of incumbent and new user perspectives. Mixing in New uses is a particularly compelling aspect of the sharing model. If the TFA has to be revised every time a new service is conceived, new services face a steeper barrier to entry both in costs and in time.

[00:08:23.05] Then under a sharing regime, permitting a variety of conforming users at a variety of priorities. Perhaps in the future, increasingly flexible radios and pervasively shared spectrum will allow a given device or network to select optimal and continually varying frequencies from moment to moment, much like an automobile navigation system offering alternate routes based on tools, congestion, and unforeseen circumstances.

[00:08:46.52] However, there are no free lunches even in spectrum sharing. A static allocation regime solves coordination problems from its inception at the price of rigidity. A dynamic sharing regime addresses them on the fly at the cost of operating overhead and limiting the functionality of each shared service.

[00:09:03.47] The proper weighting between these two factors is an empirical question. And our choices between these strategies particular bounds are path dependent in two senses-- First, we get to our present allocations by a particular intensely contested history. And if you look at our docket at the FCC, you'll see just how intensely contested. And that's just the tip of the iceberg. And unfathomable amounts of capital have been deployed to build systems arising from that history.

[00:09:27.29] And then second, while RF radiation may propagate in a vacuum, spectrum policy does not. And our policy options are constrained by government and business realities that may or may not easily integrate with notionally ideal policy in the abstract. There's a lot of talk about deploying artificial intelligence or AI and machine learning or ML to improve systems. And today with AlphaZero able to learn chess from scratch to the transhuman level in just a few days of playing against itself, I'd be cautious betting against learning machines.

[00:09:58.34] But the rules of Western chess have been fixed for hundreds of years and they are a limited domain. The rules of spectrum are a little harder to define. Live spectrum sharing decisioning via AI, Ml would require a model based on and searching for optimization of spectral efficiency. If that's what a spectrum sharing model is after and efficiency is narrowly defined, then the machine learning may indeed prove to be part of the solution.

[00:10:21.17] But I'm going to throw a bit of cold water. Anyone familiar with machine learning will tell you that you need a data ocean to train and test the model. And it isn't clear to me where that data will come from. What historical spectrum sharing decisioning will the model be trained on?

[00:10:35.70] But beyond that, there's also a question of agreed parameters. Both data scientists and domain experts would have to collaborate to determine what efficiency is and should look like. That's a

lot easier when such decisioning is done within an organization or within an industry where there's broad agreement about the subject.

[00:10:53.75] And I would venture to say that this doesn't accurately characterize the spectrum sector with its bristling complexity, frequent disagreements, and widely disparate priorities between different stakeholders. I don't think it's too much to say that good faith disagreements are incredibly common in the spectrum policy world and therefore disagreements would also apply as to the criteria, design, and implementation of AI or Ml as a method for spot frequency allocation.

[00:11:18.74] So while this is clearly part of the future, I think we should be a little cautious about the speed with which it can be implemented and not look to it as an immediately deployable solution. What's more, we have data on the [? quantitive ?] evaluation of shared versus exclusive use in two very similar bands in the 3 gigahertz range. Industry proved willing to pay far more per megahertz [INAUDIBLE] for full power exclusive use licenses in c-band than for lower powered [? third ?] licenses in CBRS.

[00:11:50.00] This isn't necessarily an argument against CBRS because c-band was uniquely well suited to wholesale clearance. Still, it should give us [? pause ?] for at least one category. 5G mid-band in the 2.5 to 6 gigahertz range Industry values full power exclusive use licenses far more than it does flexible shared access. Or to put it another way, in some industrial zones, industry appears to be much happier with exclusive use of zoning for shipyards and nuclear power plants without putting apartment buildings in the middle of them.

[00:12:21.20] American spectrum regulators have faced criticism for not making more of this vital mid-band spectrum available. And this very lack of flexibility in an environment full of incumbents is precisely what proponents of sharing can point to when warning about the future. What if we're setting ourselves up to be short of something else down the road by excessive rigidity in the present? And that's why I think the real answer is the [INAUDIBLE].

[00:12:42.17] We have to think about the future. Even the distant future and not exclude ourselves from it by making decisions today that prevent us from getting there. But while our eyes are trained on the future, we also have to identify how to succeed today, in one year, in five years. And the knowledge of how to do so is highly specific and granular and cannot be abstracted away.

[00:13:01.88] To [? quote ?] a phrase, we may make our fate but we do not make it how we wish. There's immediate pressure for successful deployments and for immediately deployable products among vendors, manufacturers, and designers. As a regulator, you have to weigh the immediate intentions here on one hand with the past and the future on the other. And you have to ask both how we get there now and how it helps us to get where we think we're going collectively.

[00:13:28.04] One current market pressure is the pressure to deploy systems that can be run with relatively light oversight in overseas deployments. It's worth remembering that as much as-- I say this with all love as a naturalized citizen. As much as Americans sometimes like to beat up on themselves, we are still a country with a very, very deep scientific and technical bench. And there are many countries that could benefit from continuing to upgrade their telecom infrastructure in a way that is relatively light touch and does not require sitting at the bleeding edge of technology.

[00:14:00.20] After all, the purpose of communications technology is to facilitate production, increase public safety, improve people's lives. Not to aspire to an ideal that does not connect actionably in the present to those goals. Implementation matters. And immediate upside drives decision.

[00:14:19.50] What's more, I'd also like to point out that there are a variety of challenges ongoing at any given time in the spectrum world. And we shouldn't let focus on getting to a goal of pervasive sharing get too much in the way of addressing media challenges for which there's limited regulatory and industrial attention. So some of these challenges that I'm working on, that my team is working on and that I care about as fundamental include addressing spectoral densification largely within the receiver model. That is without the assumption that receivers and transceivers will be able to arbitrarily choose spectrum, and thus looking at immediate challenges to reception.

[00:14:59.77] For example, I remain concerned about spurious emissions [INAUDIBLE] modulation of interference as services become more densely packed. I'm interested in looking at the possibility of reducing guard bands where possible. Each megahertz of guard band just becomes more valuable by the year, so we face more and more questions of how to bring those vacant [? lots ?] into use to the extent possible.

[00:15:21.91] There are also questions of signal security that are I think a significant importance. I want to go ahead and say to any network operators who may be listening that this is not a challenge to network security but is instead about the security of edge devices attached to that network and may not impact the network at all. So with limited ability for regulators to focus, we have to pick the battles.

[00:15:44.61] And it's therefore my view that spectrum sharing is going to continue to be an exciting possibility into the future. But we can't depend on it to replace the existing model. And there will continue to be deep interest in full power [INAUDIBLE] use as a model for I'm sure for the remainder of my term, which is probably a scope of my horizon at this point. Thank you very much for your attention today. It's been an honor and a privilege to address you, and I'm happy to take any questions.

[00:16:20.34] KEITH GREMBAN: Thank you commissioner. As I said earlier, per the Phil Weiser rule, we'll start off the questions with a student question. Jonathan Stokely is here to ask you your first question. Thank you.

[00:16:40.12] JONATHAN STOKELY: Thank you, commissioner. It was very interesting to hear you talk about spectrum sharing. And as somebody who knows enough about spectrum to be dangerous, it's the concept of being able to regulate, as you say, when people need to use it. And the last signals to bypass each other to reduce interference is very intriguing.

[00:16:57.79] As an entrepreneur, I'm curious of what opportunities you see on the horizon to help enable spectrum sharing so that we can help enable a more open future for the future.

[00:17:11.57] NATHAN SIMINGTON: Yeah, absolutely. And first of all, it's always great to hear from people who are looking for practical applications in this space. So first of all, the spectrum sharing models that we look at in contemporary discourse very often contain the concept of multiple competing administrators. Sometimes even multiple types of managers within a single sharing regime. So I think there's a lot of room there for blocking and tackling.

[00:17:38.77] This might not necessarily be the sort of thing that makes the front page of Fast Company, but this really will be an area I think where significant businesses are built up. And coming from the B2B business world, very often there's a lot of infrastructure under the skin that doesn't have a lot of visibility to the general public. But the people who manage that are doing important work and often having very successful careers.

[00:18:09.85] So as far as opportunities to operate in that space, that's one of them. Another one would be to continue looking into-- and I'm sure I don't know your particular focus, but another one to look into would be the continued development of SDR, Software-Defined Radios. So a software

defined radio is intrinsically more friendly to a spectrum regime than a radio that's operating on a more traditional model.

[00:18:37.03] Another question might be figuring out opportunistically which bands could be shared and getting in there when another entrepreneur has not yet identified that opportunity. There are some bands that just need to be quiet. But if you can find a way to coexist with the services on that band, even to offer them incentives to coexist with you whether that might be, I don't know, paying to upgrade their equipment or something like that. If the result is that you get access to that band ahead of someone else, then you've really stolen a march.

[00:19:09.49] And that may be an opportunity to gain a significant chunk of spectrum access without having to go through the full procedure of gaining exclusive use to that spectrum yourself, which just might not be forthcoming under any circumstances given the other pressures in that band. So those are some off-the-top ideas, and I hope those prove fruitful. But if you'd like to further discuss, I'd be happy to talk further offline.

[00:19:32.93] JONATHAN STOKELY: Thank you. I'd definitely enjoy that. Appreciate it, commissioner.

[00:19:43.50] KEITH GREMBAN: OK. We have a series of questions that popped up on the Q of A. The first of which was can you please speak to desirability or undesirability of receiver standards?

[00:19:54.49] NATHAN SIMINGTON: Oh, and you're really talking my language here. Receiver standards are near and dear to my heart. I'd like to thank Dale Hatfield for some very, very fruitful discussion and instruction on this topic. He and I have been over many nuances of this. Although, of course, all areas are [? mine ?] because [INAUDIBLE] the deal with making error in this area is inconceivable.

[00:20:20.74] OK. So receiver standards. This has always been a fraught question at the FCC. And I think my reading of the tea leaves is that every time someone has considered the question of receiver standards, everyone's been worried-- not everyone. But most people have been worried that the FCC finds it hard to have a sufficiently synoptic view of every possible circumstance to issue receiver standards that would be presidential and possibly have unanticipated knock on effects on a wide variety of services.

[00:20:49.82] So it's always died on the point. That doesn't mean that receiver standards shouldn't exist or are not de facto or in fact, are not even legally mandated. There are a number of federal services that do mandate receiver standards. So the question becomes, how can we get to a receiver standard proposal at the FCC that does not overly alarm industry and is sufficiently complex and granular as to not be an offensive act of regulation to do more good than harm with it?

[00:21:21.80] So the question is, I think, going to be evergreen and is now on the horizon precisely because of some of the issues that I raised at the tail end of my speech about the increased possibility of near far problems. The increased possibility of desensitization, spurious emissions, intermodulation that occur as more and more powerful services are lit up in more and more congested bands. What's more, sometimes it's the nature of this that the harms are difficult to anticipate in advance.

[00:21:50.65] So for example, with that far out of band interference, the service that's causing the interference may be acting fully in accordance with its license. And they have no ability to anticipate that that interference would exist because that interference would be in part an artifact of the de facto receiver standards in the service being interfered with. And those might not even be available as technical specifications to the party causing the issue.

[00:22:15.95] So all this is to say that receiver standards are I think a problem that's not going to go away. Whether the right approach to resolving this is regulatory through getting all potential parties to get in the room and whiteboarding together or through some sort of standard that's issued at the level of a trade organization or standard body, that's an open question. And probably it admits of a variety of answers. But I think the receiver standards have got to be very much on the menu going forward, and we cannot afford to continue ignoring them forever.

[00:22:48.42] KEITH GREMBAN: Thank you. Next question we have is thoughts on how to protect incumbents with wide deployments when new uses adversely affect their operation.

[00:22:58.36] NATHAN SIMINGTON: Yes, that's the question, isn't it? Well, I'm going to go back to my-- I'm going to go back to my property rights extended metaphor. And so not to get too law school, but we would say in some circumstances that if you have conflicting rights, then so long is there's a clear regime of resolution, the parties can negotiate among themselves and each party can place the economic value that it sees each right to have to be assisted with on the table. And then we would weigh that against the weight of legal rights [INAUDIBLE] each side and come to an economic resolution.

[00:23:36.07] Now, coming to an economic resolution is much more complex in this space because the idea of a unitary stakeholder is usually pretty absurd. So as far as protecting incumbents, one thing could simply mean-- one approach could simply be to require new entrants to pay incumbents off. And part of-- we could say that this is just part of the cost of entry. You're going to impose costs on these incumbents. Society thinks that these costs should be permitted if that's something that you would like to pursue, but you're not going to be given a free lunch at the expense of the incumbent.

[00:24:17.03] So that's one approach. Another would be to say to the incumbents that [INAUDIBLE] highly situational but would be to say to the incumbents, you're incumbency is in some sense an unearned advantage or a windfall and that you're [INAUDIBLE] and insisting on protection is simply a matter of you not wanting to pay for your ride. So again, I would say that it's highly situational. But I think in most cases, things can be resolved just through upgrades.

[00:24:52.61] In cases where there's just no physical way to resolve the tension, then at that point we really are choosing between which services there are, and if we're going to take the incumbents out then we need a very, very thoroughly big transition plan. Just assume that those situations are in the minority. When it's possible for the users to be reconciled-- and when it's possible for the users to be reconciled simply by equipment upgrades, which I'm going to point out is pervasive in the federal context.

[00:25:17.83] If you look at the amount of federal services that were upgraded in connection with the AWS-3 and AWS-1, it's very extensive. So if it can be resolved by upgrades and we can find that money from the new entrant as in spectrum relocation fund moneys, then I would say that that is a win for everyone. It's a win for society, it's a win for the new entrant, and it's a win for the incumbents.

[00:25:40.66] Where things get more dicey is when you ask questions about the rightfulness of the income [INAUDIBLE] or when services simply can't be reconciled. And if services can't be reconciled, then that's a very tough decision, and the FCC probably should not act precipitously in that case.

[00:25:57.97] KEITH GREMBAN: Thank you. We have a couple of related questions that go into a little more detail. One of the ones that popped up in our chat window was the more sophisticated the sharing regime, the greater the possibility for disputes. Please elaborate how the FCC could facilitate dispute resolution in spectrum sharing regimes. You kind of touched on that, but maybe you add a little more detail?

[00:26:20.44] NATHAN SIMINGTON: Yeah, absolutely. So dispute resolution and spectrum sharing regimes is a tough question because in a sharing regime, if you're just expecting everyone to play nice, then it can be a very [INAUDIBLE] base investigation. On the other hand, if you have explicit prioritization baked in, then the question becomes a little bit more straightforward because it's simply a question of whether all parties are correctly acting in accordance with their priority. And the whole point of an automatic sharing regime is to automate that so that no party can act outside of its priorities and thus disputes of this sort should not arise in the ordinary course.

[00:27:00.79] But this is a pervasive problem when we have a band that has a multitude of uses because one user may lead to a tragedy of the common situation. In that case, I think that means that the FCC may not have fought hard enough about what the sharing regime should really look like. And now, I suspect that this question may be motivated-- and I'm not going to attempt to find reading, but it at least makes me think of the current spectrum sharing regime that's applicable to satellite.

[00:27:27.82] And I think the FCC may need to re-examine the whole question of what satellite spectrum sharing looks like in the future as more and more services go up and more intense use is made of satellite bands. But I think that is sufficiently complex. I'm not going to try to fully address it now.

[00:27:49.14] KEITH GREMBAN: Thank you. I think we have time for one more. And next one on the docket was getting rid of guard bands can cause interference and harm spectrum use for others that didn't design for that. How can that be implemented fairly?

[00:28:04.47] NATHAN SIMINGTON: Again, that is a great question. And illuminating a guard band is something that should be done with a great deal of trepidation. So you folks are going to get sick of me and my real estate metaphors, but it strikes me a little bit like demolition of a building that was built with asbestos. It's got to be done very cautiously because there's really the possibility that you'll pollute the environment.

[00:28:32.58] So the elimination of any guard band has got to thoroughly take into account the interests of all stakeholders and not succumb to an optimism bias. We shouldn't let the potential value of that real estate blind us to the cost that we are going to impose by eliminating it. And so any question of guard band illumination is highly situational and should secure broad comment and I hope broad buy-in before any steps forward are taken.

[00:29:01.07] KEITH GREMBAN: All right. Thank you very much. I think we're out of time for questions now. So can we have a live in virtual round of applause in thanks for our keynote speaker?

[00:29:10.87] [APPLAUSE]

[00:29:11.61]

[00:29:15.27] NATHAN SIMINGTON: Thank you very much. It's been a pleasure.

[00:29:17.19] KEITH GREMBAN: Thank you. So now I'm going on to–

Frontier Justice — Governance and Incentives

https://www.youtube.com/watch?v=828sPu5BXGI&list=PLTAvIPZGMUXNWmcqlTXSrvUmWJ0RfSL9K&index=5

[00:00:00.00] KEITH GREMBAN: So now going on to the rest of the conference. Our next event is a panel that is very related to the keynote we just heard, addressing governance and incentives. Our moderator for this panel is Ari Fitzgerald. Ari leads the communications internet and media practice at the law firm of Hogan Lovells. You could of course find a full part of forum on the conference web page. So over to you, Ari.

[00:00:27.99] ARI FITZGERALD: Thank you. And I'm really enjoying this conference thus far. I'm going to start us off. First of all, I have to tell you we have the A-Team here with us as panelists, so I think we're going to have a very robust discussion.

[00:00:47.58] Let me set things off a bit by just saying that historically, the US, like most developed countries, has taken a centralized top-down approach to determining how spectrum is used and by whom spectrum regulators the Federal Communications Commission and the National Telecommunications and Information Administration have generally allocated spectrum for particular like or compatible uses and assign rights to use that spectrum by granting licenses.

[00:01:20.37] While this approach has largely been successful in minimizing harmful interference, it has at times led to underutilization. And the traditional methods for allocating and reallocating spectrum are cumbersome and slow, as you heard, compared to the pace at which technology is evolving.

[00:01:40.56] In recent years, the US government has prioritized spectrum sharing as a potential solution to these challenges, and we've heard a lot of discussion about the PCAST report that was issued during the Obama administration that really expressed a desire for more spectrum sharing. While spectrum sharing is a promising idea, it raises many questions, some of which we will address today on today's panel.

[00:02:08.50] So let me introduce our panelists. As I said before, we have the A-Team with us today. Coleman Bazelon, and first one is Coleman Bazelon. He's a principal at The Brattle Group. He has consulted and testified on matters ranging from wireless license options, spectrum management generally, and broadband competition policy, and regularly appears for regulatory and legislative bodies, including the FCC and Congress.

[00:02:37.62] Leonard Cali is the senior vice president of Global Public Policy at AT&T, and is responsible for developing AT&T's positions on telecom policy issues. He also serves as AT&T's representative on the Board of Directors of the US Council on International Business. Andrew Clegg is the spectrum engineering lead for Google. He was a major player in the adoption and implementation of the FCC's 3.5 Citizens-- CBRS-- I'll use an acronym-- CBRS service rules as founding chair of the wireless innovation forms group responsible for CBRS functional standards.

[00:03:24.25] And then finally, Vernita Harris, who is the director of spectrum policy and programs directorate in the Department of Defense's office of the chief information officer. In this position, Vernita oversees the implementation of DOD policies regarding the management and use of spectrum, and is responsible for developing and advancing the DOD spectrum internet and information and telecommunications policy positions.

[00:03:53.88] Before we launch into questions, I would like to mention that in view of the quiet period applicable under the FCC's anti-collusion rules for all applicants seeking to participate in the upcoming FCC Auction 110 for licenses in the 3.45 to 3.55 gigahertz band, the panelists here have agreed not to

take any questions regarding that auction or the 3.45 to 3.55 gigahertz band generally. So there will be no questions or discussion about that band or that auction.

[00:04:31.41] Let me start us off with a question for all of our panelists. The focus of this panel is on governance and incentives for spectrum sharing. That assumes that there is consensus on the need for more spectrum sharing among dissimilar uses. Do you agree that spectrum sharing should be encouraged? And if so, under what conditions should it occur? I'll ask Coleman to get us started.

[00:05:02.85] COLEMAN BAZELON: Thank you, Ari, and I appreciate being included on this conference. So if your question is, am I for spectrum sharing? Yes. More the merrier. The question really is why we don't see more of it. And I think the answer to when we should be seeing it is when-- or one of the reasons why it's so difficult to achieve has been more of a challenge than maybe many of us thought it would be to achieve. Is that it really requires the alignment of three different areas to line up.

[00:05:38.01] There needs to be a technical solution to sharing. It has to be technically possible. Historically, sharing has been as was noted time and frequency and geography, we call that allocation, and we're trying to get a little bit more sophisticated. So there needs to be a technical solution to it. There needs to be an economic reason for doing, it and as the economy would say, the value created by sharing has to be greater than the cost of implementing the sharing before that's something that is a good policy, but also something that anybody wants to get involved with.

[00:06:16.14] But the third one is institutional. Even if you can share, and even if it makes sense to share, we still find it a struggle to find a sharing solution. And that's because the institutional structure around sharing can be very difficult. The reasons they are difficult, and we're going to get into these more detail later, but if it's private users, it can be the problem that you have many stakeholders on one side, so it's very difficult to negotiate with a group.

[00:06:44.20] It could be that an odd problem that comes up on the private sector side is that the value created can be so much that it's hard to figure out how to divide up that pie. And we've seen examples of things fall apart, because people can't figure out how to divide the spoils.

[00:07:04.65] And on the government side, as I said, we'll get into this more later, there's a huge institutional problem with the incentive of a government agency to get involved in a sharing regime in essence because they don't benefit. It is much harder for them to benefit from the value created than it is for private party.

[00:07:26.22] ARI FITZGERALD: Thank you, Coleman. Andrew?

[00:07:31.10] ANDREW CLEGG: Yeah. Coleman gave a great answer. I expand on it just a little bit. I think there's a need for exclusive use spectrum in certain situations I used to work for, what's now AT&T. You realize that deploying a network and providing high quality of service and things like that can often require exclusive use spectrum.

[00:07:53.82] But I think the issue is not so much whether sharing should be encouraged, but I think we will see it becoming a necessity, not really an encouragement. I think there's less and less clear spectrum or less and less spectrum that can be cleared and given over to exclusive use, and sharing is going to become a necessity.

[00:08:16.13] In the low band, sharing is almost required now just because of the lack of clear spectrum. In the high bands, the advantage of going to millimeter wave bands is that you can get large contiguous blocks of spectrum based upon the applications and things, but even though there's larger blocks of

spectrum there it's still shared every band is spoken for-- virtually every band even a millimeter wave has an incumbent. And so I think even in millimeter wave, you're going to have to share.

[00:08:46.25] So to me, it's not really a question of what sharing needs to be encouraged. I think it's going to become increasingly necessary. I think we should be developing ways to make it easier to share spectrum while still protecting incumbents from harmful interference.

[00:09:07.28] ARI FITZGERALD: Thanks a lot, Andrew. Leonard?

[00:09:11.78] LEONARD CALI: Hey, good morning, and thank you for having me.

[00:09:13.76] ARI FITZGERALD: I want some controversy on this panel though too. And it was really [AUDIO OUT] that Andrew and Coleman, they seem to agree quite a bit

[00:09:23.12] [INTERPOSING VOICES]

[00:09:24.38] LEONARD CALI: You're going to be disappointed by my answer, because I largely agree. But let me say it's a yes but answer for me. I don't think we should pursue sharing just for sharing sake. We want to get the highest and best use. Now, we heard a lot yesterday, especially from Ambassador [? Coe, ?] that what does that mean in the context of spectrum use? All these uses are important. I think we want to drive as much efficiency out of spectrum as we can.

[00:09:49.31] And while AT&T supports unlicensed use, sharing use we of course also support exclusively licensed use. And all else being equal between sharing and exclusively licensed use, we feel exclusively licensed use maximizes the use of the spectrum. It's more efficient operation, it avoids complexity.

[00:10:09.29] ARI FITZGERALD: You think it maximizes the use of the spectrum or the value of the spectrum?

[00:10:14.00] LEONARD CALI: And part of that is, if your power levels are higher, you're able to make more efficient use of it, you reduce complexity, you could do your planning and resource use. It avoids a lot of the interference issues raised by sharing. And perhaps most important of all, it provides the certainty you need to drive an economic business case.

[00:10:33.30] And so you've seen hundreds of billions of dollars invested in world leading networks in this country based on exclusively use of spectrum. Even in the context of unlicensed, we'd prefer not to see it mixed with different uses because of the fear of interference, which right now we have with regard to 6 gigahertz.

[00:10:52.64] But that said, I think Andrew said it well, I think the reality is, you're going to see a need for increase sharing. So in that case, we do need more spectrum, we need more spectrum, I think, for each of the users, but we're going to have more spectrum for sharing as well.

[00:11:10.05] Let's see. So the question for me is not should we have sharing? The question for me is, can we clear spectrum? And if we can't clear a spectrum, then, can you share it in efficient ways that we're technically, I agree with Coleman's points that it has to work technically. It has to work economically. And then we have to get the players together to make sure we could overcome any institutional resistance to sharing.

[00:11:35.04] The last point I make here is, I do think it's a band-specific determination. So I do think you have to look at the band, make the determination, and then go from there. Going forward, I think, as Andrew pointed out, many of the bands are going to require sharing.

[00:11:48.53] ARI FITZGERALD: So sounds like thus far, at least the first three panelists have agreed that you have to ask yourself the threshold question whether clearing is possible in a band for you actually then take the next step to try to facilitate sharing. Vernita, you have a very unique perspective as the person that DOD with a lot of responsibility for spectrum management. What's your view on this question? I think you're on mute right now, so take yourself off mute.

[00:12:29.37] VERNITA HARRIS: You're exactly right. I was on mute. So thank you so much, Ari, and thank you to my other panelists. I don't know if you're going to get any controversy on this question actually. From a DOD perspective, we no longer have that beach property spectrum that we can just clear. So from our perspective, spectrum sharing must be the new normal.

[00:12:56.54] For DOD, spectrum sharing means sharing as defined as the use of the spectrum that allows for mutual use without the degradation or harmful interference in a manner that provides current and future users sufficient regulatory protection that does not result in loss of access to the spectrum. And from that perspective for us, spectrum does not involve relocation or vacation of the ban by incumbent users.

[00:13:30.96] So again, spectrum is our new normal and we need to do everything that we can to make sure how we do that. It's a operational need that we can't get away from. We recognize this last year, the DOD released the electromagnetic spectrum superiority strategy that describes the challenges the US national security faces from threats emerging from our adversaries.

[00:14:02.51] So for us it requires spectrum, we see the value. And again, that's just our new priority and a norm that because spectrum sharing requires us the freedom to move or will allow us the freedom to move across bands to keep pace technologies that have been developed so that we can develop and deploy AI capabilities, and that rely on spectrum.

[00:14:31.22] ARI FITZGERALD: So basically you're saying that DOD benefits, and many government agencies benefit from innovation and spectrum sharing technology with respect to spectrum sharing technologies. I mean, DOD stands to benefit if more spectrum can be shared?

[00:14:47.87] VERNITA HARRIS: Absolutely. I think the United States tends to benefit and everyone will benefit if we can share. And there are technologies out there that have been developed that will allow us to do that.

[00:15:00.93] ARI FITZGERALD: Well stated. Thank you. I guess we've talked a little bit already about spectrum reallocation, so let's really dive into that a little bit. In recent years, there's been a lot of focus on reallocating spectrum from primarily federal use to primarily commercial use. And although federal users have often been allowed to stay in portions of the reallocated bands temporarily or permanently, the goal of these processes has not been so much to encourage spectrum sharing as to facilitate reallocation of the band so that it can be divided into geographic area licenses auctioned and then used primarily to provide commercial services.

[00:15:48.05] And it's already been stated by a panelist that exclusive use spectrum all things being equal, exclusive use is better for provider or service providers view, exclusive use licenses flexible use, exclusive licenses as better alternatives than sharing spectrum.

[00:16:11.58] So these spectrum reallocations though have, for the most part, been mandated by Congress largely at the behest of the commercial mobile industry and have required extensive work though by the FCC, NTIA, and the affected federal agencies. You think about the Sysmex process as relating to the AWS S3, the reallocation of spectrum which now comprises the three band.

[00:16:41.15] So they've often involved also intense lobbying by all of the sides affected, and these reallocations can often take a long time to accomplish. These times take a long time to accomplish. So our spectrum reallocations of this sort, the best way to accommodate new commercial uses, or there other approaches that would take less time but produce equally or better results or at least results that are acceptable for the commercial sector. So why don't we start with Leonard in addressing this question? And, Leonard, I know you've already spoken to this issue a bit.

[00:17:24.76] LEONARD CALI: Yeah, so reallocation has been used, and it's been used because it's an excellent way of deriving value from the spectrum.

[00:17:34.18] ARI FITZGERALD: Takes a lot of time though.

[00:17:36.25] LEONARD CALI: It takes time. But here's the issue with sharing. Sharing takes time as well. In fact sharing may take more time. CBRS it's going on nearly a decade since the [INAUDIBLE] Report and that's not enough that's CBRS was a new technology, because it was an innovative. It's probably the most advanced pilot of sharing in the world. So it would take a long time.

[00:17:55.34] But I think sharing takes a long time because you have to work out all the rules which are complex. In addition, any new sharing methodology is going to have operational risks associated with it, that can also create further delay. CBRS used the enhanced sensing capabilities, but we've identified issues with that and now there's proposals to move to an incumbent informing capability there.

[00:18:20.74] I don't want to say that's necessarily a delay but it's an evolving technology. So we don't want to accept, or I don't accept that reallocation and exclusive licensing necessarily takes longer than sharing. I think sharing takes time I think it's going to be banned specific again.

[00:18:37.24] The point I would make, though, is I think time to market is critical. But if you're really concerned about time to market on spectrum, what we really should be looking at is getting a cogent coherent spectrum pipeline out there. So participants stakeholders know what's coming in when. Maybe we look at local siting policies to get infrastructure deployed, and we focus on co-investment pro-competition policy framework. So I think those three things will drive speed to market more than any differential between models for sharing spectrum or not sharing spectrum.

[00:19:09.82] ARI FITZGERALD: Thanks a lot. Vernita?

[00:19:13.13] VERNITA HARRIS: Thank you, Ari. So this is a really interesting question and we actually talk about this internally. DOD recognizes that spectrum reallocation is one of the tools to make spectrum available for commercial wireless industry. However, it should not be viewed as the only tool. We do think going forward that spectrum sharing must be the first consideration. Decisions must be based on solid engineering.

[00:19:44.21] There are no shortcuts here and decisions. We need to make sure that we're not undercutting the decisions that need to be made by taking shortcuts. We need to evaluate and determine when Specter can be made available. So that goes back to Leonard's point about the spectrum pipeline available for new purposes, whether through reallocation or sharing. But for us, I'm going to see here we say this throughout the panel, spectrum sharing has to become the new normal for us as we start to look forward.

[00:20:17.61] ARI FITZGERALD: Would you disagree a little bit with Leonard that the threshold the first question the government should ask itself is, is sharing possible? Is that the first question or-- because that wouldn't be Leonard's first question.

[00:20:34.11] VERNITA HARRIS: Our first question is it's always going to be can we share? We need to share.

[00:20:39.63] ARI FITZGERALD: Yeah.

[00:20:40.74] VERNITA HARRIS: So it's not vacate.

[00:20:46.08] ARI FITZGERALD: Andrew? I'm hoping that to facilitate some type of controversy here.

[00:20:51.54] ANDREW CLEGG: Sure. I'll start with some soft controversy. First of all, reallocation, clearing the government out of the band is very disruptive to the government. It also can take a really long time. So I don't think, and to some extent it depends on the band, but I don't think, going forward, clearing the government out of bands and reallocating to exclusive use is really necessarily the best way to go.

[00:21:27.35] There's also a consideration here about who can access the spectrum. If you completely clear bands, so let's look at the 3.7 gigahertz band, it was not federal users but it was cleared and auctioned for a tremendous amount of money. And in the end, there were basically, when you look at the totality of expenditures and licenses one, it was basically three licensees that one the vast majority of the spectrum.

[00:21:59.50] Look at CBRS though, on the other hand. In CBRS, because it was shared spectrum and because there's a free tier, the general is access tier, and there is a license tier, the priority access license tier. We enabled access to a much greater range of licensees, over 200 licensees in the CBRS band compared to effectively three in the 3.7 gigahertz band.

[00:22:27.40] And the power licenses went for about $0.20 on the dollar on a per megahertz pop compared to, for example, the 3.7 gigahertz auction. So it opened up spectrum access to entities that would not have the economic wherewithal to go after exclusive use licenses.

[00:22:49.09] ARI FITZGERALD: But, Andrew, at the same time some of the rules for that, the CBRS option, they were constructed to optimize that result. I mean, they were on these the licenses for

[00:23:02.41] [INTERPOSING VOICES]

[00:23:08.17] ANDREW CLEGG: So the original rules were most optimized, but then the rules, of course, changed. The license areas became much longer. The licenses were basically granted forever instead of three years. And so we would have probably seen an even greater diversity of the original rules that stayed in place. So the benefit of the CBRS model in that case over exclusive use is it allowed a much greater variety of entrants into the band at a much more affordable price. And by the way, the DOD did not have to relocate anything out of the CBRS band.

[00:23:41.52] ARI FITZGERALD: Yeah. Thanks, Andrew. Coleman.

[00:23:46.20] COLEMAN BAZELON: Thanks. So I do have to first channel my inner Tom [? Haseley ?] here and remind Andrew that even though there was only three main licenses out of the band, there's going to be 300 million users on that spectrum and that in fact the BRMS spectrum is the most shared spectrum if you abstract from the ownership rights and talk about just actual people using it, it's the most shared spectrum out there.

[00:24:16.56] But on this point about the government sharing, I got my start as an analyst at the Congressional Budget Office, and so I'm pretty sensitive to federal budgeting issues. And it's worth noting that the exclusive use auctions is what and the value from those auctions is what motivated the political will to direct reallocations, as you note they tend to be directed.

[00:24:44.28] The economists get involved, and we get all excited about there's value to be created from a trade, that we can identify a band that can create more value in private use either previously exclusively and I'm perfectly. I think it's just a continuum as to whether it's exclusive or shared at this point, and I take this point that it's most of it's not going to be a complete vacating of the government users. But the problem is the value created, there's a huge constitutional problem with that being shared with the agencies that are on one side of creating that value.

[00:25:20.88] And that's that you cannot pay money to a federal agency without it being going through the congressional production process. And so you cannot credibly make that an incremental dollar to the agency that a congressional committee won't just take off of their appropriation. So they're unable to physically they're just constitutionally unable to capture the value that's created by participating in that.

[00:25:49.45] It's imperfect. But I think the workaround on that that will facilitate and can quicken these transactions is that barter is possible. So to the extent that it's not a transfer of a property right from a federal agency to the private sector, but instead, it's a partnership of a redevelopment of a system where much along the sort of d-block model with AT&T partners with and then gets benefit from excess capacity sort of thing.

[00:26:25.50] I suspect that's much more the model for federal users for sharing and transfers from federal users is that they'll end up with their missions enhanced in a way that will be harder for congressional committees to just reduce budgets in the alternative.

[00:26:45.66] ARI FITZGERALD: That's really great Coleman that's sort of a good segue way into the next question, which gets to incentives. And I guess we'll start by just incentives for sharing. We'll start by talking a little bit about what you guys perceive as the barriers to sharing right now. As Vernita mentioned, true sharing exists where an incumbent user and the new users can co-exist without the incumbent having to move or change its operations.

[00:27:20.04] So I guess I'm going to ask you guys to the general question first to talk about the barriers to this true spectrum sharing. Are they primarily technical, legal, institutional, mindset related? Coleman, you mentioned the Constitution, the appropriations process, so let's talk about that as well.

[00:27:42.90] Are they all of the above? Does it depend on whether the incumbent is a user as a federal agency with the mission whose benefits cannot be calculated solely in economic terms? Are the incentives ever the same for federal commercial incumbents? Let's start with Andrew. I know I threw a lot out there, and that might be a couple of questions but--

[00:28:13.01] ANDREW CLEGG: Sure. Thanks, Ari. I mean know obviously, I look at things from the engineering side and so I look at some of the challenges for sharing from the technical side. I think one of the challenges we've had in shared spectrum is true of CBRS and true of other bands, is what I believe to be the tendency towards overprotection of the incumbents.

[00:28:45.52] I think it comes from several different reasons. But one is, traditionally, for example interference criteria for incumbents for fixed service for satellite services, whatever, you look at the history of where those come from, and they typically come out of IDR recommendations from a long time ago.

[00:29:08.35] ARI FITZGERALD: Yes.

[00:29:08.77] ANDREW CLEGG: And this is back when all of these services had their own bands, and they'll be well let's create an IT recommendation that establishes our interference criterion. And back in the 1960s, nobody was caring, because nobody was sharing the band.

[00:29:21.17] ARI FITZGERALD: Right.

[00:29:21.46] ANDREW CLEGG: And so the satellite industry says, OK, we need to be protected down to the one photon limit. We can't possibly have a stray photon enter our satellite. And nobody else is paying attention and back in 1963 or whatever somebody signed off on that and said, yeah, who cares? That sounds like a good selection criteria.

[00:29:38.05] But today we're still operate, because now they can pull out this, blow the dust off the world record and say, hey, this is our protection criteria. And we saw some of that in CBRS. We're protecting some of these satellite dishes to 150 kilometer radius. It's as the area is larger than the State of West Virginia. We're protecting these individuals. I mean it's insane.

[00:29:59.77] And you look at a more modern example, you look at the radio altimeters, for example, in the 4,200 and 4,400 megahertz band. They're claiming they're worried about interference from the 3.7 gigahertz service. 220 megahertz away. And in fact the 4.2 to 4.4 gigahertz radio altimeter is actually only operate in the center 100 megahertz of that band for the most part. So there's an additional 50 megahertz of guard bands.

[00:30:25.03] So they're arguing that we need at least 270 guard band to the 3.7 gigahertz service. And then if you look at that and say, well would they need that much guard band at the upper end as well? So that's 540 megahertz they're consuming plus the 100 megahertz that their systems operate in. They're saying they're 100 megahertz bandwidth systems require 640 megahertz of spectrum protected for them to operate.

[00:30:53.02] When you talk about if you ever get into spectrum sharing considerations with a service like that, it becomes almost untenable to share spectrum. So I think the overprotection of incumbents based upon questionable interference criteria and assumptions I think is a real challenge to spectrum sharing. I have several others but I don't want to take too much time but that's one of our main concerns.

[00:31:21.04] ARI FITZGERALD: That's a good one to discuss. And you're absolutely right that those protection criteria were created was that all of the stakeholders for that particular service got in a room and basically developed the criteria. The SEC doesn't national administrator has to actually accept it full bore. They can take it under advisement, but they often do accept those criteria. Coleman, you've already mentioned a couple of great barriers. Andrew just talked about the technical barrier, what are your thoughts?

[00:32:02.39] COLEMAN BAZELON: Well, I agree with them that the problem is well characterized by a completely one sided view of the property rights the faux property rights that the incumbents get 100% protection. The lens I take to that, though, is that that exists, I believe, because there is no mechanism for resolving disputes efficiently between users.

[00:32:26.92] And this was the real purpose of my question to Commissioner Simington, that if you are going to trade with somebody, or cooperate with somebody, there has to be a backdrop to what happens if you disagree. And to use his analogy, to land, there's rules about how neighbors interact with each other. And if you drive across my lawn, we don't have to go to court, because you're not going to drop across my lawn, because if you did, I'd take you to court and I'd win. And we all know I'd win so it doesn't happen.

[00:33:04.04] But none of that exists in spectrum. In spectrum, if you have a dispute, you have to bring it to the FCC and as it set up now as an inherently political process where lobbyists and political decisions end up resolving this, and there's no sort of rules or set of law about how to resolve disputes between parties. Even the fact that we have all the rules tilted to one side, the fact that if an incumbent gives up

some of their property right in a trade, and the person they trade with sort of takes more than they were supposed to, there's no good way to resolve that.

[00:33:45.81] Well, I'm not as worried that the incumbents have in a very cozy and sense it doesn't really matter so much who has the initial property rights so long as the transaction costs of a trade are reduced. And here, to reduce the transaction costs of a trade, you need good rules of the road and expectations about how disputes between spectrum users would be resolved.

[00:34:06.38] ARI FITZGERALD: You're saying basically, you need to have the government does need to set a standard, but the parties should be able to contract around that standard. It's important to have a standard, but then once that standard is established, it should be possible for the parties to contract around it.

[00:34:23.36] COLEMAN BAZELON: Exactly. Just as we managed it with the spectrum partition and desegregation rule.

[00:34:28.58] ARI FITZGERALD: Yes.

[00:34:29.45] COLEMAN BAZELON: Where the government says, here's your license. Now, you guys can do whatever you think is right and we're going to bless it, and there's rules about that. But we need that in the sharing regime in essence.

[00:34:40.49] ARI FITZGERALD: And, Leonard, will this carriers often resolve disputes regarding interference at the border of their licenses all the time. The FCC sets a standard for what the signal levels should be at the border of a geographic area license, and the carriers use that standard and then contract around it. But they have this standard that they use as a baseline, I guess, but-- thanks, Coleman. Vernita?

[00:35:13.19] VERNITA HARRIS: Thank you, Ari. So from a technical-- I agree, from a technical legal and institutional mindset, there are is incentives for all barriers to increased spectrum sharing. So I do think that we need to think about how do we get beyond these barriers.

[00:35:31.43] From a technology standpoint, we all been talking about CBRS that is one way that we can enable greater sharing we've seen promise and been working across DOD, the CBRS framework it's showing really good promise, and the depth and the services are all happy with that process. And I know that there continues to be continued discussion on how to improve it. So that was a huge win, I think, for the spectrum sharing, and we can all see that.

[00:36:08.42] However, any new spectrum sharing framework, it still needs to be rigorously tested developed by all stakeholders, and future learning and like frameworks may employ artificial intelligence and machine learning use of these enabling technologies for sharing will require time and resources to develop, and we believe these investments are necessary to meet the demands of the increasingly crowded spectrum the environment.

[00:36:35.66] From a legal regulatory standpoint, flexibility isn't it to allow for agile especially for DOD operations. The US regulatory framework is not flexible enough from our perspective. So for some of our planned operational scenarios, that rely on sharing technologies. For example, some of our radars require regulatory flexibility to be able to operate their full potential and we're building work we're continuing to build, and our next generation radars will need to be agile that can operate across the wide selection of spectrum.

[00:37:15.81] ARI FITZGERALD: What you're saying is that you're looking for your radars to have access to what is currently non-federal spectrum?

[00:37:24.74] VERNITA HARRIS: That could be a possibility. Basically what I'm saying is that you have to have flexibility in your regulatory approach. And right now, we're limited to the bands that we're assigned. But what if there's technology that will allow DOD to share with commercial operators and when we're using the band, they're not going to use the band. So we just need to have more discussion and more studies.

[00:37:56.57] ARI FITZGERALD: Great. Thank you. Leonard?

[00:38:01.16] LEONARD CALI: Great. So let me suggest three areas, and I think they're very similar, which you've heard, but I want to go through them. One is the technical. It's got to work. Federal agencies have missions to accomplish, and those missions [AUDIO OUT]. And you've got to make sure whatever sharing you have works. Devil's in the details, are you overprotecting incumbents maybe in some circumstances certainly are and others are not.

[00:38:24.21] So you need to make it work. We need I think made the point that you want to have it tested you want to experiment with it you want to make sure it works, and unless it works, that's going to be a first barrier.

[00:38:33.98] The economic barrier. I don't think you can overstate. This is the investment incentive and what's the business model. CBRS did have it has today it had even more so in the initial envisioning of it. The idea of hyperlocal eyes, temporary licenses, that great innovative, because a kit in the garage companies could come in, acquire, use, and then move on. But the spectrum alone isn't sufficient. You need something, you need equipment, you need infrastructure, you need investment to make it work.

[00:39:04.83] So it goes to that second point about the economics. Can you share in a way that drives a business case that's going to result in investment? An ecosystem like infrastructure, of course. And then the third thing I mentioned, and I think Coleman made the point, a mechanism for dispute resolution. I mean, and it goes to detecting the interference identifying who's responsible for it and then remediating it.

[00:39:29.33] And that's critical, so I would say it's across the board. Clarity up front. The less clarity you have about all dimensions of sharing and then how you're going to ensure coexistence as the force is a critical component of this. I mean, we saw problems in 5 gigahertz DFS, and I highlighted the challenge of maintaining coexistence in a reliable way.

[00:39:51.89] ARI FITZGERALD: And its remediation of the interference quickly. That's key. I mean, it takes you two years or three years in case of that DFS and 5 gigahertz that doesn't help anyone. Thank you very much. Well, listen, we've been talking about some of the barriers.

[00:40:12.23] Quickly, if you guys could just share with us the success stories, what you think successful spectrum sharing, what has examples of successful spectrum sharing. And you can talk about specific bands if you want to. Andrew, do you want to start us off there?

[00:40:32.04] ANDREW CLEGG: Sure. I mean, naturally I have to come back to CBRS. We are a spectrum access system or SAS. Operator 105 with more on the way. Despite the pandemic, we were fortunate enough to kick off CBRS almost completely coincidental with the beginning of the pandemic.

[00:40:52.96] But despite that we are over 160,000 deployed base stations under SAS management right now so we've had a lot of deployments most of those have been outdoor, we have not seen enterprise deployment at the levels that we'd like to see, but that's mostly because most companies aren't back to the office and we expect that to pick up later.

[00:41:16.05] There's a lot of interest in CBRS among non-traditional uses, National Football League, all sports and racing have been using it. All sorts of very interesting things. The general authorized access, the free tier of CBRS has been much more popular than I think anybody expected.

[00:41:37.88] There's 100 different models of CBSDs out there. Leonard was talking about you need the equipment ecosystem. We're at 100 different FCC certified models of CBRS base stations. So we see CBRS has been quite successful. So far, we've been working very well, by the way, with the duty and other components of the government in working out sharing arrangements. I think there are tweaks that need to be made.

[00:42:04.91] As we've pointed out many times, my soapbox is we need to move to this informing incumbent capability rather than in-band sensing which has inherent faults to it, but it's still x are working the environmental sensing capability is working well, but I see would be a much better way to go.

[00:42:23.66] And we have not had a single reported case of interference to a protected incumbent in the entire first 18 months of CBRS deployment. So unless a Bonita has a stack of interference complaints about ready to throw at us as far as we know we haven't been interfering with anybody, but that. So I take that as a relative success.

[00:42:47.54] ARI FITZGERALD: Yeah. Vernita, is that all those instances of interference classified or have there not been any influences to your knowledge?

[00:42:56.86] VERNITA HARRIS: No, I haven't. Not to our knowledge and when there has been interference, I do believe that it's been reconciled pretty quickly. We're pointing to the citizen radio service CBRS, it's a success from our perspective, and it shows how, working with FCC and NTIA and DOD, we have worked together to accomplish and collaborate and partner on spectrum sharing.

[00:43:24.65] And CBRS is a success story. It has allowed us to look at how we prioritize as we're prioritizing 5G in the United States. We have been able to make wide swaths of spectrum available by spectrum sharing. So I agree with Andrew that there needs to be some tweaks, but I do think that we're working to make those tweaks.

[00:43:53.78] But this is a success story, and so I do think that the more we can look at these sharing frameworks as the norm, sharing is our new norm, the better off we're going to be because of the congestion that spectrum is undergoing right now. Thanks.

[00:44:11.18] ARI FITZGERALD: Excellent. Any of, Leonard or Coleman, you want to add anything to what was stated?

[00:44:17.92] LEONARD CALI: Yeah. First, I would like to give a shout out to the FCC, which actually has tried a range of sharing models over the years. And again, if you look at the US wireless market, both exclusively licensed as well as unlicensed working, you look at CBRS, it's world leading pilot, so that has to be said. CBRS, I'm a little less enthusiastic about, only because I think the jury is still out on it. It's certainly far less dynamic than you would think when we talk about dynamic spectrum sharing.

[00:44:49.45] Basically the sharing between tier two and tier three are scheduled through the [INAUDIBLE]. Not a bad thing, but I just want to highlight it's not as dynamic. And the dynamic component about sensing the ESC scheduling one service has to go off has its problems and it's going to need to be replaced by a different system. So not a criticism of CBRS as much as a too early to tell right now. I think the jury's still out.

[00:45:13.72] Some of the other sharing experiments or sharing models put in place by the FCC, it's all very context specific, so you have contention-based protocols. They generally work 6 gigahertz. They're

going to keep the unlicensed juices from interfering with each other, but they're not protecting the incumbent use, because the consensus-based protocol doesn't work there.

[00:45:33.61] TV white spaces, it appears to be working operationally, but I think the best that can be said is how successful is it remains a point of dispute commercial right is that because of a long period of regulatory uncertainty, is it because the blocks are too small is because there's no investment model behind it.

[00:45:52.15] ARI FITZGERALD: The commission took away spectrum. There's less white space.

[00:45:56.43] LEONARD CALI: Yeah. That's right, but they really, really do. And then you have DFS. We talked a little bit about the challenges there early on, especially with 5 gigahertz. So the bottom line is, I reiterate. The nation has had just extraordinary success exclusively licensed model.

[00:46:13.90] We have vibrant unlicensed uses. Those are the real successes we should recognize. I do think we need, as we said at the beginning more daring, and I think we have to continue to push the technology there, but we have to be sure it works before we go forward.

[00:46:29.79] ARI FITZGERALD: Thanks a lot.

[00:46:32.85] COLEMAN BAZELON: I have two points to sharing. I'm sorry. Two quick things to add to this discussion. One is, as far as sharing models obviously, it's worth saying there's not one model, there's no answer. It does depend on the question. We all need a place to sleep at night. Sometimes we'd buy a condo, sometimes we rent an apartment, sometimes we rent a hotel room, sometimes we use Airbnb, it just depends on the users.

[00:46:58.40] The other thing I just want to bring into this is that, from the economic perspective, I need a little mea culpa here about something that I got quite wrong over the years, which is, in sharing, you do need a new regime, and CBRS is a nice example where you need some infrastructure, TV white space infrastructure too. But in CBRS, you needed some infrastructure to facilitate the sharing. I viewed that as just a cost of sharing. That you have to pay some money, set up this stuff, so that you can get to the benefits of sharing.

[00:47:32.69] I think one of the things I'm starting to-- my eyes are starting to open to is that infrastructure could be a whole other benefit, a source of benefit in itself. And I've heard stories. I was at a conference last month where they were talking about the sharing regime and the necessity of being able to share puts in place all sort of technology infrastructure find [INAUDIBLE]. All of that stuff that actually facilitates a whole lot of other things that I think were unanticipated when it was set up. And so thinking a little bit more broadly about these regimes also having facility benefits separate from just facilitating the sharing itself.

[00:48:11.88] ARI FITZGERALD: Yeah. Thank you. And, Coleman, if you wouldn't mind, before I start asking for audience questions, just if you could help us elicit what this panel believes the guiding principles should be for government policymakers that want to encourage sharing where they believe it's viable-- where viable-- specifically I think you've highlighted some of the principles that you believe policymakers should embrace. Can you just again tick off your list, and then we'll ask Andrew and Vernita and Leonard to do the same before moving to audience questions.

[00:48:56.93] COLEMAN BAZELON: Certainly, the sharing needs to be value enhancing. And I want to be clear that as an economist, I don't mean just economic value. When I say value and when an economist has value enhancing, we do appreciate that there's a lot of non-market value. And it can be created that certainly belongs in the equation as to whether or not benefits outweigh the costs.

[00:49:21.79] But I think there's a couple of principles. One is clarity of policy. This goes to the enforcement issue. Just be clear about who has what rights. I don't think we should shy away from the fact that incumbents have right. There may be something offensive about somebody gaining a windfall, but as a practical matter, they can block a reallocation. Paying them off is really in the public interest, even if you have to swallow a little bit before doing it.

[00:49:57.66] And I think with those in mind, the parties themselves that see value to be created by the process.

[00:50:09.75] ARI FITZGERALD: Thank you, Coleman. Leonard and Vernita, any comments on what principles should be-- what the guiding principles should be?

[00:50:21.32] ANDREW CLEGG: So I have two suggestions of principles. I'm not sure if they're the biggest principles, but from my experience in CBRS. First of all, don't base your sharing requirements and sharing rules on a mountain of worst case assumptions. Look at the end-to-end interference budgets. Don't take the most conservative for every single parameter that goes into the sharing. So don't base your sharing rules on worst case assumptions.

[00:50:53.58] ARI FITZGERALD: Like the Monte Carlo analysis or from probalistic?

[00:50:57.26] ANDREW CLEGG: Probabilistic. Joint probabilities. Don't take the 99th percentile of the propagation model plus the 99th percentile of building entry loss plus on and on and on, because that becomes infinitely improbable, but that's what the rules end up sometimes being based on.

[00:51:16.07] Then the second is, and this is timely, I think we should allow sharing frameworks and systems to evolve based upon lessons learned. In CBRS, we had our spectrum access certified and our environmental sensing capability systems certified two years ago, and the expectation is you had your code, you had your hardware certified, it will not change from here until the end of eternity.

[00:51:47.17] And we've learned a tremendous amount in the meantime of how we can make spectrum use more efficient, how can even protect Virginia's incumbent use even better, but technically we're not allowed to change our system. There is no process in place to make it easy for us to evolve our systems. So I think future sharing systems should be built in methods to be able to evolve efficiently and quickly.

[00:52:11.88] ARI FITZGERALD: And so it's interesting, because Coleman makes the point about the need for clarity, but what you're saying, in some sense, if you're too prescriptive, if the standards that are put in place are too prescriptive, it makes it very difficult for the ecosystem to take advantage of learnings. The point that you made, Andrew, about what you learned as the sharing matures, through the sharing.

[00:52:47.08] ANDREW CLEGG: I was going to say, look at it this way. The fact that we have that there has never been a reported case of interference into incumbents from CBRS means that we can adjust the dial a little bit. Means that perhaps we can allow operations closer to incumbents or allow greater number of CBRS users near an incumbent. You haven't caused interference it means we're over protecting. So let's take that lesson, let's reduce the protections by a half a dB and see how it goes and keep doing that and tweaking the system until we get to that proper [AUDIO OUT].

[00:53:23.59] So I don't think it's against what Coleman said. Start with relative certainty, but in order to increase the efficiency, let's learn and adapt based upon experience.

[00:53:38.68] ARI FITZGERALD: Thank you. Leonard?

[00:53:41.41] LEONARD CALI: Over for four thoughts and they're related to our conversation. One is make the threshold determination. Can you clear it, if you can clear it, can you share it, is there value, is the value enhanced? So make that threshold determination. The second thing is establish a trust information sharing process. Where yesterday the importance of trust the importance of getting the stakeholders in the room, the importance of good faith negotiation. And it may be naive but I do believe that you get the stakeholders in the room and you really talk it through and share data.

[00:54:11.83] You can drive towards the clarity, which is my third point. I understand what Andrew saying about the need for flexibility, but recognize the less clarity, the less certainty you have upfront, that's going to translate into less investment and less use, because people will migrate to things they can rely on more specifically. So you have to decide, is this an experimental allocation or is it something that you really want to put to work.

[00:54:37.09] So I'd urge clarity across all dimensions of who's who can use it under what circumstances, what power levels, where, when, which geography, and the like, but I think clarity it helps a lot.

[00:54:48.53] And then the final point I'll make is one we discussed earlier, which is ensure you have the mechanisms to detect, identify, and remediate interference. You put those four things that they can help.

[00:54:59.89] ARI FITZGERALD: Thank you. Vernita, any thoughts on these?

[00:55:03.91] VERNITA HARRIS: Yes, so say three principles that we're employing in DOD right now, especially from the spectrum policy program office very engaged in a whole of nation effort to solve spectrum sharing. We believe that strong partnerships and effective collaboration across the government and industry, academia, and with our partners is how we're going to win spectrum sharing.

[00:55:31.85] And if you've spoken to Mr. [INAUDIBLE] he has a saying that DOD understands that whoever masters spectrum sharing will own it, and we certainly believe that and we're working towards that. And that will help us reap economic and/or security benefits from this mastery.

[00:55:51.88] The second spectrum management tools we should viewed as a necessary infrastructure that requires continue investment to meet current and future needs. And also we may need to look at how spectrum management is done in this country and is this an opportunity to look at how we reform sector management policies.

[00:56:14.89] And then finally, when evaluating spectrum decisions, I think that federal agency spectrum users, we can't value spectrum based on commercial terms and I believe Coleman said this. So agencies where we need to--

[00:56:34.89] ARI FITZGERALD: The mission driven

[00:56:36.77] VERNITA HARRIS: Yeah, to use spectrum efficiently and effectively to achieve our mission. It's not based on the commercial value of it, so we have to look at things differently. So if that could be taken into consideration.

[00:56:49.17] ARI FITZGERALD: Thank you.

[00:56:50.61] VERNITA HARRIS: And I would just add, just a couple of things. We need spectrum to do our mission and our operational mission and meet our priorities. And I think Andrew you said something about IAC and I want to just make sure. I don't think that there's a clear definition that we're all on the same page as to what IAC means. I've heard different viewpoints here and I've heard the viewpoint from NTIA, and I've heard the viewpoint from some CBRS operators.

[00:57:23.64] We have there's different definitions. And if we want to have clarity on IAC, you need to really be on the same page. For DOD, it is one tool in our toolbox. Is not the only tool, and this concept for this right now it's a concept for us. And I believe is a concept for NTIA so we really need to better understand what that means for everybody. Thanks.

[00:57:48.96] ARI FITZGERALD: Thank you.

[00:57:49.86] COLEMAN BAZELON: Ari, I'd agree that mission's the important thing as a citizen of this country, I want the need to protect us. That doesn't mean spectrum is special. I mean, we need steel for tanks and despite President Truman's effort we never nationalized the industry because of the importance of steel and I think the same is true for spectrum.

[00:58:15.09] ARI FITZGERALD: Thanks. This has been a great discussion. I know we have a lot of questions tuning up from the audience. So I'm going to now turn to the audience for questions. And consistent with the wiser rule, I'm going to ask that the first question be posed by a student from CU. And we do have Stacey Weber with us. Stacey is a student at CU, and want to give Stacey the opportunity to ask the first question.

[00:58:51.08] STACEY WEBER: Good morning. Thank you so much for just an incredible discussion. It's been amazing to get to listen to all of you. I was really interested in the comment that we need the technology to be there for sharing as well.

[00:59:05.20] I'd just love to hear more about either what that technological development is that you might like to see or an area where there might be need for some innovation. I don't know if that goes to questions and comments we've had about receiver standards or secure information sharing but I'd love to hear your thoughts on the side of technological development too.

[00:59:26.68] ARI FITZGERALD: Great question, Stacey. Who wants to get a start, Andrew?

[00:59:31.99] ANDREW CLEGG: Sure. I can think of two right off the bat. In fact, I'm glad you asked that question because I didn't get to put my points on the table. So one of the technological developments that I think is important to bring spectrum sharing is improved propagation models. Might not be the most exciting thing in the world to most people.

[00:59:52.09] But as an example, we are basing sharing in the city's broadband radio service band and in the upcoming 6 gigahertz automated frequency coordination band upon a model called the irregular terrain model, ITM, that was developed by the Institute for telecommunication sciences of NTIA back in the 1960s. And the data they use, the empirical data that went into creating the ITM model was acquired in the 1950s. Before even Sputnik was launched, I think before TV dinners were discovered.

[01:00:33.73] Because we are basing spectrum sharing in the 2020s and beyond upon data that were acquired closer to the time of Marconi, much closer to the time of Marconi, than today, and that model is in fact impacting how many CBSDs we can put out today and how many unlicensed devices in 6 gigahertz will be able to put out tomorrow. So we need investments in better propagation models.

[01:01:05.32] And then a little less specific but I think equally important, and somebody had mentioned it earlier, the dynamic access aspect of spectrum sharing. So right now, CBRS operates on a time frame every few minutes the device has to check in, and if one of the DOD systems come online, they need to shut down within 5 minutes. So that's relatively fast. In the automated frequency coordination world in 6 gigahertz, they have to check in every 24 hours, which is not very fast.

[01:01:37.19] But the reality is with 5G and 6G and beyond coming, we have the ability to adjust system parameters on the millisecond time scales. So I think one of the technologies it would be interesting to

develop is to be able to implement spectrum sharing on a much faster time scale so you can adjust interference per parameters on milliseconds or seconds like time scale. I think that's a longer development cycle, but I think it's a very important one.

[01:02:08.45] ARI FITZGERALD: Thank you. Any of the other panelists want to respond to Stacey's question?

[01:02:14.12] VERNITA HARRIS: So, Ari, I'm Vernita Harris. Hi, Stacey, that's a really good question. And it goes last year DOD, we released our 2020 electromagnetic spectrum superiority strategy. And as part of that strategy, we recognize that we need to look at how we are planning to pursue technology investment and partnerships are part of that, and understanding our capabilities is another big part of that.

[01:02:43.24] And so you will see that as we drive, as we start to implement our strategy, you will see us focus using spectrum as more strategic across the DOD, how are we using spectrum to meet all of our priorities and mission. So really good question and thank you.

[01:03:06.52] ARI FITZGERALD: At least exciting. There's a question here. There is an interest in hearing from the panel about your thoughts about receiver standards. FCC receiver standards. It was raised by Commissioner Simington, or the same question was posed to him. What's your thought about the viability or advisability of FCC imposed receiver standards? The questioner mentions that this issue has been debated for the last 20 years-- at least the last 20 years at the FCC.

[01:03:51.99] COLEMAN BAZELON: An offer prevention on this. I'm not the engineer, so this is not my domain as to what this should be. But these seem to fall under this category of a mixing of technical right standard and a political reality. And I think if you look at a lot of things, I think GPS might be one for the example but there's others, where there might be a technical standard, but regardless of what the technical standard is, there's a constituent that is going to get protected beyond what that standard tells you.

[01:04:32.70] And so the problem is that you don't know what you're using. I like Andy's point about clarity isn't about precision of rules. It's just about knowing the rules you're under it. It's OK to change them over time, but here's an example where the problem is the lack of clarity around these standards more than fine tuning the technical standards themselves.

[01:04:58.17] ARI FITZGERALD: If you made the receiver standards prospective, obviously you wouldn't be able to deal with the install base, that way, but at least you would be setting certain standards for future.

[01:05:15.87] COLEMAN BAZELON: I think the commissioner is off the call, so I can say this out loud. The problem is not getting the standard prospectively, the problem is the credibility about how it's going to be addressed when [AUDIO OUT]

[01:05:30.72] ARI FITZGERALD: It's a really good point. Anyone else address the receiver standard question?

[01:05:37.27] ANDREW CLEGG: Just real quick. Generally in favor of in an ideal world, receiver standards would be valuable. But my concern is that they first of all, they would increase the cost of equipment. If you have standards that make equipment perform better than the typical equipment right now it gives the manufacturers less flexibility to provide inexpensive devices in exchange for accepting less performance.

[01:06:11.81] The other problem is the spectrum changes, and it's going to change even more as we go on. So a standard adopted today or not adopted today might necessarily be the right standard or the right lack of standard for that particular receiver in that particular band in the future.

[01:06:33.40] Again, in an ideal world, telling manufacturers that every receiver has to employ brick wall filters, it's a little bit difficult to determine whether that would be worth the cost and ultimately whether the lack of adaptability and able to change, adapt to changing conditions is really built in there. So I don't know. Generally I'm in favor of it, but how it's implemented could be a very complicated mess.

[01:07:03.94] ARI FITZGERALD: Thank you, Andrew. Leonard, Vernita, any thoughts on the receiver standards question?

[01:07:11.96] VERNITA HARRIS: I'm not an engineer, so I'm going to take that question back to my space and get smart on that one. I'm sure they do.

[01:07:22.42] LEONARD CALI: Yeah, and I should take the question back too, but I think it's obvious we don't want old equipment that doesn't have the appropriate filters in it to prevent more efficient and effective use of the spectrum. But it becomes like everything else a very specific question.

[01:07:37.94] ARI FITZGERALD: Yeah.

[01:07:38.86] LEONARD CALI: Where do you hit that balance where? There's so little embedded base and be economically replaced versus gee there's a lot of equipment out there, it's been developed it's been invested in, it's spread wildly, and what do you do what that point?

[01:07:54.09] ARI FITZGERALD: There's a reliance on it all the points that Coleman made.

[01:07:56.80] LEONARD CALI: Yeah, and to Andrew's point, he said, technology keeps changing. And if you put a standard in place, does it very quickly become obsolete?

[01:08:08.74] ARI FITZGERALD: Thank you. There's a lot of questions about CBRS and the CBRS model. So someone asks how likely is it that we'll see the CBRS model adopted for other bands in the future? And Andrew, you want --

[01:08:29.56] ANDREW CLEGG: Yeah, real quick. I did a presentation for the [? TAC ?] a little while ago about the evolution of spectrum sharing. And if you look at the model adopted for TV white space and you look at the model of that adopted for CBRS and you look at the model adopted for 6 gigahertz HFC, they actually look remarkably alike.

[01:08:53.56] There hasn't been a whole lot of evolution in the structure of how the cloud-based spectrum sharing systems work, from TV white space starting 20 years ago to 6 gigahertz HFC that'll start next year sometime hopefully. So I think the answer to that is the CBRS model really has been adopted.

[01:09:18.75] Now, if you're talking specifically about three-tiered sharing, general authorized access and priority access and in the incumbent that remains to be seen. We think there's a lot of benefits to the three tier model, it makes sure that spectrum isn't warehoused and spectrum is always used, whether it's licensed to somebody or not. So that remains to be seen. That'll just be situation specific. But as far as the actual architecture of CBRS, that's basically the same as TV white space, CBRS, and 6 gigahertz HFC.

[01:09:57.12] ARI FITZGERALD: Thank you. Mark [? Lofte ?] [? Quist ?] asks the question, why don't we have more public private partnerships where DOD is merely a secured user on commercial networks. DOD assets connect to existing wireless networks the same way a DOD test facility uses an electric power grid used by private citizens and businesses.

[01:10:20.97] Can we make wireless infrastructure? Actual infrastructure? So, Vernita, I think this is a question that you may want to address, and if anyone else from the panel wants to take a stab at it, please feel free.

[01:10:37.68] VERNITA HARRIS: So this is a question that came up in our RFI on how we use spectrum and how we access and wireless infrastructure access. So this is something that we're looking at where we have not come to any conclusion, but we're continuing to study. And so we are also looking to partner with industry to look at how we are using spectrum and the infrastructures set to do that. So stay tuned.

[01:11:12.78] ARI FITZGERALD: Thank you. Anyone else want to address that question?

[01:11:21.02] COLEMAN BAZELON: The institutional aspect to it about, if you're buying a service, that's something that's a subject to appropriations and competing funds in a way that build your own infrastructure you now have it known it. It's cheaper to operate. So that institutional aspect of government use is going to influence the outcome of that, even if it's a good idea to lease.

[01:11:48.84] ARI FITZGERALD: Mohammed L. [? Magazzi ?] asks the question. Again, it's a CBRS-related question. How can the CBRS concept be exported to other countries, or has it been? He seems to think that at the moment, it seems to be quite US specific. Andrew, can you?

[01:12:10.37] ANDREW CLEGG: Yeah. It is US specific. Everybody's waiting to see how it works out here. Other countries have adopted a two-tier sharing model where the incumbent licensee shares with an underlay service. And typically, those arrangements have been worked out between the services almost like leasing spectrum not through an automated central thing such as we use in CBRS. So the answer is it really has not been exported to other countries yet, and I think everybody is taking a wait and see. I know Len himself is taking a wait and see approach.

[01:12:47.61] And I have to be honest, it is the first extensive shared spectrum deployment, and we'll have to wait 10 years to see how it all worked out. I think so far, it's working out quite well, but we'll just have to monitor over the times, and I think other countries are doing the same thing. I don't think is necessarily be 10 years for a country other than ours adopts it, but they are taking the, let's see how this works out in the US first.

[01:13:17.97] ARI FITZGERALD: Thank you, Andrew. I want to get through a couple more questions. We have a few minutes. Michael Honig asks, can you comment on the challenges and potential benefits of designing overlay rights that enable secondary use and allow bargaining between an incumbent and another service provider who wishes to share? I think we talked about this already during the panel. Coleman, do you have any thoughts about this?

[01:13:44.97] COLEMAN BAZELON: It is wonderful construct for dividing up a set of rights and then letting the rights holders optimize from there. Same comment about enforcement as to whether or not the rights work. They get to the [INAUDIBLE] end.

[01:14:06.91] ARI FITZGERALD: A lot of questions about suggesting that the government would be better off using more commercial networks, so I'll just ask this, Richard Bennett, wooden federal users who manage their own networks be better off as customers of commercial networks in most cases? Vernita, I think probably have a perspective on that and experience.

[01:14:42.52] VERNITA HARRIS: So just talk about it's we are experimenting with that. And so right now we have 5G we're experimenting, we have a large scale experiment at Hill Air Force base for 5G dynamically sharing for 5G, and so we're looking to see those results should be, I think, next year, and

it'll be an interesting conversation to have with our stakeholders and we will make sure to communicate that with folks. So stay tuned.

[01:15:14.86] LEONARD CALI: Sorry, I'm throwing a plug for commercial networks. Obviously commercial networks, you have the scale, you have the expertise, you have the ongoing investment in upgrading, you have the cybersecurity protection built in. You also have the added benefit of the government agency being able to leverage commercial innovation and commercial off the shelf devices that are being provided to hundreds of millions of people across the country.

[01:15:37.39] ARI FITZGERALD: Absolutely. Really good points. The last question I'm going to read is a pretty simple one but I'd love for all of you guys to think about answering this one. Victoria [? Samah ?] just basically asked the question, how does the race for spectrum space impact ordinary citizens? I don't know, you could spend a lot of time talking about that one, answering that question, but does anyone want to--

[01:16:08.88] LEONARD CALI: I'll throw in. The commercial wireless industry has gone from 1G to 2G to 3G to 4G, now 5G, and we're planning 6G. The rate that the spectrum is critical to that, look at how unlicensed use is in the US spectrum is critical to that, look at how the speeds and performance have grown and latency has been reduced on your network there's a lot of investment in technology going into that but spectrum is critical. So this is a critical experiment to the extent these devices have become part and parcel of our lives, both commercial as well as social spectrum's key.

[01:16:43.83] ARI FITZGERALD: I think that's a great way to wrap up this panel. I want to thank our panelists. This has been excellent. I've learned a lot. Thanks again, and I think if we can give that virtual round of applause, we should do that now. So thank you very much.

[01:17:02.40] ANDREW CLEGG: Thanks, Ari.

[01:17:03.54] LEONARD CALI: Thank you, Ari.

[01:17:04.83] VERNITA HARRIS: Thank you. Thank you, Ari.

[01:17:09.60] ARI FITZGERALD: Thank you.

Moderators' Wrap Up

https://www.youtube.com/watch?v=3VfvZXWPaC4&list=PLTAvIPZGMUXNWmcqlTXSrvUmWJ0RfSL9K&index=6

[00:00:00.00] KEITH GREMBAN: Ari and Nomi. And then we have a special guest with us for this panel, David Redl. So David Redl is a former assistant secretary of commerce for information and communications and former NTIA administrator. Again, you can find a full bio of David on the conference website page.

[00:00:18.45] So welcome to all the panelists, and thank you very much for participating in our conference. So I've got a set of questions that hopefully we can tie all these things together. So I'll have the first question I have to Scott and then let every one of the other panelists weigh in on it. So pretty easy to start off with. So Scott [INAUDIBLE] Scott, what would you consider the key takeaways from your panel? What should we walk away remembering from this?

[00:00:47.55] SCOTT PALO: So I have a quote from Peter that is, "Spectrum is not rocket science." So I guess that would be my first take away. But the follow up from that, we had a lot of discussion about sharing in terms of trust coordination and collaboration are critical to achieve the end goals.

[00:01:13.72] And I think David also pointed out an interesting thread that space service bands are already inherently shared with other services. And then even within the bands, within the space services across a range of operators who do their own self coordination so that some of those elements that are maybe less typical in the terrestrial environment have been part of the heritage of the space services.

[00:01:48.93] KEITH GREMBAN: OK, thank you. Nomi, how about from your panel? You're on mute.

[00:01:59.45] NOMI BERGMAN: Yeah, I think first we talked about what is spectrum sharing? And I think there was general consensus that it's an operation of independent systems that [INAUDIBLE] together that dynamic mechanisms would be required for harmful interference. We then next talked a little bit about real scarcity. And I guess I heard from our panelists that maybe there isn't such real scarcity, but yet they got a high value placed on spectrum and that often operators sometimes ask for spectrum, not just because they need it but they want to be careful that they still have it.

[00:02:41.37] But there was great optimism for spectrum sharing. We went through some of the historic efforts. Everybody thought that we're learning a lot from CBRS although it has been very complex. And I think that there was a lot of caution on our panel about well, we should definitely be looking at all kinds of technologies to embrace sharing. Let's try not to make it too complicated.

[00:03:09.54] There was also a lot of interest in some of the technologies to support spectrum sharing such as having better identifiers so that there could be better enforcement. Good discussions about trust, which I kept thinking about overnight as well. So anyhow, that's much more of it. Those were a few headlines.

[00:03:28.86] KEITH GREMBAN: Thank you. Ari, next.

[00:03:31.02] ARI FITZGERALD: Yeah, there was a little bit of overlap between my panel and Nomi's panel. A little overlap between all of the panels. My big takeaway-- my key takeaways were the gold standard still seems to be exclusive use spectrum where possible.

[00:03:53.46] But there was a realization by the panelists on my panel that there's not a whole lot of spectrum left that can be allocated in that way. And so sharing is going to happen. It's a reality

[00:04:10.53] There was a lot of discussion about making sure that the rules are set as clearly as possible. Ex-post enforcement when the rules are violated was viewed as very, very important. The trust point that Nomi mentioned was also stressed a lot on my panel. It was important for all stakeholders to trust each other and to understand each other's motivations, including the motivations of federal government users that are focused on mission and may not be able to quantify the benefits of their use of the spectrum in the same way that the commercial providers can.

[00:05:00.44] KEITH GREMBAN: Right. Thank you. And so David, since you weren't a moderator of a panel, can you take a step back and give us the high level view of this?

[00:05:08.01] DAVID REDL: Sure. So looking at the themes across all of these panels, I think there's three things that struck me as I looked at them. One was-- and this happens seemingly with every new issue in tech and telecom. We're talking about spectrum sharing and I think if you asked every one of the moderators to define spectrum sharing, you'd probably get a different definition.

[00:05:30.92] I think when we had a look at these panels, the panelists were all working from different operating definitions. And that is a function of you are where you sit. And that struck me as part of this-- that we don't have a common vocabulary for what we mean when we talk about.

[00:05:44.54] And to take the most striking example-- the commercial sector. [INAUDIBLE] looks at sharing. It says sharing means DOD, shrink your footprint as small as you can, and we'll get everything else. And you ask DOD. The DOD sharing means we change absolutely nothing, and you just find a way to work around everything we're already doing. And neither of those are what is an optimal outcome.

[00:06:04.11] And I think that leads to the second point that all of the moderators have brought up so far. And that's trust. And I think what you can see here and maybe what we danced around a little bit but I think we got to is the trust deficit. In these conversations, there is a trust deficit between the FCC and the NTIA at the moment.

[00:06:22.04] So you've got two spectrum regulators that can't trust each other for the time being. There is a trust deficit between government users who constantly hide behind the fact that they have national security as an excuse, whether it's true or not. And the [INAUDIBLE] who constantly hides behind, we pay for spectrum, as the reason why they should have it, neither are good answers unless you can justify why you need to be in that position. And I think until we get past that trust deficit you're not going to be able to solve this spectrum sharing problem that we see. And it's a problem because there's real opportunities that are being held back.

[00:06:56.51] And we heard a little bit of that throughout the different panels. The last thing I'd put out there is-- and this is one that I Silicon Flatirons has done a lot of work on. I've talked about it before at Silicon Flatirons is if we're going to look at spectrum sharing, we have to address the disparate economic interests when it comes to spectrum sharing.

[00:07:13.37] At the very end of the last panel, Len Cali brought up the economics of a commercial wireless system. You get to free ride on their investment. You get the scale benefits of being part of a handset economy that's a commercial off-the-shelf handset economy. And that's great, but that economic value is of limited utility to some government users.

[00:07:32.66] And frankly what they're trying to do may not be explainable in what we ordinarily think of as Wall Street economic terms. I think a 30,000 foot overview. That's really the things I saw. Common definitions need to be addressed, trust deficit needs to be addressed, and the economic incentives of each of the parties need to be addressed.

[00:07:52.91] KEITH GREMBAN: Great, thank you. So Nomi, I'll toss the next one out to you. You were the leader of the technology panel. So are there areas of-- do you leave this with hope or concern? Are you an optimist or a pessimist? Where--

[00:08:11.00] NOMI BERGMAN: I definitely am an optimist. And I think I go back to-- and then I want to come back to the trust point though. But I go back to Marty Cooper's comments that always emerging new technologies have more than kept up with our needs. And we heard so many of them throughout our panel. So I'm definitely an optimist.

[00:08:38.78] And just tying that into the points we just heard from my fellow panelists here that I do think that the technology investments that we can make to increase trust at this stage they may be more important than the technologies to increase efficiency, which I think in the past I might not have said, but I think it's becoming that important. If we can make progress in the technologies that increase trust, I think then we'll have more runway to develop better technologies to increase efficiency.

[00:09:11.60] So that would include things like technologies to improve identification, enforcement, and probably alongside some of the privacy and security. So I think those are-- if I were to give advice coming out of our panel, I think that's going to be really important.

[00:09:32.99] KEITH GREMBAN: Right, thank you. Any of the other panelists want to add on that?

[00:09:38.58] ARI FITZGERALD: I agree. I'm optimistic as well because I do think the technology is improving. And I do agree with Nomi that focusing a little bit more on technology that actually helps build trust among stakeholders as opposed-- both are important. Increasing efficiency is very important as well. But the trust is really important.

[00:10:05.87] And I think something that came up on my panel was there's a lot of discussion even today, I don't know how long it's been since the 5 gigahertz CFF issue surfaced, but people are still talking about it because it took a long time to resolve the issue when people were essentially just enabling the DFS functions or capabilities on devices that we're supposed to have those capabilities. When they did that, interference was caused.

[00:10:43.55] The victims were very concerned about it. It took a long time for them to resolve that interference issue. We've got to figure out a way to address enforcement. We've got to be able to-- as Len I think mentioned on my panel, we've got to figure out a better way to remediate these issues. If we are able to do that-- remediate more quickly-- that will go a long way to building the trust that we all know that we would have if spectrum sharing is going to become more extensive.

[00:11:20.02] SCOTT PALO: I'll make a general comment. We can choose to be optimists or we can choose to be pessimists. That's an active choice. And choosing optimism leans into building trust. Choosing optimism leads into trying to find partners and trying to work through the problems.

[00:11:41.49] When we lean toward pessimism, we become insular. We build those walls. And so I think if we're going to make progress in the area that-- I came across on all the panels is building trust and collaboration, I think we have to decide to be optimistic. And that will move us in those directions.

[00:12:06.45] Now, I'm sure everybody has battle scars. And I think you've got to figure out how to put some of those aside. Those who have been around longer have more. Those are the students here who are just getting into spectrum. They don't carry that baggage. And they tend to be inherently optimistic. And I think that's important.

[00:12:29.37] KEITH GREMBAN: Thank you. David, you looked like you were you're getting ready to say something there. Did you want to add to that?

[00:12:35.76] DAVID REDL: No, I chuckle as clearly the New York cynic on the group. Choosing to be optimistic is a choice, and I agree with Scott. It is. I think there is a bit of a first mover disadvantage that has played out time and again for being optimistic. And so it's a two way street. Both sides of these transactions or all the sides when it comes to real true dynamic sharing are going to have to go in with a rosy outlook and fresh expectations.

[00:13:08.64] The expectation of I just get to do what I want and nothing gets impacted, which seems to be where everybody starts in these conversations is going to have to get set aside. That playbook unfortunately has been run to exhaustion. And if we stick to that-- as Scott points out. If we don't choose to go down a different path, we're going to run up against that brick wall over and over and over again. And I'm hopeful that people go that direction.

[00:13:34.87] ARI FITZGERALD: Yeah, David makes a really good point. And basically, we should be optimistic, but we also should not be under any illusions that we're going to get everything that we want. Based on prior, everybody has scars here. Everyone has the scars to prove it, especially David. It's good to be optimistic, but we can't go in with rose colored glasses. We really have to know what we're getting into and recognize that these issues are very, very difficult. A lot of strong feelings on all sides and--

[00:14:17.90] DAVID REDL: No, Ari you're absolutely right. I mean, look I worked for health industry, I worked for Congress, I worked for the administration in my career. And so at this point I think everyone in spectrum policy has something they hate me for along the way, which is a unique position to be in any rate. Yeah, I think part of the challenge to this.

[00:14:37.58] And I think these kinds of conversations is that everybody has to drop the pretense and have a real conversation about what is in the art of the doable both technologically and economically. You can't expect the wireless industry to show up with billions and billions and billions of dollars to pay for spectrum that's unusable for them. And you can't expect the US government to make things that are physically impossible possible because we want to raise money by auctioning off spectrum.

[00:15:04.40] And I think the sooner we recognize that each side has a legitimate starting point from which we can all work, the better off we'll be. That's not where we are right now on spectrum policy. And frankly, the way things are going with everybody being locked down during a pandemic and not able to have face to face conversations, I think that's affirmatively harming us. It's not that I don't love doing these Zooms.

[00:15:29.78] I think we've all learned to embrace Zoom culture, but I've heard across from many of you at a negotiating table before or across a conference room table, and it is different. It's affirmatively different to sit across from someone and have a real honest person-to-person conversation than doing it sitting at your desk with 1,000 distractions around you. And I think as crazy as that sounds, I don't know that we'll be able to have those frank conversations until people are sure they're not sitting there watching the recording light blink on Zoom while they're talking to somebody else.

[00:16:05.86] NOMI BERGMAN: Great comments. If I could just also add, I really like what each of my fellow panelists are saying. I just want to go back to Scott's point. I thought you said that really beautifully, Scott, and I wanted to tie-in.

[00:16:20.47] There was a comment in the Q&A during my panel where John Chapin drew an analogy to what's being done today with roaming between mobile network operators that one could say that that is an existing example of sharing of local resources. And certainly, you can see that in roaming, trust is inherently there because there's a trusted commercial agreement and trusted implementation

of the agreement. And so I just think it's really nice proof that sharing can work well when there's trust in quite innovative ways.

[00:17:10.61] KEITH GREMBAN: So let me build on that. And you mentioned technology that could help us build trust. And then I want to go back to one of the comments that Andy Clegg made in Ari's panel about the-- I'll call it interference limits that came up from the time of Marconi I think he said. And I've got some experience with that where an entity will claim interference limits that just-- whoa! That what's the justification for that?

[00:17:41.98] And that would seem to me to be one of the areas where we need to build trust. That we want to be able to know that the other party is speaking fairly in dealing with the right kind of numbers. How do we establish an environment? Are there technological tools we should be developing? How do we establish this environment to ensure that we're not just arguing numbers with whoever yells the loudest?

[00:18:12.10] ARI FITZGERALD: I'll take a crack but I'm not an engineer. But I will tell you that it was very interesting what Andy said. He was basically complaining that a lot of times the protection criteria that's developed that the incumbent systems always cite when they oppose or express concern about a new entrant coming in is always based on worst case analysis. And he was suggesting that regulators move to a probabilistic analysis.

[00:18:52.72] Taking into consideration more what is likely to happen, I am a little-- maybe I'm an incrementalist. I've seen the FCC try to do that in various proceedings, but I am also a little skeptical that the regulators are never going to go where Andy wants them to go there because often in these FCC proceedings-- they last a long time-- the incumbents, they're formidable-- they've become very political and they are stakeholders often with significant political power.

[00:19:41.68] And the FCC I think just instinctively doesn't want to do anything that increases the potential for interference to any incumbent service. That said, the FCC has in recent years focused more on the probabilistic analysis, and they've pushed away some of those old ITU recommended protection criteria. They've distinguished them.

[00:20:14.29] I think that whatever happens is going to be incremental. Whatever progress is made to get the regulators to focus more on likely case as opposed to worst case in setting these protection criteria is the incremental. They're not going to be-- it's not going to be a significant change over a short period of time. But again, that's a lawyer's perspective.

[00:20:51.01] DAVID REDL: I'll jump in. There was a question in the Q&A also that PR put in for us that points out that there was a comment about receiver standards as a bit of a thread throughout the comments. And I think I can tie that in to what Ari was saying, which is politically-- and occurs both on Capitol Hill and at the agencies-- it does seem like sometimes there is a tendency to believe that some services have an absolute right to exist without changing. And that can't be the case.

[00:21:21.55] We can't allow any service to just go out there and assume that the RF environment around them will never change, and that they have an absolute right to exist. Receiver's standards is a bit of a third rail for a lot of people who talk about this. And I'm not the first one to bring this up, but I feel like this is a good point to pivot to and say, but that doesn't mean you don't set ideas about receiver performance as part of the conversation.

[00:21:50.35] And you set expectations-- and by the way this goes towards our trust deficit point. Is that you need to set expectations that this is what the RF environment will look like. You need to build your device to assume you will be receiving this level of emissions from out of band. If you choose not

to, we're not going to force you to build your receivers the way you want. But buyer beware, caveat emptor. If you build a cheap device and you get an interference, it's a whole big mess and not the FCC's problem. They're going to tell you to go fix it yourself.

[00:22:20.09] And I think that's the issue we have to get to-- is that right now it's a first in time, first in right situation. Once you put yourself out in the band and occupied that band and God forbid there are any omissions in whether they're your fault or not, you feel like you're owed a remedy. I think we have to set some kind of expectations.

[00:22:38.90] And once we set those expectations and both sides understand what they're getting into, you can establish that level of trust. I trust you will build a device that isn't so cheap that me operating within my parameters in my adjacent band is going to interfere with you and cause me to go to the FCC and answer questions. I think that would go a long way towards both what Ari is talking about and towards the trust deficit that we've all been talking about.

[00:23:04.80] SCOTT PALO: So I wanted to follow up on what David was saying. And maybe this also connects back to some of the economics as well. And I think when we think about spectrum in some of these use cases, the scientific use cases and interesting and from my perspective somewhat different beast trying to operate significantly below the noise floor or operating investments and very expensive equipment. They're trying to push the state of the art and it's hard to articulate a economic case a lot of times with the scientific use case.

[00:23:43.17] And so I guess I'm posing a question with regards to sharing. We talked a lot about whether federal users and the commercial users but in some sense scientific-- those are also the federal users. What's the thoughts there with regards to sharing and standards and managing systems that are operating near the thermal limit?

[00:24:12.19] NOMI BERGMAN: Interesting. Keith, I'll jump in. I think I'll just jump in and just share some technologies that I think are going to be important to cultivating this trust. And actually, I've learned a lot of-- some of this maybe I had learned before, but some of this I've more acutely learned in preparation for the panel.

[00:24:31.48] I learned about work that NTIA got Seismic to do to see if they could use NTIA's and the FCC's equipment authorization rules. If they could be modified to require that all transmitters used unique identifiers. And I think that identifier is going to be-- I know I just mentioned it a little bit earlier, but just to say a little bit more about it. I think it's going to be really important because there's an assumption out there that everybody will play nice with usage of spectrum.

[00:25:03.43] But people and companies cheat, and this requires enforcement and requires incentives so we have a way to prosecute bad actors. And I think these identifiers are going to be important. And we have a history of doing this on radio and I guess you have ham radio also where there's unique identifiers where you use small amounts of bandwidth. And I think that this concept-- Dale was telling us a little bit about some work he's written on RF fingerprinting.

[00:25:37.39] I think it's going to be really important as an important way to create trust. And another thing I learned in preparing for the panel and I want to give credit again to John Chapman for work he's doing. I don't want to steal his thunder but a concept he's putting together called Spectrum science which involves everything from the monitoring techniques, again, where you would need the ID to identification to management techniques.

[00:26:06.85] Ways that you could perhaps dynamically control interference behavior. And then ways that you could also enable information sharing as well. So I do think all of this is going to be very

important to finding new ways to share hopefully, in a more complex dynamic way than the more static methods of sharing that we have today.

[00:26:39.45] DAVID REDL: So if I can chime in on that. Nomi, I don't disagree with you in terms of fixed transmitters. I think in somewhere, Amie Stepanovich is smiling that I'm bringing this up. I think with respect to individual commercial mobile transmitters. I think you'd have a serious privacy concern with individualities. And as it is, energy skimmers are enough of a privacy nightmare. And those are heavily controlled and regulated. So I don't disagree with you, I just throw that out as a cautionary tale.

[00:27:04.04] NOMI BERGMAN: You're so right. You're so right. Thank you, David. I did neglect to say that. Please, please go on, yeah.

[00:27:08.78] DAVID REDL: But to Scott's point, I hear you. And I think if we're going to be looking at how to ensure any of these uses for which you have haven't-- as I said earlier, a non Wall Street typical economic case. Certainly, scientific research falls into the bucket of non Wall Street typical when we're looking at spectrum use.

[00:27:28.37] I think the leadership of how we're going to look at that is going to have to come from government. Whether it's the executive branch or the legislative branch, there's going to have to be someone who affirmatively says, it is more important to society that we do x with respect to this band and this scientific research in this location or these locations than it is to put more spectrum in the commercial marketplace.

[00:27:52.76] And I don't know what those would look like, where those options would be, but I think it's something that if we're going to do it, it's going to have to be led by the government. It's not something the market's going to work out on its own because it's not a typical economic use case. So I just throw out there that if it's going to happen, I feel like it's got to come out of the .gov set.

[00:28:13.84] KEITH GREMBAN: You're smiling at that. Any comments to follow that up?

[00:28:18.85] ARI FITZGERALD: I agree with what David said about passive services and the scientific community and their use of the radio spectrum. Certainly, policymakers have to decide what is a public good? What they deem to be socially valuable regardless of what the economic-- what the economic value might be or what the perceived economic value might be. But that's what policymakers do. That's why we pay them the big bucks, right?

[00:29:00.01] DAVID REDL: Keith, were we making big bucks when we were [INAUDIBLE] I don't remember that.

[00:29:03.34] KEITH GREMBAN: I was just thinking about that.

[00:29:06.61] ARI FITZGERALD: That was a joke.

[00:29:11.35] KEITH GREMBAN: Anybody else want to pick that up or? So, I'm taking notes as we've been talking. And early on, Nomi mentioned technology for trust. And I can think a number of technologies that were brought up over the course of the conversation. One was Andy Clegg advocating for better propagation models. Nomi brought up transmitter IDs. We could talk about automated enforcement mechanisms.

[00:29:44.36] So what other technologies are needed? And if you were the investor or the government deciding where to invest the money to push spectrum sharing forward, how would you prioritize these? Where would we start? Is the propagation models the most important thing or?

[00:30:06.29] DAVID REDL: I'm not sure it starts with the government. And I'm going to sound like I'm beating a dead horse here, but I'm going to come back to the trust question. I think it's got to start by some sort of consensus about a way to move forward that respects all the players in the game. And that can't be handed out from the United States government.

[00:30:26.28] It's going to have to be to use an overused term at this point-- a public private partnership. Not in the traditional sense. It's going to have to be a meeting of the minds between commercial users, unlicensed users, government users, scientific passive service users. All of these people are going to have to agree, yes, this has promise for us, and we're not being cut out.

[00:30:48.77] I think to date, that's part of the challenge that we've seen with all of the paths we've taken forward. Is that somebody feels like they're in the short end of the stick and that they were told this is the solution and get on board. I just think until we have everybody at the table-- and frankly, the closest we've come to having everybody at the table to play the game is when we had the PCAST during the Obama administration. I think that was the closest we came to having enough people at the table to have a general consensus on trying to drive some technology forward in spectrum sharing.

[00:31:20.27] Now, look, we could spend another complete hour arguing about the failings of the PCAST model. And I know Ari and I have spent several hours arguing the failings of the PCAST model in the past. I think that's the closest we've come.

[00:31:32.85] And it does show that you can get people at the table to make compromises. You need a bigger group than that or at least a more representative group. But I think that's how you're going to have to do it going forward. So to the extent that the government has a role at all, I would say it's their convening authority. It's getting people at the table to have candid conversations.

[00:31:52.48] KEITH GREMBAN: OK. Ari, you've spent hours arguing with him. Do you want to argue right now?

[00:31:56.05] ARI FITZGERALD: No, I agree with what he's saying. I'm trying to figure out a way to disagree, but I'm agreeing with everything he's saying. I will say that just the debate about what propagation model to use.

[00:32:10.39] Again, I don't want to bore people. I've spent too much time at the FCC in these proceedings on both sides. Sometimes representing potential new entrants. Sometimes representing incumbents. And getting everyone to agree on what the write propagation model should be will end up being very difficult.

[00:32:37.15] I'm almost convinced to take the approach that Coleman was suggesting, which was to whatever-- no matter how messy the process was or unfair the process was in setting whatever the applicable protection criteria is, set that criteria and then give the parties the ability to contract around that criteria.

[00:33:07.39] It doesn't help often new entrants-- if the FCC sets the standard for protecting incumbents that are just too difficult, it's going to make it very difficult for new entrants to actually put together a viable business. We've seen that a lot. We've seen how new entrants have spent years and years at the FCC getting approval for some new service to be introduced into a frequency band but only fail at the end of that process. Failing from a business perspective because the rules were viewed as too stringent.

[00:33:53.02] But once there are rules, parties can contract around them. And we've seen that framework actually work as well. So I'll just throw it out there. I guess I'm-- again, I apologize for being

an incrementalist here. I do think that we're never going to have agreement on what the right propagation model is or what the correct-- whether the FCC should be focused on probabilistic analysis or worst-case analysis in determining potential for interference.

[00:34:35.08] It's going to take-- that's going to be very difficult. It's going to be very difficult to get everyone to agree on those types of concepts. But I think in some ways that's more important to just set the standard and then give parties the ability to contract around them, whatever they are.

[00:34:58.27] KEITH GREMBAN: Thank you. Nomi, Scott, any thoughts on that?

[00:35:04.57] SCOTT PALO: I think it was well said by Ari. No additional comments.

[00:35:12.20] NOMI BERGMAN: I agree as well. I do think that these efforts-- and I like what David said about probably the importance of public private partnerships and also of engineering organizations and standards organizations in establishing the role of these new elements. I see in the questions we've gotten-- there was a comment from John Rowe about giving standard organizations a greater role. I think that's very interesting.

[00:35:40.60] And [? Paytre ?] is also asking about identifiers and fingerprinting. And I think his comment is-- I know he's asking a question about how to get this over regulatory bodies internationally. But I do think that's all the more reason why this needs to be debated in engineering organizations to determine how we will have to do it internationally. I completely agree with the premise there.

[00:36:14.35] KEITH GREMBAN: OK, well, we've got about just under 10 minutes left. I guess I'd like to ask for closing thoughts on this. Where do we go? Let's start back at the beginning with Scott.

[00:36:33.09] SCOTT PALO: I guess, again, I'll circle back to being an optimist. And I think it's continuing conversations, such as these. One of the comments we had discussed in our panel was a couple of things. One was we have to make spectrum understandable to the non-expert to have broader engagement.

[00:37:00.52] And then we also have to-- it's important to engage a multidisciplinary wide group of stakeholders to be looking at problems. To be bringing the perspectives that are unique for each one of the stakeholders to the issues. So I think it's hard work. Takes conversations and efforts to gather, discuss, collaborate, and events like this conference help to move that forward.

[00:37:39.99] KEITH GREMBAN: Thank you. Nomi?

[00:37:41.94] NOMI BERGMAN: Hey, I also agree with Scott. I remain an optimist. I think there are so many really exciting technologies that offer so much promise for inter-service sharing. And I think we learned in our panels about the many wonderful historic efforts that are happening, such as Jonathan shared updates about the there ITS experiments that they're running.

[00:38:11.28] I think the CBRS effort has given us an incredible opportunity to have a really large real-world experiment in spectrum sharing from which we're learning so much. So we can see this is worth it. And I think we just need to continue having these discussions. And yeah, I think this is very good and a great conference. Thank you for putting it together, Keith.

[00:38:37.65] KEITH GREMBAN: Thank you

[00:38:38.52] ARI FITZGERALD: I agree, Keith. This has been a great conference. I've really learned a lot. One thing I'd like to see-- and I think we probably will see something like this during the Biden

administration-- is this exploration of sharing by design or identification of a spectrum band where sharing is viewed as being more feasible than other designation of a couple of bands for sharing.

[00:39:16.83] And I think it would be a great green-- one of these great experiments-- greenfield experiment. A place where there are incumbent operations but where we think that it doesn't make a whole lot of sense to try to reallocate the spectrum because of the incumbent uses and because of the difficulty of moving incumbents off that spectrum. I think if we can identify a couple of bands, and I know that people like John Leibowitz has already suggested a couple of bands.

[00:39:56.65] If we can identify spectrum bands like that, I think it would be well worth the effort to try to promote spectrum sharing in those bands. And I didn't get a chance to ask my panel the question that I wanted to ask them about that. But it's definitely something that I'd like to see.

[00:40:20.17] DAVID REDL: Well, Ari from your lips to the Energy and Commerce committee's ears because not 14 hours ago they put out text that would make 31 to 345 available for opportunistic peeps until such time they decide to put licenses in there.

[00:40:32.67] ARI FITZGERALD: Well, that's great. And they did it because I was thinking about it, right?

[00:40:37.44] DAVID REDL: The telepathy length you have with the staff, yes. I'm sure.

[00:40:42.72] KEITH GREMBAN: OK, David. I'm looking to you to back [? Clayton ?] up there.

[00:40:48.39] DAVID REDL: Yeah, no. I thank you, by the way, for having me on this panel. I realized I was not a moderator on any of the earlier panels. So in some ways, I am Waldorf and Statler from the Muppet Show coming in from the balcony with snarky remarks. But look, I think this was a really good panel and a really good wrap up to what was a very productive spectrum conference. Thanks Silicon Flatirons for that as usual.

[00:41:12.51] I think we have a pretty decent consensus among the group that there is a path forward. It's just going to be real hard. And until we have-- as Scott put it-- a decision to be optimistic by all of the parties that would be involved, we're a little bit at a standstill. And once we get there, I think we've got the technology.

[00:41:32.11] And if we had people to have the drive to do it, we really could move forward, at least along the lines Ari is talking about with finding some bands to try this out and see if it's worth doing on a larger scale or if it's a spot market kind of thing where we can't find a broad set of spectrum bands or spectrum opportunities where this makes sense. But we'll never know unless people take Scott's approach and say, OK, I'm willing to set aside my pessimism and my preconceived notions of what I'm going to get out of this band, and I'm going to go forward and say, how can we look to the future on this one.

[00:42:10.43] KEITH GREMBAN: Great. Thank you. Thank you all. I think we've got to wrap it up and move to the questions now. Again, citing the Phil Weiser rule, we've actually got two students lined up this time with questions. So I guess you've generated a lot of interesting thoughts here. First student is Kaden Dailey.

[00:42:43.08] KADEN DAILEY: So, thank you, everybody, for all the information. This has been really interesting. I don't have much of a tech background, but I want to definitely get involved. I've got a little bit of an economics background. So hopefully, that can be a little bit useful.

[00:43:00.75] But my question is centered around what the role of transactional law and contracts would play in spectrum sharing. So is there a significant role for it? I got it right here. Or are the constraints and limitations that have been placed on it, do they make the opportunity costs for getting actual transactional law involved too high? If that makes sense at all.

[00:43:40.07] ARI FITZGERALD: I think it's a great question. And I do think there's a role for contract law. Again, this happens all the time within the communications industry. The standards get set by the government. But that doesn't mean that private parties can't themselves negotiate around the standards.

[00:43:58.79] And if everyone agrees if in the bilateral negotiation-- in the example of spectrum sharing, if the party that has the spectrum agrees that it's OK for a party that wants to share the spectrum to share the spectrum, it doesn't matter what the rules are. They can work around the rules. But it's very important to set the rules.

[00:44:36.64] Those are standards that the government sets. But if the parties agree that they can deviate from those standards without any one party raising any issues with the government, then they can do that. And in those situations, contract law is very important. Negotiating those contracts, those agreements-- those voluntary agreements-- becomes very important.

[00:45:07.70] DAVID REDL: I think one thing you brought up that I think is worth noting is the one line you're using that was bilateral. I think this only makes sense when you're talking about a bilateral relationship. And if you want to see where this plays out-- obviously, if we're looking at a opportunistic environment, you can't know who the parties are, right? All the parties is anybody who has the right equipment and is willing to play by the rules. So there is no way to really negotiate a contractual change to that.

[00:45:34.01] But if you want to see how it plays out with fewer parties than that, look what's currently happening between the United States government, T-Mobile, and DISH with respect to shutting off their CDMA network. That bottom, that is a question of contract and antitrust law, and it's playing out very publicly in a way that is making it difficult to move the ball forward if you're at T-Mobile because they want to shut down an older technology and they're having a challenge doing so because of existing contractual arrangements.

[00:46:01.79] So I would urge some caution. I'm not sure it's the magic bullet we would all like it to be when it comes to trying to find ways to make spectrum sharing easier, but you're absolutely right. Obviously, in the CMRS world where you have all these bilateral relationships it makes great sense.

[00:46:21.61] NOMI BERGMAN: I love the question. And I love that my fellow panelist who's an attorney answered it first since it's about contract law. I love that. I guess I would just also point back to-- I know I commented earlier about roaming as an example of where there is existing proof for sharing local system resources.

[00:46:38.88] And that certainly fits right into Ari's answer where two or more commercial operators found a way through their own agreement and through contractual agreement to find a way to share spectrum. And then certainly, the first [? AT&T ?] example is another example of the same thing. So I think we have really nice precedent for hopefully continuing to do just what you're suggesting with your good question.

[00:47:09.38] SPEAKER 6: Great, thank you very much.

[00:47:15.54] KEITH GREMBAN: Thank you. And our next student question is from Taylor Hartley. Taylor, if you'd come up here.

[00:47:35.90] TAYLOR HARTLEY: All right. Hello, again. Taylor Hartley, I'm a master business student graduating in May. So this has been a really fun two days. I've learned a lot. I think my biggest takeaway was just how important it is to use the spectrum efficiently. And why I thought DSS or Dynamic Spectrum Sharing. I think that's super cool.

[00:47:59.41] And I know this has been mostly conversations between science and policy. And I know that things like government incentives and policies are really going to help drive using the spectrum efficiently. So where do I come into play as a young business woman who's interested in this space, who's passionate about it?

[00:48:20.99] What can I do internally within businesses to promote this? To use it efficiently. And how do I help everyone build trust within this area? What can I do?

[00:48:39.27] SCOTT PALO: I think a lot of the trust is built on personal relationships and networks. So what you can do as you understand your organization's goals, is understand how they interact with other organizations How do they cross where the conflicts, and how can you have really frank and open conversations to the extent you can share information and build relationships?

[00:49:09.96] And your colleagues-- you will move through different organizations as David pointed out. He's sat on opposite sides of a three-sided table there. So I think that as you go through your career, it's that network and those relationships that will enable you to be effective going forward.

[00:49:37.28] DAVID REDL: Yeah I can't improve on what Scott said. It is very much an interpersonal game. The spectrum worldwide may be growing as more and more people get interested in it. It's a fairly small community as technological community element. And I think absolutely when it comes to what you can do to help, it's show up with an open mind. Based on what we were talking about before. And build relationships with the right incentives in mind.

[00:50:16.31] KEITH GREMBAN: OK.

[00:50:16.61] TAYLOR HARTLEY: Good. Thank you.

[00:50:24.19] KEITH GREMBAN: OK. Thank you. So we've got a couple of questions online. We've got some themes here that have gone across the panels. So I'll read one from Peter Burrell-- when it comes to not policing transmitter receiver quality, is there a carrots and stick approach the FCC implement? This could be along the lines of if a threshold that they could have no guard band on the radio but if it doesn't they need to eat into their lease for a guard band. Anyone who wants to attack that?

[00:51:00.83] DAVID REDL: So I'll jump in. There's no one-size-fits-all approach. And I'll channel my inner Dale Hatfield for this one. No one has worked harder on adjacent band interference and receivers than Dale Hatfield in his career.

[00:51:14.93] The reality is there will be different approaches depending on who the two adjacencies are. Two adjacent CMRS providers as I already pointed out, have every incentive to strike a contractual agreement to make sure that they're in a good spot and that they're maximizing the use of the band. They've paid a lot of money for it.

[00:51:33.27] On the other hand, putting a CMRS provider next to a scientific band produces the kind of situation where you'd have a very hard time coming up with a carrot and stick approach that could work similar to the CMRS model. You've got high power versus low power. You've got money

generating versus non-money generating ostensibly. And I think if you're going to look at this from an SEC perspective, it's going to have to take each new allocation at face value and say, how are we going to do this? Because there is no such thing as a standard interface between two adjacent spectrum bands. So I agree carrots and sticks are great and mixtures of the two, but it's going to be individual tackling of each new situation.

[00:52:25.18] ARI FITZGERALD: I think David said it well. I know about situations where the SEC has actually expressed the expectation that the incumbent was going to have to take certain steps to protect itself from emissions from a new entrant, making its operations more robust with filtering or taking other measures. And I think we will likely see more actions like that from the SEC and other regulators as the demand for spectrum increases.

[00:53:10.74] But the burdens that are imposed on the incumbent vary from band to band. David said based on whatever the conditions that exist in that particular frequency band. And I don't I don't see that changing much in the near future.

[00:53:33.47] DAVID REDL: That being said, I like where your head is at. I think there are going to be times when you have to look to internalize guard bands. I think there are going to be times where you have to look to say we're going to put some performance requirements out there for your receivers. I think there are times when you're going to have to be more granular with emissions limits. All of those are potential options.

[00:53:59.50] And frankly, when you're looking at auction spectrum, looking at whether or not you build that into the auction revenue base. That some areas will be standard part 27 rules for the non FCC geeks, the standard power levels that we see for almost all of the frequencies that are used in your cell phones, or if there will be more of a variable to it based on a more dynamic spectrum environment than we have typically auctioned off. I think those are all viable options, but absent a unique use case to put them on, it's hard to know which one is the right answer.

[00:54:41.12] KEITH GREMBAN: Anyone else want to weigh in or? OK we've got another question again from an anonymous attendee which is-- any thoughts on the need for precise positioning in the context of using detailed propagation models?

[00:55:05.27] DAVID REDL: I know when to let engineers answer the question.

[00:55:11.18] SCOTT PALO: I was going to say, Keith-- I was going to defer to you. You have more expertise than I do on propagation.

[00:55:18.81] KEITH GREMBAN: Yeah, my thoughts are that precise positioning is very important. Knowing your propagation model for very precise propagation is going to depend very much on your position. If you're in an urban setting and your position accuracy doesn't tell you whether you're behind a tree or behind a building versus in the middle of the street on a direct line with the transmitter, you're going to get a completely different set of answers.

[00:55:50.85] So the positioning is very important. And it will become more important as we get into higher frequencies, which have smaller propagation distances. And hence you're going to have to have much more accurate positioning and propagation analysis. Anyone else want to jump in on that?

[00:56:10.73] NOMI BERGMAN: Well, I certainly agree and especially-- I agree with your point and especially as cell sizes become smaller and smaller and smaller. I don't know that much else to answer on it, but I definitely, certainly agree with that point.

[00:56:24.32] DAVID REDL: I would add that while propagation models are great for a priori decision making, once you've got things in the field and as we're seeing play out now as the FCC looks at its most recent iteration of mapping, there is also a role for ignoring propagation models and doing real-world testing and finding out what the ground truth is. So I think it's worth-- we're throwing that out there, that while we agonize a lot over ex-ante propagation modeling, we should be as concerned with ex-post testing.

[00:56:55.91] KEITH GREMBAN: I couldn't agree more with you on that, David. Measurement campaign is critical moving forward as well. Let's see. I think we've answered all the questions that we've got at this point.

[00:57:12.20] So thank you very much everybody. This has been a great, great conference. Thank you to the moderators and David Redl. Very interesting conversation. I enjoyed it. I even got to answer a few questions myself. Thank you.

[00:57:32.39] So with that, the formal part of our conference is over. I'd like to go into a few announcements before we close.