Recording available at:
https://www.youtube.com/playlist?list=PLTAvIPZGMUXNVhIOoXZBAF49k505QGno4

[00:00:10]
Amie Stepanovich: Silicon Flatirons is a research center at Colorado Law School. We work with students to give them the tools they need to pursue careers in tech, law, policy, and entrepreneurship.

[00:00:23]
Phil Weiser: When I started, Silicon Flatirons was an experiment. It was me and some students putting on a few conferences without really a plan where it was going to go. My initial motivation was because I didn't believe you could have impactful policy discussions unless you brought people together across different disciplines. Silicon Flatirons Center has given me an image of what a team can look like.

[00:00:44]
Margot Kaminski: And it really made Boulder into a location that was seen as on par with DC or Silicon Valley and other places around the country that are leading thought centers in the field of law and tech.

[00:00:58]
Dale Hatfield: What's excited me the most is to see it grow, but not only just grow in terms of the number of people attending our different events, but growing in terms of the different areas that we have been involved in.

[00:01:13]
Blake Reid: When a law student says, "I've got a passion for understanding the intersection of technology and law but where do I get started with that?" What Flatirons provides is vision to actually go angle for a job during their second summer where they're actually going to get to be involved directly in setting tech policy or in advocating around tech policy.

[00:01:33]
Amie Stepanovich: The Silicon Flatirons community is incredibly unique in how close it is and how people are willing to band together to move conversations forward.

[00:01:44]
Margot Kaminski: It's one thing to be sitting in a room by yourself reading articles and it's very much another thing to actually be sitting at a table talking to somebody about their daily experiences of trying to navigate compliance with the complexity of law.

[00:01:55]
Harry Surden: We're all a community of friends who enjoy spending time with another.

[00:02:01]
Delaney Keating: The people we engage with through here are very much thinkers and thought leaders so they're contributing too, whether it's our strategy or our resources, in really meaningful ways.

[00:02:11]
Brad Bernthal: Silicon Flatirons has changed the dynamic between Colorado law and the surrounding community as well as the national community.

[00:02:20]
Margot Kaminski: One of the great joys of my profession is talking to people who are really early in their careers and helping them get excited about what you're excited about.

[00:02:28]
Brad Bernthal: We get the types of people in the room that everyone thinks should be talking to one another but often are not.

[00:02:35]
Blake Reid: I get to work with students, I get to work with attorneys, I get to work with policy makers, at the intersection of all these issues.

[00:02:41]
Kristelin Garcia: Students are first and foremost so everything is generally student-driven.

[00:02:47]
Sara Schnittgrund: And it is centered around people who are wanting to engage with students.

[00:02:52]
Harry Surden: I've seen students come into Silicon Flatirons just having a little interest in it in year one, and by year three they're passionate about it and they've found their career.

[00:03:03]
Sara Schnittgrund: And I think that that really helps the standing of the university more broadly and it also attracts lots of really interesting and talented speakers.

[00:03:12]
Margot Kaminski: I think what I'm excited to see happen with Silicon Flatirons in the next 5, 10, even 20 years, is for it to blend continuity with change.

[00:03:23]

Amie Stepanovich: It's not enough to have smaller conversations anymore. The world is all connected and Silicon Flatirons is going to reflect that global nature of the Internet as we move forward into 20 years in the future.

[00:03:38]
Phil Weiser: I hope it continues to operate with the same spirit of experimentation, of adventure, of seeking out new challenges, that we've done over the first 20 years.

[00:04:11]
Keith Gremban: So, we were going to have a little bit of time for some housekeeping notes but we're experiencing our first technical difficulties today, but we'll go ahead and get started even though it's a tad bit early. So, hello everyone. Oop, Vanessa's up.

[00:04:33]
Vanessa Copple: Hi, everyone. Zoom did a little trick on me but I'm here. My name's Vanessa, I'm the senior events manager for Silicon Flatirons, I have a couple housekeeping notes for you all. Thank you so much for joining us online, I miss seeing you in person but we're so glad we could have you here. This is the Zoom webinar format, and in case you're unfamiliar, if you're in the audience we cannot see or hear you so don't worry about it.

There's a Q&A option available, you are encouraged to upvote any questions that are very important to you, which means you can click on the thumbs-up and it will move its way to the top if there are more votes for that, I know there's been a lot of really great questions so far.

For those of you seeking CLE credit, I will send a survey out by end of day today that will also have the affidavit link attached and CLE materials are available from the event web page, the event map, and if you don't need any CLE and don't know what that is, don't worry about it.

We will be having an Airmeet social lounge after our last panel concludes to encourage socializing. It's a lot of fun, it was very worthwhile on our first day and I hope to see you there. And with that, I'll hand things back over to Keith.

[00:05:51]
Keith Gremban: Okay, thank you Vanessa, and hello everyone and welcome to day two of our Silicon Flatirons conference on Evidence-Based Spectrum Policy. We're delighted to have you all here today and I think today is going to be another great program and I'm looking forward to some great talks and some great discussions. We had some interesting speeches and discussions on Tuesday. I'd like to call attention in particular to Dale Hatfield's speech which generated quite a lot of interest and

we've had several requests for a transcript. So, both Thyaga's keynote slides and Dale's script have been posted to the event page.

Before I go any further, I want to begin by acknowledging that wherever we are, we are meeting on the lands of First Nations peoples. The traditional peoples of the land in Boulder are the Cheyenne, Arapaho, and Ute Nations, and I'd like to pay particular respects to the elders past, present, and emerging who lead these communities. Thank you.

The format today is much the same as Tuesday. We'll have a keynote address, panel discussions after that to explore the issues concerning evidence and spectrum policy, Q&A following each panel, and then as was stated earlier, a virtual breakout room at the end of each day. And we're trying to capture the hallway experience that you get from a face-to-face conference by setting up virtual environments using the Airmeet collaboration tool to give attendees the opportunity to interact with panelists, the speakers, and the moderators.

A couple of reminders to the moderators and panelists. First, Silicon Flatirons follows the Wiser [Phonetic 00:07:26] rule in which students get the first question. I also need to remind everybody of the No Acronym rule. Remember that audience and panelists may be from different domains, please define all acronyms on first use. In any Airmeet, a table is set up for each moderator, panelist, and keynote speaker at the end of the day. It may take a minute or two to get started, but once you're in, you should move to your table and take a seat because you aren't automatically placed at your table, you actually have to take the effort and take a seat. And with that, let me hand off to Rachel Anderson to introduce our keynote speaker for today. Rachel?

[00:08:06]
Rachel Anderson: Thanks so much, Keith. Our keynote this morning is from Eric Burger who currently serves as the Assistant Director of the Office of Science and Technology Policy at the White House. He was previously the Chief Technology Officer at the Federal Communications Commission from 2017 to 2019. Dr. Burger, take it away.

[00:08:26]
Dr. Eric Burger: Rachel, thank you so much for an awesome, succinct introduction. First, I wanted to thank the University of Colorado Boulder and the Silicon Flatirons for inviting me to speak today. I've always enjoyed the panels at Silicon Flatirons, both participating and especially the audience interaction. I'm disappointed we cannot be meeting in person but I hope that next year we can gather in person. As Keith noted, it is hard to follow Dale's keynote. Many of you in the virtual audience including me owe a lot to Dale for his mentorship, advice, and more especially, his sense of humor. Also I don't have Thyaga's cool background, as in visual

background. Actually, I don't have his technical background either. With that, let me jump in.

The Administration identified 5G to be a critical component of the industry for the future. The industries of the future, besides 5G and advanced communications, include AI (artificial intelligence), quantum information sciences, biotechnology, and advanced manufacturing. These all require vast amounts of data and interconnection with many, many more wireless devices than legacy wireless networks can support. American leadership in 5G is critical for economic growth and national security.

With that in mind, the President and his Administration have taken decisive actions to advance American leadership in 5G. We are accomplishing this on multiple fronts — freeing up mid-band spectrum, cutting taxes and removing regulatory hurdles in order to boost investment and accelerate deployments, securing America's communications networks from foreign adversaries, and preventing the spread of untrusted network equipment around the world, just to name a few.

Some of the readings for this conference, as well as some of the discussion on Tuesday, debated evidence-based policy making versus policy-based evidence making. I am not going to go there, however I will focus on how a specific policy goal tied to evidence, namely technology, physics, economics, and operations research science, resulted in the unprecedented freeing of 100 MHz of prime 5G mid-band spectrum from federal to commercial use, all while ensuring America's military readiness. This was the AMBIT process, AMBIT stands for America's Mid-Band Initiative Team. The keyword for this effort is "Team."

This was an example of the federal government at its best. There was fantastic cooperation across departments and agencies, leading to unprecedented results for the American people as well as the Department of Defense. This was the fastest time from identification of spectrum to making it available for commercial use. It's the fastest transition plan development and the fastest time to auction, limited only by the Commercial Spectrum Enhancement Act, or CSEA.

So, first let's look at how spectrum was made available in the past. One hugely successful auction was the Advanced Wireless Services-3 Auction, or for the FCC wonks in the audience, Auction 97. That auction raised just shy of $50 billion, that's billion, in winning bids. From a financial perspective, it was a winner. The National Telecommunications and Information Agency identified the spectrum at the end of 2010 and DoD was by far the largest user in the AWS-3 band. Just four years later, the FCC started the auction. Four years between identification and auction is not too bad, however according to NTIA's latest report to Congress, federal agencies are still clearing assets out of the band almost six years after the auction closed.

What could we do better? Well, let's take a look at the Citizens Broadband Radio Service, or CBRS. NTIA identified the CBRS band to have potential for private sector use. NTIA, the Federal Communication Commission or FCC, and DoD or Department of Defense, negotiated a scheme where DoD would continue to use the band. DoD would share the band with private sector priority licensees when DoD was not using the band, and then unlicensed users could use the band when no one else is using it. This coordination happens through a spectrum access system coupled with low power service rules.

A lot of science went into CBRS. The players spent most of the time between identification of the band and auction by answering the question, "How can we allow commercial users to share federal spectrum without harming the incumbent user?" I would offer we successfully answered that question, even if it means low power operation that might be shut off with literally one minute's notice. How long did it take to answer that question? Well, NTIA identified the CBRS band in the same report that it identified the AWS-3 band back in 2010. I'll note the FCC completed the CBRS auction a little under two months ago, or almost a decade after NTIA identified the band as eligible for commercial use.

Now, one might point out that DoD did not operate everywhere in the US in the CBRS band, which this meant was DoD operation significantly impacts only about 40% of the US population and over 80% of mobile customers. That is not exactly the most ideal situation for commercial deployment. So, what did we do with the AMBIT process? In November 2019, the President gave a charge to DoD and OSTP to make 100 MHz of contiguous mid-band spectrum available coast to coast at full commercial power with an option starting in 2021. That was a very clear policy directive.

But what about the evidence for evidence-based policy making? The good news here is physics is physics. The bad news is DoD's operation in the band are generally matters of national security and disclosure could compromise those operations. Given that situation, the Office of Science and Technology Policy assembled a team of cleared experts. They were some of the leading radar academics as well as former Navy and Air Force radar systems designers. That was our platform for collecting preliminary evidence to formulate the right question.

So, I would offer to answer this question of what made this exercise the fastest expected transition of spectrum from federal to commercial use ever, well, jumping off from what my colleague from Canada, Adam Scott, identified on Tuesday at this conference, we reformulated the question. The usual question asked when repurposing federal spectrum is one or a combination of the traditional ‘Coates’ approach. That is if the private sector's use of the spectrum is more valuable than the incumbent federal use, will an auction prove the hypothesis by raising enough funds to pay to vacate the federal users from the spectrum? Or the conventional sharing approach where the question is how can federal users share spectrum with private sector users without disruption to federal users?

AWS-3, for the most part — with an asterisk which I will get to in a moment — is an exemplar of the former approach, and CBRS is an exemplar of the latter. Our innovation was reframing the question in a new way. We asked if federal users could not fully vacate the band, how can federal users change their operations to get out of the way of commercial users?

In other words, we were exploring a third way. Instead of either forcing federal users to vacate the band or putting a squeeze on commercial users, could we make the spectrum effectively available without a total move of the incumbent federal users? Given that reformulated question, OSTP's experts did a preliminary analysis and realized that we could make the same contiguous 100 MHz block available coast to coast — that's the 3450 to 3550 MHz band. We also realized that because of the high density of critical systems in the band in Alaska and Hawaii, coast to coast would be for the contiguous lower 48. It would be at full commercial power — and I'm going to bring in that AWS-3 asterisk again, which I'll get to in a minute — and all while protecting DoD's mission readiness and thus protecting the nation.

With the reformulated policy informed by the evidence we'd gathered from the precedent, a six-month process began to work out the details. So, how did we do it? It was a collaborative process. DoD, the White House, OSTP, NTIA, and the FCC, as well as others like the Office of Management and Budget worked together. It was not the usual case of NTIA telling DoD to free spectrum, DoD coming up with a plan, and delivering that plan over the transom to the White House. Rather, we all worked together. Given the utmost importance of protecting the nation's security, over 180 people, mostly from DoD, more especially from DoD service branch operations, as well as personnel from the FCC and NTIA, collaborated together on the analysis and development of new operating plans and procedures to make DoD operations in the band transparent to commercial users.

The result of the first pass of that exercise was we found that 93% of the population of the US could have full power commercial mid-band 5G service all the time, simply through changing the way DoD used the spectrum. So, what about the remaining 7%? Addressing that, the basic principles we had were to minimize or eliminate DoD's use of the spectrum to do geographic concentration.

So, for example, in the White Sands Missile Range in New Mexico, there are a lot of missiles and not many people looking for commercial 5G service, so concentrating DoD's use there. And temporal avoidance. So, for example, when doing maintenance of DoD systems where you have to turn the radars on, do it late at night during times of low commercial use. DoD had a realization as we were working through this process. In the old way of doing things, they would come up with hard and fast worst case service rules to protect DoD, to protect the incumbent.

This is where the above mentioned AWS-3 asterisk comes up. During the long transition for AWS-3, DoD, NTIA, and industry had been working together to work out the various idiosyncrasies of particular deployment locations, like near aviation radars. The DoD's realization was that if industry worked cooperatively with DoD on deployment up front, as well as during operations if there are still national security needs for occasional use of the spectrum, then commercial users could have much more spectrum to use for much more of the time.

What does this cooperative planning look like? Well, examples are things like, "Please don't point your 5G antenna beams directly into the aperture of my radar. There isn't anyone there that wants service, they would be cooked, and it messes up my radar." And likewise the other way, "Be aware of very high power transmitters around the corner from your 5G antenna and the side lobes or out-of-band emissions from that radar could melt an unprotected 5G receiver. You might want to protect it because DoD won't be buying you a new one."

There's still some areas covering about 1% of the population where DoD still needs occasional exclusive access to the band for national security purposes. For the most part, we are talking about once a month for a few minutes at 3:00 in the morning or semi-annual exercises that DoD plans more than a year in advance. The expectation is that, for the most part, although DoD get exclusive use to the spectrum, it will be at times that commercial users won't be using it, making the DoD use transparent from a commercial perspective.

There is a small portion of the contiguous US, about 4% of the population, that cannot reliably get the full 100 MHz all the time due to an airborne system that eats 40 MHz of the spectrum. And its solution is to make the 60 MHz that is available, to make it available at full power immediately, and work with the private sector on how to deploy on a much more limited basis in the 40 MHz that DoD still occasionally uses. The long-term plan, paid for with auction proceeds, is to move that particular system out of the band; however, unlike other auctions, use can begin immediately. Contrast this with the old way, which was to wait for the auction to conclude, acquire new systems, deploy the new systems, and only then can commercial use start.

So, what does this mean for evidence-based policy making? As noted earlier, how we ask the policy question really does frame the solution space. CBRS asked the question, "How can DoD share with industry without impact to DoD?" Over 10 years, evidence was collected, rules proposed, spectrum was made available and auctioned, or used by rule, or used in unlicensed manner. AMBIT asked the question, "How can DoD get out of the way of industry without adversely impacting readiness?" Over six months, evidence was collected, rules proposed, and we're expecting an auction within a year. More importantly, that spectrum will be available for full commercial deployment at full power immediately after the auction.

So, with that, I want to again thank Rachel for the great introduction, Keith for keeping this all together, and for your time and patience looking at my picture with all that hair in the background. Thank y'all very much.

[00:25:59]
Rachel Anderson: Thanks so much, Mr. Burger. So, following the Wiser rule, we're going to have a student ask the first question. So, with that, I would love to invite Sloane to unmute and go ahead and ask your question.

[00:26:18]
Sloane: Hi. Thank you for being here today, it was great listening to you speak about a lot of things that I did not personally know. I am currently a 2L at Colorado Law and my question for you today is with so much passion behind evidence-based analysis into spectrum, there's still a step one. And that step one is convincing others that that evidence matters. How do you ensure that the people who make decisions are taking the evidence that you have scraped and found as true?

[00:26:54]
Dr. Eric Burger: Well, thank you, Sloane, for your question and good luck. You're, at this point, I think, almost halfway there to being done so good luck with the studies there. Yeah, I think it is a case of success breeding success and this process that we went through didn't do necessarily... There was the top-down which was that policy cut of, "We want more mid-band spectrum available, make it happen." But then we had that phase of really formulating the question and that did take a little bit of research.

I think part of the success here and in other areas of the government, that taking a pause, collecting the evidence of how best to get that policy goal achieved, and then kind of running with it. Because if you think about it, once you have the question asked properly, then that's where the expert agencies can really do their expert thing and collect the information and do the analyses, and run the cost-benefit analysis that's necessary to come up with good, either laws or rule-makings or policies and procedures.

[00:28:25]
Sloane: Thank you so much for answering. I hope you have a great rest of your speech and keynote.

[00:28:32]
Dr. Eric Burger: [Laughs] Thank you very much.

[00:28:35]
Rachel Anderson: Yeah, this is such an interesting... Framing, like you're talking about a reframing of the question and having worked this summer for NTIA, I worked with so many really brilliant people. And something that came up yesterday in the talk, I'm not sure if you were able to listen in, but something that came up yesterday was Paul Kolodzy was pointing out that a lot of times, the engineers are getting so bogged down in one question and then the question will change. And he was saying it would be so helpful if we could follow that question to its root, come to a solution, and then move on.

So, did you find in that process that in the collaborative effort of all of these agencies, that that was something you experienced across the board or was it easier? It sounds like it was easier having the policy objective very clearly on the front end of this task.

[00:29:43]
Dr. Eric Burger: Thank you, Rachel. That is kind of addressing this policy formulation and a few of you may end up on Energy and Commerce (E&C) or something like that doing the laws. You know, the successful laws are, "Here's the policy objective for the nation." Like we want everyone to have high-speed broadband access or they want to be able to afford it or whatever the policy objective is. As opposed to, "We want everyone to have broadband access and we're going to do it this way." It seems to always be best to leave the, "We're going to do it this way," to the scientists and engineers and economists.

And we did have the, I should say, luxury of being given the end point and importantly, the timeline. Given the timeline we had, we couldn't spend 10 years. Or you could say we spent 10 years doing CBRS, we couldn't spend another 3 or 4 years extending into this band. We had to really look for novel ways of approaching the problem. And in a sense, it's also the caveat, because the engineers and economists and lawyers in the expert agencies, if Congress tells them, "You've got to do X," they're kind of constrained, they've got to do X. If that X is high level and it allows them to come up with innovative ways of doing it, that's great. But if X is highly specific, then you got to do what the law says. So, thank you.

[00:31:53]
Rachel Anderson: Yeah, I believe we have time for one more question coming from Keith. Keith?

[00:32:00]
Keith Gremban: Oh, thank you for the talk, Eric, that was great. I want to touch back on the CBRS. So, we've just completed the auction for that and deployments are going to start. And that is kind of one very significant step towards that AMBIT spectrum sharing. So, what do you expect to be learning from the CBRS experiment? And if you pull out your crystal ball, what direction is spectrum sharing going to be going? Are you going to reduce the sizes of the areas? Like CBRS is county-sized. Or more dynamic, smaller time intervals? Where do you think we're going to be going in the future on this?

[00:32:47]
Dr. Eric Burger: So, Keith, thank you, that's great because now I can wax poetic in my OSTP R&D role. You may be aware, the DARPA successfully completed last October the spectrum collaboration challenge. And for those, I'm guessing especially the lawyers who might not be aware of what that was, it's like the typical DARPA, "Let's have a competition," and it was like the ultimate in "co-opetition." There were a number of teams and it was driving both software-defined radio, cognitive radio, technology, AI, but also cooperation. Because the winning team was not who could jam everyone else so that they could use the spectrum.

Basically, they were given spectrum, there were incumbents there, and those incumbents were modeling cellular providers, they were modeling television distribution systems, and this was, "How can you use all of the spectrum around those incumbent users?" And in fact, they did have to change the rules because early on, the winning algorithms were the one that crushed everyone else, so only their stuff got through and it didn't get through very much. So, the rules were changed a little bit and basically, everyone had to get some aggregate through and then whoever got the most above that got the extra points and won and they did announce the winners back in October.

And so this concept of AI cognitive radio has a lot of potential for, as Keith, you were saying, really small moment-by-moment. In the DARPA world, it was in milliseconds, the CBRS world is minutes to longer. So, you can envision a future world where spectrum sharing is either like hyper-efficient, what we today call unlicensed, because if you think about it, Wi-Fi is a cooperative protocol. And in places where you still have incumbents that, no joke, really need to be protected, which would be like ballistic missile defense, I think we would all agree ballistic missile defense is kind of important to the nation, that you have some sort of coordinated spectrum access, just like we see with CBRS.

So, they're not at all mutually exclusive. It's not that, well, CBRS is the only way we'll... You can guest [Phonetic 00:36:00] if you might use something but you still got to check in, I don't know that that's necessary in all bands. Likewise, I don't know that a pure AI solution is necessarily the way to go and you've got a lot of critical communications, whether it's ballistic missile defense or FirstNet radio responders. It's kind of a little bit wasteful when you're in normal times.

And when you have an emergency that takes down a bunch of your communications network, you really need some dedicated spectrum for people to be able to respond. So, the answer is all of the above. A lot of exciting work both at DARPA, they've got follow-ons to more of this cognitive radio, as well as NSF has got a lot of programs going on in that area as well. So, thank you, that was great, great question.

[00:37:03]
Keith Gremban: Thank you very much, Eric. I'd love to ask you some more questions but we need to move on to our panel. So, thanks again, very interesting points you bring up.

[00:37:14]
Dr. Eric Burger: Thank you very much, you're welcome, and good luck for everyone for the rest of the conference.

[00:37:20]
Keith Gremban: Thank you. So, before I introduce the moderator for the next panel, we seem to have lost two of our panelists in the crowd attending here. Chris Gregory, can you raise your hand in whatever screen you're on so that we can promote you to a panelist and Steven Yesco [Phonetic 00:37:40], could you please do the same? Oh, I see Chris now.

[00:37:43]
Chris Gregory: Hi, I think I'm in the right place.

[00:37:45]
Keith Gremban: Okay. [Laughs] Okay, so, our first panel for the day is on Evidence and Spectrum Sharing Among Active and Passive Services. The moderator for this is Doug Kinkoph. Doug is an Associate Administrator of the NTIA, National Telecommunications and Information Administration, following my own No Acronym Rule. I had the pleasure of working with Doug while I was at NTIA and while there, Doug worked on areas as diverse as spectrum management, public safety communications, and broadband deployment so he's got quite a background in this area. So, Doug, over to you for the panel.

[00:38:25]
Doug Kinkoph: Thank you, Keith, and I would reiterate that I also enjoyed working with you during your years at NTIA out there at ITS Boulder Labs. I am not on the screen because I have some technical difficulties but I'm joining you at least by phone. And good morning, it's a pleasure to be moderating the panel today on Spectrum Sharing Policy Among Active and Passive Services and I will say that from time to time, this issue has popped up on my plate. We don't have a lot of time, this is a subject that we could spend a lot of time addressing.

So, let me quickly introduce today's panelists. Their full bios are on the Flatiron website, I'm going to just do an abbreviated introduction. First, we have Chris Gregory, he's Vice President Engineering at Hawkeye 360, a Radio Frequency Geolocation Analytics firm that deploys a constellation of low Earth orbiting or LEO small satellites. Jennifer Manner is our second panelist, she is Senior Vice President of Regulatory Affairs at EchoStar Corporation and Hughes Network Systems. Next, Chris Tourigny is an electronics engineer with the Federal Aviation Administration's Spectrum Planning and International team, Spectrum Engineering group. And finally, Dr. Ashley Zauderer is a Program Director in the Division of Astronautical Sciences within the Directorate of Mathematical and Physical Scientists at the National Science Foundation.

Before I jump into the questions and we kick this discussion off, I just want to ask the panelists if anybody has any quick remarks they'd like to give? Okay. Well, let's kick this off. First, I think it's important to get a feel. Keith, we've read the abstract you guys have written, I've read David's opening kind of setting the stage remarks, which I thought were great. I'd like to get a feel from each of the panelists, and I usually don't run right down the list, but I'd like to get a feel from each of them of what does evidence mean for spectrum sharing among active and passive services relative to your unique position in the field? So, if we could start off with Chris, that would be great. Chris?

[00:41:00]
Chris Gregory: Yeah, thank you. So, I guess I'll just start by saying I'm an engineer and not a lawyer and so for me, I'm coming at this from the standpoint of collecting evidence using tools that are designed to sense RF energy and to geolocate the origin of that RF energy. So, what it means to me is it sounds like we have multiple people who want to use the spectrum, they don't want to deal with one another.

And I think where Hawkeye 360 and our technology fits in, really both for the active and the passive users, is anyone who is suspecting interference or experiencing some kind of interference can be helped by a technology that can search for not only the signals that potentially may be interfering but also try to pinpoint the location. So, passive users who may be doing radio astronomy and may be bothered by someone using old [Phonetic 00:42:02] band cell phone technology too close to their devices could be aided by our technology to find and potentially notify the user that's jamming them. And then active services in terms of making sure that spectrum is truly clear where it's supposed to be clear and being used where it's supposed to be used. I view our role as a pool provider and a source of evidence that can then be used by folks who would enforce policy.

[00:42:36]
Doug Kinkoph: Thank you, Chris. I'm just going to go right down, if you have any remarks, Jennifer?

[00:42:47]
Jennifer Manner: Sorry, I have a large dog who likes to bark so I'm always on Mute so it takes me a second to come on. So, anyway, thank you, Doug, and thank you to Silicon Flatirons for having me. I'm a lawyer but I like to think I'm somewhat tech-based and analytical in how I do things. I've been giving a lot of thought, Doug, to this and the other questions you sent us, and I'm not quite sure quite how to answer your question, but let me start by saying I think there's many ways successfully for passive and active services to share together.

And I spent a lot of time over the past few days reading all the papers on evidence-based decision making and so forth and really thinking this through, and I do think spectrum sharing is possible. We've been successful both at my company and other companies I worked for. Chris Gregory and I used to work for MSV and SkyTerra before it was Ligado so I know a lot about the L-band program there. And successfully shared as an MSS operator for a number of years with a number of services and the same with my current company.

I think, Doug, what this really comes down to though, to do this successfully, which I'm really focused on, is I do think we need evidence-based decision making but I think that evidence has to be objective and not subjective. And unfortunately, what we often see from policy makers, and I've been a policy maker myself three times, is a somewhat subjective choice of what they choose to view as fact-based. And I do think that that's a problem and I also think you have what I view as the objective decision and then you have a certain amount of policy making when it comes to spectrum sharing.

And one of the things I would urge, and Doug and I have been on the CSMAC (Commerce Spectrum Management Advisory Committee) and this is something I do believe, is there really needs to be a rethinking of how we manage spectrum in this country. Because traditionally, we've been supposed to use the public interest, but the public interest has been redefined in so many different ways over the years that I think even with objective facts, you still have the overlay of the public interest when you're coming to sharing decisions and there seems to have been a walk away from technology neutrality.

And when I talk about technology neutrality, I don't mean equal. Passive services can't always win and active services can't always win. But you have to have a standard and you have to be able to walk away from certain things. One of my concerns has always been with auctions is that money talks and even though the communications access, you're not supposed to take into consideration the money coming into the Treasury, that's still a consideration. So, I don't know if that answers your question, Doug, but it's kind of some of the issues I've been struggling as I prepared for the panel. Thank you.

[00:45:43]
Doug Kinkoph: No, I think those are very good points. I think your argument of evidence, subjective versus objective, is very interesting and one of the things that I know I and others deal with. It's not just public interest. I guess this is public interest but some of the stuff we have to deal with are the national security issues that aren't always public and that need to be weighed in consideration of the other evidence. And so sometimes, that is not as public as we wish it could be, but need to be weighed by the importance or critical nature of many different missions of the federal agencies. So, your point's well taken, and let me just ask Chris or Dr. Zauderer if they have any comments on this first question.

[00:46:39]
Chris Tourigny: Yeah, I do, thank you.

[00:46:43]
Doug Kinkoph: Yeah, Chris.

[00:46:44]
Chris Tourigny: Thank you, thank you Silicon Flatirons. I've been participating on the technical side of domestic and international spectrum policy making for a decade and a half and I have seen a slow pivot towards better evidence to improve decision making. And I don't speak for the Federal Aviation Administration, but as an engineer involved in several domestic and international programs, "data-driven" is a common phrase that you hear, more so now that before, and it's also a central idea of several of our domestic programs.

So, evidence is becoming more and more important in decision making or policy making, not just in spectrum but a lot of other aspects of operating big things. Spectrum policy making usually involves a technical analyses or several technical analyses to guide users or to guide specific assumptions, maybe provisions or limitations in some cases, to ensure that new policy doesn't impact users operating under the existing policy. And we appreciate those studies being data driven. I know "data-driven" is a phrase that's probably overused and evidence is more refined though than raw data.

So, how does it get refined? In several of our programs, domestic and even some cases in the international work, we present studies to committees or organizations, maybe they're federal advisory committees, maybe they're standards development organizations. And the intent is to accumulate support for key parameters that you would like to end up in the policy. And this process typically involves the evidence being analyzed by both sides of the issue — one for truth but also for relevance to the case that you're trying to make. And ideally, that review process provides better evidence that may be used at the decision and policy-making levels to improve the outcome. And I think everybody's idea of improving the outcome should be that you have successful sharing and compatibility in the end, post policy making activity. Ideally, this validation process from all stakeholders' perspectives improves the chance of public dispense in the end.

[00:49:31]

Dr. Ashley Zauderer: I guess to add a couple final thoughts, Doug, I come to this panel as a radio astronomer but I really wanted to pick up on something that Dale Hatfield said yesterday. When we think about sharing between active and passive, every active transmitter actually has a receiver that is passive to actually detect that signal. Things like altimeters, or if you're transmitting some signal, you have to receive it. And so often when we think of passive services, we're thinking of radio astronomy or Earth remote sensing because they're so sensitive, maybe a million times or more sensitive, but we're actually still detecting a signal that is naturally transmitted, such as from a black hole or from the sun.

So, one thing that I wanted to bring to this conversation is first discussion of that, acknowledging it. But second, I really liked what Eric Burger mentioned in the keynote, in terms of reframing the question. So, when we ask about evidence, what is the hypothesis that we're actually trying to address and then that drives what data we need to collect. And I wanted to mention that this was discussed a little bit yesterday. There's several kinds of evidence. We can look at models or sharing studies that are often simplified. We can look at experimental data in the field. We can look at the legal precedent that's set, for example, in the radio regulations or in the FCC record. But we want to know what is the hypothesis so that we can then explore how to actually move forward.

And so when we collect the data, I just wanted to emphasize that I really think your assumptions matter and you need to be clear about that. The simplifications that you make matter. And finally, your experimental design matters when you actually collect that data. So, for example, when you're trying to do sharing studies with the military, if you only did it during the day and not at night, you might think there was no issues, so you need to make sure that you do the right experimental study. Maybe you evolve that study over time if you get new information. That's kind of the scientific method, that you continue to collect new data and make those revisions to your experiment as needed.

So, those are just some thoughts as I think about evidence and how to get the best information we need moving forward, because it is a continually evolving process, we're never going to be set.

[00:51:41]
Doug Kinkoph: Thank you, Ashley, appreciate that. I'm going to be jumping around here a little bit. So, usually when we think of sharing between active and passive they're geographically dispersed, but what are some of the motivations to share spectrum between active and passive services? So, is it all one way? As an example, all cellular companies just simply needing more spectrum, and I'm not picking on the cellular companies. Or do passive services need additional spectrum as well?

And Ashley, I'd like to specifically kick that to you first and ask you if, when you're answering that, are you aware of any new phenomena that would require larger or new passive bands from the NSF or from your own experience? You see anything coming down that, because historically, a lot of these passive bands have been identified by a physicist and not engineers. Whether it's hydrogen lines or the frequency at which water vibrates for a meteorologist, those are not dictated by engineers but physicists. So, I'm just curious as you answer that, if you see any need for new or larger passive bands.

[00:53:03]
Dr. Ashley Zauderer: So, the answer is absolutely yes. The bands that are protected for passive services were noted for being very special spectra lines at rest. So, for example, the neutral hydrogen where we can see our galaxy at 1400 MHz, discovered by Karl Jansky when he was searching for noise in a receiver. But the cutting edge of astronomy and research is actually much broader bandwidth, looking to collect continuum data, other kinds of emission mechanisms, looking at the spectra lines red-shifted.

So, if we're looking for the epoch of reionization, this is kind of the earliest moment in a universe, where you can see hydrogen, that's actually shifted to about 70 MHz, which is not a band that's protected for astronomy. So, over time, astronomers have been able to get around this by choosing sites that are geographically remote. But a challenge that we're now facing is that the geographic quiet zones are no longer adequate to protect our sites. So, for example, the National Radio Quiet Zone only requires coordination from ground base transmissions.

And so as we think and we move forward, I think a good way to move forward is another thing that Eric mentioned, both geographic but also temporal sharing. Is there a way that in at least certain geographic sites, you can consider having access to certain parts of the band for various special experiments, similar to having access to a road in New York City for a marathon for a very special purpose, but then most of the time, you do actually use it for a different purpose? So, I mean, it is definitely the cutting edge, a lot of great science that's been done in the past 10 years has been using spectrum that we don't officially have allocations in, but we're able to use because we go to those remote geographic locations.

[00:54:47]
Doug Kinkoph: Great, thank you, Ashley. Others on the panel? Would you like to jump in on the motivations to share spectrum between the passive and active providers or users?

[00:55:02]
Chris Tourigny: I could add a little to that if you like.

[00:55:06]
Doug Kinkoph: Sure. Is that Chris?

[00:55:08]
Chris Tourigny: Yeah, it's Chris Tourigny.

[Crosstalk 00:55:09]

[00:55:09]
Doug Kinkoph: ...I know it's Chris. [Laughs]

[00:55:11]
Chris Tourigny: [Laughs] It's at least one of them. Yeah, the aviation community benefits from what you would consider traditional passive service, mostly in meteorological application. We don't operate systems that operate in passive services, although there are similarities that Ashley has pointed out. In particular, to radar receivers and passive system receivers.

And we have several examples of where passive services such as radio astronomy or EESS passive. I'm sorry, that's an acronym, Earth Exploration Satellite Service, passive, and meteorological satellite services operate in spectrum adjacent to aviation systems. Many of these exist, of these examples, have been around as long as the aviation systems and we have some systems that have been around for 70 years.

But to us, the distinction between passive and active isn't that important to sharing and compatibility. If they have a recognized right to operate or somebody needs new spectrum, as we do at times, we try to figure out how to make it work. A receiver is a receiver. There are different processing details that might make some things more difficult than others but the approach that you take to trying to figure out coexistence is similar between passive and active services.

[00:56:44]
Doug Kinkoph: Thanks, Chris.

[00:56:46]
Chris Gregory: Yeah, let me...

[00:56:43]
Doug Kinkoph: Yeah, go ahead, Chris.

[00:56:49]
Chris Gregory: Yeah, thanks. I just want to chime in a little bit on a few of the things I've heard. So, one of the things that really jumped out at me was the discussion that Ashley had about the hypothesis testing and really trying to understand the mechanisms by which one system or another is interacting or interfering with another.

And I just wanted to kind of weigh in from the industry side from a bit of a practical perspective, that the better the hypothesis, the lower the cost and burden in terms of time and resources on a company like Hawkeye to help. If we're told, "Hey, there's a band and we need to protect it and we need to search for anybody who's in this band anywhere in the world," the bill is going to be much higher than if there's a precise hypothesis that says, "Look, we know of these type of services that are interfering on a regular basis. We think it's accidental, we think these people don't even know who they are, but this is the geographic area or this is the time of day."

Anything that can help with the hypothesis of what might be wrong, I think the more mature that thought process can get, the more we can direct assets to police it at a low cost.

[00:58:10]
Jennifer Manner: And Doug, I'd like to weigh in too, if I can, this is Jennifer.

[00:58:13]
Doug Kinkoph: Yeah, Jennifer, please.

[00:58:14]

Jennifer Manner: So, since I'm the only commercial operator... I know Chris is commercial but not involved with monitoring. So, first off, I want to make it clear, at least from my view, I can only talk for myself, I think we understand and companies I've worked have always understood the importance of the passive services and they're important from so many levels — public interest, security, and so forth. And I particularly think I've had a good experience working with NSF and other folks who we've had to work with to protect, though sometimes I have been known to throw snowballs at radio astronomy stations in Hawaii when I get a little frustrated, but I would do that at cellular operators too and others.

But I think the one thing that's really, I'm happy to see [Inaudible 00:59:04] change, years ago, [Inaudible 00:59:09] 2000, there was a debate over what band was going to be made available for IMT and there were three bands under consideration — a military band, a weather band, and my band. At that point, I worked for MCI and we were MMDS (Multichannel Multipoint Distribution Service), which is now BRS (Broadband Radio Service). And there was no question that weather was being taken off the table and being protected, so it became a fight between military and commercial uses, and ultimately, we ended up with an outcome that worked for me at the ITU (International Telecommunication Union). But I think the point there was we just took it off the table.

And I think with evidence-based decision making, what we're seeing more and more is that it's not just a yes-or-no issue anymore, and this is true for all the bands, it's a maybe issue, which goes to Ashley's hypothesis. Which is we're starting to look at this, and by using — I still can't get used to evidence-based, I'm going to use fact-based decision making — but by using facts and looking at things, maybe there is a way to share and maybe it's temporal, as Ashley said or something else. Or maybe there's not. I mean, there's still going to be certain bands which I'm sure we're never going to share. And I would say that even for protected [Phonetic 01:00:23] bands and satellite bands may be too sensitive.

So, I really think, Doug, what I'm excited about and what I think I've seen over my length of career, which I think is a little longer than Chris Tourigny's, is that we're starting to look at things and because of fact-based decision making and the willingness of folks to engage, we're making better use of the spectrum resource.

[01:00:46]

Doug Kinkoph: Thank you, Jennifer. Let me pull on that string for a minute. And I did hear before from Ashley the comment of new technologies, etc. Historically, passive and active have been separated geographically or in adjacent bands. And I know this is not a group of engineers [Laughs] but Chris, I apologize for just probably insulting you, as you are. The question I have is are there new technologies or technologies that you see coming down the pipe or that exist today that would allow for co-sharing of spectrum between active and passive services in the same band within the same geographic area? Maybe some type of time syncing, etc., but I just wanted to hear if any of you, if you have thoughts on that.

[01:01:43]
Chris Gregory: I mean, time syncing is inherent to just about everything that uses any kind of network RF (radio frequency) energy. And so I see zero technical barrier to a quiet moment of the day that is scheduled for measurements to be made, that could be done in a way that is not invasive to service, depending on how long it would take to do that measurement. But yeah, just the eye level point is we keep track of time down to fractions of a second and so I don't think any operator could try to claim that they don't have the ability to mute their transmitters on a schedule.

[01:02:30]
Doug Kinkoph: Thanks, Chris, and for the audience, that is like for a micro or a millisecond you would go silent and allow the readings to take place and then turn them back on. Chris, I think that's what we're saying here. That doesn't work for all, but in some cases that may be a solution to get us the sharing within the same geographic and within the same band. Others have any thoughts on that?

[01:02:58]
Dr. Ashley Zauderer: Yeah, Doug, this is Ashley. I'll weigh in just very briefly from the National Science Foundation perspective. So, the technology definitely exists. So, if you look at, for example, radio receivers, they collect data on very, very, very small timescales and then tend to average that to get down to the sensitivity they need. So, you can imagine, as Chris was saying, timesharing on nanoseconds, where if you know someone's transmitting, you can not be observed in that particular time. But this is going to require us to take a step towards a much more automated spectrum management system that's machine to machine, and not sort of something that's going to have to go through humans and take hours or days.

And so this is something that we're definitely hoping that we can put research funding towards in specific geographic zones. So, I think Thyaga spoke about it on the first day, looking to kind of catalyze this concept of national radio dynamic zones where we can really try to work out the details of this dynamic sharing in some very small places. Similar to what CBRS has done but try to start expanding that. Because the technology is there between machine learning and artificial intelligence, it really just has to be implemented.

[01:04:09]
Doug Kinkoph: Yeah, no, I agree, Ashley, and I know that's something that NTIA has been looking at also. But I do believe that it definitely has to get to a machine-to-machine

application for it to work in that timeframe, those milliseconds, etc. So, we've been throwing out a lot of stuff to the audience and I think sometimes it's hard. I have to think about it when you start thinking passive and active services and systems in everyday life, to understand the impact of the passive systems on everyday life.

And could we just take a second here? Because sometimes that discussion, the policy discussion, gets a little esoteric. And just maybe if we could help with the audience a little bit of understanding what type of impact passive systems have on their everyday life. And Ashley, you talked about the weather forecasts, there's public safety, etc., but I know all of you come at it from a different angle. So, if you'd just take a minute and talk about the impact and the importance of the passive systems, that would be appreciated.

[01:05:33]

Dr. Ashley Zauderer: I can keep talking real fast, Doug, just to add a couple of other passive things people don't think about. So, your GPS, to know exactly where you are, the Earth, we have to know its orientation. And so observations of galaxies far away actually help to provide the most precise Earth orientation which is really important. That's something that the very long baseline astronomy, VLBA (very long baseline array) system, contributes to.

Additionally, none of us what to get hit by a gigantic asteroid, so NASA (National Aeronautics and Space Administration) leads a Planetary Defense program to detect and characterize all potentially harmful near-Earth objects. And then we use radio astronomy to actually bounce radars off of these objects and characterize and understanding of do they have a possibility of hitting us. And that's something else that hopefully will never impact our lives but it is a very important mission. And again, you can see those time critical limited pieces, it's not something all the time.

And then a final thing that I think impacts all of us is the issue of solar flares. This is something that can impact all communications. And so we definitely want to make sure that we're understanding and monitoring our sun and we can have a sense to be able to predict when we need to move our communications into a protective mode. And so this is where radio astronomy observations of all these stars out there seems like it's just basic research, but that's what's led us to understand how stars evolve, how they die, when they flare, when they might blow up. [Laughs] So, this is the kind of thing that may help us predict when we might get solar flares, based on the 11-year cycle that we do already know about. So, those are just a couple examples I thought I'd throw out there.

[01:07:09]

Doug Kinkoph: Yeah, thank you, Ashley. And I know we don't have a meteorologist on the panel, but the passive satellite sensors at the 24 GHz, or as I mentioned already, for the vibration of water which is used for forecasting models for everyday life, to help forecast hurricanes, tornadoes, etc. So, I know there is quite a bit of important soil measurements for climate change, etc., that is used on the meteorologist's side, so there are a host that I'm aware of. But sometimes people just don't relate passive to their daily lives and what it means to their daily lives that they use every day, like GPS. Anybody else have any comments on that question?

Chris Tourigny: Yeah, I could add some tactics that we use in policy making on the technical side. And yeah, it is hard for the general public to understand many of these things, it's hard for us to explain to our families what we're doing. Policy discussions oftentimes do seem esoteric but there's importance there.

Evidence, which is the central theme of this conference, does help with that and the scientists and engineers, we are usually terrible at marketing. But the more successful ones learn over time, many times from losing issues, that no one is going to care about what you are trying to achieve unless you can explain it well and you can explain it well to diverse crowds. There's the proverbial that the science doesn't leave the laboratory unless you can communicate it well. Evidence is a powerful tool that we have used in helping diverse crowds understand what it is that we're trying to accomplish.

And there's various approaches. Economic was discussed earlier but there's also the social approach and a moral approach. In aviation safety, we have to look at all different aspects, money isn't the only thing that motivates us. And your crowds are going to have different... Or these different flavors of evidence are going to strike people differently and in different ways and it's good to have a good think about it and make sure that you have honest evidence that is speaking to your audience, because most of the time, you will be dealing with a diverse crowd.

[01:09:45]
Doug Kinkoph: Thank you, Chris. I know we're getting close to going to Q&A. I'm going to ask a final question here and then Keith, you can set it up for Q&A. I'd like to ask the panelists — if you guys could look, pull out your crystal balls a little bit and give us an idea of what the most important spectrum policy decisions for active and passive services will look like into the future here.

[01:10:12]
Jennifer Manner: So, I would love to go first on this one, Doug, if that's okay.

[01:10:16]
Doug Kinkoph: [Laughs] Yeah.

[01:10:16]
Jennifer Manner: I've been giving this a lot of thought.

[01:10:18]
Doug Kinkoph: Please, Jennifer.

[01:10:19]
Jennifer Manner: So, aggregate interference, I think this is the most unvalued issue and I have serious concerns both domestically from FCC, I don't have as much experience with working with NTIA on aggregate , and with the ITU. I think we've got 5G coming, I saw in one of the Q&As, people were talking about 6G already, which is reasonable. We've got mega constellations coming in. Starlink's talking, I don't remember, is it about 48,000 satellites?

I'm concerned from a commercial operator what sort of aggregate interference we're going to see. We always get, "Oh, it's never going to happen," but maybe that was true with a 66-satellite fleet like Iridium, or a 3G, 4G world. But I think this is a concern not just to the passive service but also to the active services. And it's interesting, we raised this early on in the early 5G, in 2007, in the FCC's 5G proceedings, that this was going to be an issue and Julie Knapp's view was — who I think is fantastic, my old boss — but Julie's view was, "It's not a real issue, you don't have to worry about that." And I worry about it so I'm sure Ashley loses sleep over it. So, that would be my number one issue, Doug.

[01:11:45]
Doug Kinkoph: Thank you, Jennifer, appreciate it. Others? Chris?

[01:11:50]
Chris Gregory: Yes, I'd like to double down on that last one. I really think that the way the various active services that we see being pitched — Starlink, we have OneWeb, we have several others, we have the Piper. And everybody seems to want to fly hundreds or thousands of spacecraft that all have transmitters on them whizzing around the Earth at all different elevations.

And I just want to say that I think that sometimes theories are developed to predict how the interference may happen. And they're developed by people who, I believe, are well-intentioned but they're also in the business of trying to get a business plan approved and get started. And I would just like to say that I think that the enforcement mechanisms that governments need to have to be able to, I hate to say it this way, but Lord help us if all of these businesses succeed and are all interoperating the way that they are striving to be. History tells us that these very large projects have a probability of success and failure, but if they were all to come to fruition, we would be in an incredibly complicated situation to just detect how they're interfering, let alone trying to predict why they're interfering and how to mitigate that.

So, I think governments around the world are going to have to really invest in evidence-based collection mechanisms if they're going to have a chance of enforcing some of the licenses that they're granting.

[01:13:40]
Doug Kinkoph: Very good points, Chris, appreciate it. Anybody else on the panel?

[01:13:44]
Chris Tourigny: Yeah, I'd like to triple down on that actually. In most of our studies that we've done, we're always including an aggregate factor, we're always including safety margin, and we are always attacked in our studies with those two things. One, because they're easily not understood, and two, because they are necessary. And they stopped making spectrum a long time ago but these applications and users are exponentially increasing and encroaching on other users from both directions.

We in aviation, we benefited a long time from exclusivity, but those days are long past, and it's going to get more and more difficult to ensure adequate operations and we will likely see more "oops" from poor or missing evidence in policy making, but that is the right approach. The right approach is having a mature, filtered, high quality evidence to help drive decision making. The passive services are under the same pressures and it takes hard work and dedication to the mission to maintain sharing and compatibility.

As for a recommendation, the biggest lesson that I've learned is that giving the subject matter experts the ability to be less certain, either initially or maybe less worst case, by giving them an opportunity to reexamine sharing and compatibility periodically, or after evidence has been collected, is the best way to make efficient use of the spectrum. Many times, the attitude or the process is once this decision is made, time freezes and we're going to be stuck with whatever it is and there's no going back. Drives towards squatting, that drives towards extreme worst case in studies, and it's an unfortunate mitigation to, I would say, poor policy making in the past. Not in every single instance but certain examples in particular.

A better way is do a more flexible approach which would require different business models maybe than we have or we're used to. Specifically, an incumbent would be more trusting if there was an assurance that they can recover the desired level of performance post-policy making.

Keith Gremban: Okay, I've got this...

[Crosstalk 01:16:09]

[01:16:09]
Doug Kinkoph: Yeah, no, those are exc... Go ahead.

[01:16:11]
Keith Gremban: As interesting as this conversation is, I need to interrupt so we can have a few questions before the panel's over.

[01:16:18]
Doug Kinkoph: Yeah. Thank you, Keith.

[Crosstalk 01:16:21]

[01:16:21]
Keith Gremban: Sorry, this is fascinating, I was really enjoying it.

[01:16:26]
Doug Kinkoph: [Laughs] I'm not online so I don't see the queue so I apologize. I'll go ahead and introduce Corian Zacher to ask the first question of the panel, a former student. So, please, Corian, please ask your first question.

[01:16:47]
Keith Gremban: You're on mute, Corian.

[01:16:49]
Corian Zacher: Hello, everyone. Thank you so much for being here and for sharing your experience and your insights. I think we heard a consensus that at least some degree of data is crucial to spectrum sharing. But as you've all mentioned, there are some data that the federal government doesn't collect and make available and that information would be really important for effective spectrum sharing. Could you talk a little bit about specifically what information would be helpful and how that could improve spectrum sharing decisions?

[01:17:27]
Doug Kinkoph: I will ask, Jennifer, from an industry standpoint, do you have any thoughts out of the gate?

[01:17:35]
Jennifer Manner: I think there's a broader issue so I'm not going to say specifically what. I'm a lawyer [Inaudible 01:17:41]. But I think the answer is there's a lot of information that's not available. So, I'll give you an example in getting full information. Because so much information is commercially sensitive or is claimed to be

commercially sensitive or claimed to be sensitive for whatever reason, it's very hard to do a full analysis.

So, the EPFD limits are a way that we share with NGSO (non-geostationary) [Inaudible 01:18:11] GSO (geosynchronous orbit) operators. And unfortunately, the way the ITU's rules work is a system could be launched and operating and then could fail to meet the EPFD (equivalent power flux density) and you wouldn't know beforehand. But if we could have that information, I'm sure there's other things. Ashley seems to be shaking her head so she may have a better example than me. But it's that sort of information. What we often find is if the other party's not willing to share that information, that's one thing. Oftentimes, countries go into the ITU process, for instance, and just refuse to give the information. And you can't have a full sharing study so I think it's very fact-specific.

And I just want to touch [Phonetic 01:18:52] Pierre, if it's okay. Pierre had asked me a question about why I'm using fact-based and not evidence-based. Evidence-based doesn't mean it's factual, Pierre, if you look up the definition. It's facts and information. I'm very focused on what's actually facts, and information has a very broad term in my view and can be used to gain things, so that's my reason that I feel strongly. I don't know if that's really the answer Corian's looking for but that's, I think, having the information you need and having it available.

I'll give you an example. There's a fight right now between Starlink and some of the other people on a sharing issue and Starlink's saying, "We won't give it for anything but this particular use." And the problem is it could be that the analysis shows something else and that it's not usable. So, those are the sorts of things. And I'm sure [Inaudible 01:19:49] the same thing so I'm not saying I'm holier than thou, but it is an issue.

[01:19:56]
Doug Kinkoph: And sometimes it's not even a lack of facts or evidence, it is just disagreements on who has usage. Jennifer, you said the fact but we can even disagree on the facts at time in policy making and that goes all the way back to your subjective versus objective comment. So, it really does depend on what is needed based on the bands you're talking about, the situation you're talking about. Does military sit in that band? Does weather, etc.? If we're talking about sharing in this context, it really does vary by situation. Do others have any comments on this question or we can go to the next one?

[01:20:41]
Chris Tourigny: I could just add that it's a very good question and it's a very difficult answer, mostly because interference is in the eye of the beholder or the receiver that's receiving the interference, and it's very hard to come up with a standardized way

of producing a set of data that would be useful. And for example, you may have a scenario that would be harmful interference to a GPS receiver or a radar receiver, but the very same interference source would be tolerable to a communications system that has much higher signal-to-noise or can tolerate that particular type of interference. So, it is something that's important but it's not something that's trivial.

[01:21:28]
Doug Kinkoph: Good point, good point. And Keith, if these are coming in on the Zoom Q&A, I cannot see them, so if you could ask those questions if you're seeing them or someone else.

[01:21:42]
Keith Gremban: Okay. I think we have time for just one more question and this one came for Ashley from Gregory Lapin [Phonetic 01:21:53]. 6G cellular standards are now being written that include the use of terahertz frequencies. Is it realistic to think the terahertz small cells could be made to coexist with radio astronomy monitors?

[01:22:04]
Dr. Ashley Zauderer: Thank you, this is a great question and one that we actually studied in great detail the past four years. And so in the terahertz region of the atmosphere, you have a lot more attenuation from signals, and so sharing is much easier between cellular devices and radio astronomy if you just put sort of geographic restrictions around where you actually want it to be transmitted.

So, I think at sea level, you're talking about tens of feet you can attenuate most signals that would be used for small cells. And so if you have a radio telescope, for example the US, we operate, I think, there's one in Arizona, one on a mountain in Hawaii where Jennifer was throwing snowballs, and one down in Chile at the Atacama. And so at those heights, you're not going to be impacted by 6G at the ground. So definitely I think the attenuation when you have a lot of atmosphere really does help you, and that's something that can be taken into account, so yeah.

[01:23:02]
Keith Gremban: Okay, and now unfortunately, we're due for a quick break. Everyone can go grab a fresh cup of coffee. Thank you so much to this set of panelists and Doug for moderating. This was a very fascinating discussion, I know there's been a lot of talk on the chat line about this. So, thank you all. Let's take a break. We'll reconvene at 11:30 Mountain Time which is 1:30 Eastern. Thank you much.

[01:23:31]

Doug Kinkoph: Thank you, Keith, appreciate it and thank you to all the panelists, appreciate you guys taking your time. Thank you.

[01:23:36]
Female: Thank you.

[01:23:36]
Chris Gregory: Thanks, Doug. Thanks, everyone.

[01:23:39]
Doug Kinkoph: Yep.

[Silence 01:23:40 to 01:34:45]

[01:34:46]
Keith Gremban: Welcome back, everyone. Our final panel of the conference is on Resilience in Position, Navigation, and Timing, or PNT. I will be the moderator for this panel. We have a great slate of panelists lined up and I think you'll find it fascinating to learn about some of the unexpected ways in which all of us depend on PNT systems. I think it's fair to say that our modern world would not be possible without PNT.

So, let me introduce our panelists and if they can all pop on their video and audio. First to introduce is Dana Goward who is President of the Resilient Navigation & Timing Foundation which I think says all you need to know about why he's on the panel. Tim Godfrey is the Technical Executive of the Electric Power Research Institute, or EPRI. It was surprising to me to learn about how the electric utility industry is so dependent on PNT. Another panelist is Stefanie Tompkins, she's currently the Vice President for Research and Technology Transfer at the Colorado School of Mines. I met Stefanie and had the pleasure of working with her when she was a program manager at DARPA where she was leading programs on GPS free navigation. And our final panelist is Jade Morton who is a Professor in the Aerospace Engineering Sciences Department at CU and also President of the Institute of Navigation.

So, welcome to all of you. Thank you very much for participating in our conference. I'll lob the first question out to Dana. So, Dana, PNT actually affects our everyday lives, perhaps unbeknownst to most of the population. Can you identify some of the ways in which we depend on PNT systems?

[01:36:40]
Dana Goward: Sure, and thanks for the introduction, Keith. And first of all, let me say that PNT today is mostly synonymous with GPS. And one of the ways that we have at our nonprofit of demonstrating that is a little applet on our home page that shows

this particular little picture in an airport. And there's just about nothing in this picture that is not supported by GPS services in some way. So, we've got it set up so if you mouse over the credit card machine, you see that it's connected to a network, and network synchronization depends upon GPS timing. Trucking, of course, transportation, all modes of transportation including air travel depends very greatly on GPS. You'll also see as you mouse over there are a couple hyperlinks at the bottom of each pop-up that gives you access to a paper on each one.

Folks would probably be interested to know that even weather forecasting is dependent in some ways on GPS because weather forecasters measure the very slight differences in how GPS signals are received on Earth due to moisture content. Things like precision agriculture — very, very important to precision agriculture because it greatly reduces the amount of pesticides and the amount of fertilizer needed and makes agriculture much more efficient and also reduces the ecological impact of fertilizer and pesticides. Of course, there's law enforcement, maritime, by the military, rideshare applications, and I think we even have something for the stores over here, and financial systems.

All of these things, just about every network technology that you can imagine and many non-network technologies like digital broadcast. So, for example, the criticality in broadcast and land mobile radios is due to the GPS timing is used for spectrum efficiency, the very highly precise timing signal allows multiplexing or multiple conversations on the same frequency at the same time. So incredibly broad, silent, and essentially a utility that very few people completely understand the impact of.

[01:39:05]

Keith Gremban: Out to the other panelists, would anybody like to add to that from their specific domain of expertise? Stefanie?

[01:39:17]

Stefanie Tompkins: Sure. One other thing that's sort of always intriguing is what both the location and timing information from GPS offer to science, particularly when you think about distributed sensors. So, a lot of times, in order to study something, you're going to leave an array of sensors somewhere unattended for extended periods of time. These might be monitoring seismic signals or sound signals or things like that. But in order to combine that information later and figure out what really happened, you have to have very precise information on the timing. And if the sensors move at all, then you certainly need to know where they were as well. And so a lot of pretty profound discoveries are coming out of that type of application of sensors combined with PNT.

[01:40:02]

Keith Gremban: Interesting. Jade?

[01:40:04]
Jade Morton: Yeah. I also would like to add something and I think Dana have heard me talking about this before, is the sensing part of the GPS or GNS. He had mentioned briefly about GPS has been used to provide information about moisture content in the air. But GPS actually does a lot more than just sensing the moisture in the air. GPS has been used to look at the [Inaudible 01:40:29] which can have a huge impact on infrastructures on the ground or in space and even though they might not happen as frequently as the meteorological ones that impact our lives, but when it does happen, the damage or the impact can be so huge that we have to worry about it. And GPS become, I would say, probably the most popular or reliant [Phonetic 01:40:51] tool to do that sensing.

On top of that, there's another area of GPS. It's become its own field, it's called GNS reflectometry. It's looking at the reflections, which you would typically don't really like because they're called multipath, it impact our range measurement accuracy. So, for years, navigation community treated them as a nuisance factor. We have many experts who work in the field of mitigating the multipath. But today, the multipath reflections have become very much the tool for us to study a lot of properties of the Earth's surface.

For example, we're using them to retrieve ocean wind speed and look at soil moistures, even water bodies, their extent and their evolution. And so these are all reflective signals that's picked up by antennas mounted on the bottom of aircraft or satellites. And they give you almost instantaneous coverage over the world because we have so many satellites transmitting signals that it's already there available. So, those have really high impact for things that will impact your life but you may not be aware of, but they are there and they're really getting a lot of use.

[01:42:18]
Keith Gremban: Tim, did you want to add anything to the conversation here?

[01:42:24]
Tim Godfrey: On this first topic, I will talk more to this later but definitely, Dana could add a point on one of the light fixtures in his little cafeteria illustration that would point to the electric power delivery being very much dependent on GPS timing synchronization. I'll have more of a chance to talk about that later on my next question.

[01:42:50]
Dana Goward: We do have that but I didn't want to spend the whole day on the thing. [Laughs]

[01:42:55]
Keith Gremban: Okay. Well, let me turn to Stefanie for the next question. So, Stefanie, in the past 10 years ago, there have been a number of proposals in spectrum policy that had potential impact on PNT systems and satellite systems in particular. This is a conference on evidence-based policy making, so what kind of evidence could or should be used to inform these policies?

[01:43:20]
Stefanie Tompkins: So, when it comes to sort of spectrum-associated PNT technology, so the evidence is going to include everything from out in the field, real world, collection of data. So, you're going to be collecting information about signals you receive and looking for interference. Looking at things like multipath and other issues as Jade has just mentioned. You're going to probably also be doing a series of controlled experiments, possibly in the lab or in some type of outdoor field setting where you can actually look at very specific aspects of signal behavior. And then you're going to use a lot of physics-based modeling in order to sort of take what you do know and propagate that out through scenarios that you can't necessarily measure in.

I think the world is moving more towards also using machine learning techniques where you're gathering lots and lots of data and then you're learning directly from what's actually happening in very complex situations where the physics models can't quite...you'll bring everything together. But it's worth pointing out that with all of that, in a world that's very dynamic and really complex, you can't completely reconstruct real-world scenarios with perfect prediction. So, I think evidence also does include and has to include sort of testimony and information from users as to what they're observing and what they're seeing and what the impact might be so that the modeling, data collection, and sort of anecdotal cycles can kind of circle off each other in order to get as much information as possible.

But having said all of that, collecting the evidence and interpreting the evidence are different things but I think we're going to get to interpretation a little later on in the Q&A.

[01:45:12]
Keith Gremban: Okay. Does anybody want to follow up on that?

[01:45:14]
Dana Goward: So, I'd like to say that I'm in favor of evidence-based, or as one of your earlier speakers said, fact-based proceedings. I'm also in favor of motherhood and apple pie so I'm not sure those are really issues that are in dispute. But I think as Stefanie said, as we'll probably get to later, it's a matter of what you do with

what you have in terms of evidence and facts and it can be often as much a matter of social and individual psychology as it is science.

[01:45:54]
Keith Gremban: Jade, did you want to add to that? Yeah?

[01:46:04]
Jade Morton: Yeah, I think she covered it really well. Yeah.

[01:46:06]
Keith Gremban: Okay. So, it was interesting for me that you brought up modeling, Stefanie, because I don't think that's really been brought up before in this conference and there's always the issue of constructing and validating the models. Any suggestions for how that can be done in this domain? Not to put you on the spot. [Laughs]

[01:46:29]
Stefanie Tompkins: [Laughs] It's a little unfair, Keith, because I think you're [Distortion 01:46:30] the expert. [Laughs] But well, I mean, to give people an example, this is not strictly related to PNT. But I've worked with people in the past who were struggling a lot with sensors that were operating on the ground and finding that their assumptions about how radio waves were propagating within a couple of inches of the ground surface were not at all what they had actually expected, and so there were clearly other things going on.

So, in order to improve their models, you have to do all of those things that I said. You have to go out and you have to collect a lot of data, and then you have to start going back and trying to look at what you understand about the physics, and interpret what might be causing the discrepancies you're seeing between what you predicted and what you actually observed. And so again, all of those tools sort of come to bear and then ultimately, hopefully, you can improve that model and then that model can then be extended to many, many applications and improve overall system-scale models and predictions.

So, I think there's a lot of things like that where direct encounters of signals with the real world don't quite behave exactly as you expect, especially the closer you look. And as things get more complicated, we have to start having these finer and finer resolution sort of models and there's a lot of work yet to be done.

[01:48:02]
Dana Goward: Which seems to say that modeling is the beginning and not the end of the discussion.

[01:48:10]

Stefanie Tompkins: Totally agree.

[01:48:14]
Keith Gremban: Okay. So, let's move on here. So, Jade, we've learned a lot about our dependence on PNT and talked about how policy can affect this. What does it really mean for PNT to be resilient? I mean, this is your research area, what mechanisms can we apply to get resilient PNT?

[01:48:34]
Jade Morton: That's a really good question. How many hours do I have?

[Laughs]

[01:48:40]
Stefanie Tompkins: How many days do you need?

[01:48:41]
Jade Morton: Yeah, yeah. Well, I will try to make it kind of more concise. Indeed, it's an area that we've spent a lot of time — I mean, two decades. And not just me, many of my colleagues have been working in this area. And there's no silver — is that called a silver bullet or something like that in this country, you have this term? That one thing can solve all the problems. So, it's really about taking the approach from multiple fronts hoping that together, they could make sure we have resilient PNT solutions.

So, one of the first line of defense typically is to make our systems more robust, to make our receivers more robust. So, that involves every stage of the receiver design from antennas to the front end and include receiver signal processing and to post processing. So, from the antenna perspective, people have been doing arrays and allow people to do beam forming so you can kind of close out interferences or sources that could degrade your signal-to-noise ratio and clever algorithms that allow you to steer the beams.

And in the front end, we're talking about building hardware that can block and monitor the signals more and create a more steep [Inaudible 01:50:17]. And receiver signal processing is where people have to spend a lot of time on. Also algorithm [Inaudible 01:50:25] developed to not only mitigate those impact but quite often being able to identify, even characterize, all these different [Inaudible 01:50:36] factors. And so a lot of people work in that area, this is where a lot of research is happening.

Now, there's a limit about how much you can do about that because it doesn't matter how hard you try, the adversary could always jack up their power, have better clever schemes to trick you into doing things you don't want to. So, sometimes, the second round of defense is coexistence. Okay, I've got to get my navigation solutions, what should I do? And so we've done some assessment about coexistence, how bad a situation it is where we can still coexist, generate a solution to meet our requirement. And that usually is not a highly desirable scenario but you've got to do what you have to do.

The [Inaudible 01:51:29] area is on augmentation and when things are getting bad, you really need a solution, what do you do? That's when you pull all the other tricks out of your sleeve. You start going back to how did we navigate before we have GPS? You start bringing the inertial sensors, you start bringing other radio signals, we call those signals of opportunity. Things like your cell tower, your RT signals, or network signals, anything that is in the air that gives you information about the distance between the receiver and the transmitter that somehow could constrain your navigation solution.

So, there is very active research areas, alternative sensing, and quite often, we don't really want to just use them as a standalone, because why can't we use whatever GPS is available? Maybe there's still one signal coming from particular direction of the sky was not blocked and was not jammed, maybe you could use that. And so this augmentation is also a very, I would say, a very big field and it has been really good in helping us to improve the resilience of PNT. And now, there are times we might need a backup system where it can work standalone. And this is one like the original LORAN system and other terrestrial-based navigation system.

But today we'll start talking about potentially having maybe either augmentation or standalone, maybe not coming from a LEO anymore like GPS, coming from the LEO constellations. And it has its pros and cons. These are all very active research areas that we're engaged in. There are just a lot of approaches and I think in each of those fronts, we're making progress and hopefully, all we want to do is be one step ahead of our adversary and being able to offer the kind of solutions one will need in all these circumstances.

[01:53:38]
Keith Gremban: Dana?

[01:53:40]
Dana Goward: Yeah, thanks. So, I certainly agree with everything that Jade said. But in the larger context, I think it's important to point out and remind everybody that PNT is not a system, it is a service, it is a critical service. And systems engineering tells us that when you have a critical service or capability, then you need multiple independent sources of it so that you have better redundancy. And also in the event that one of them is faulty, the other sources will outvote the faulty one, for example.

And so as a completely different example, I used to fly a helicopter that had three methods of controlling the flight controls. One was electrical and two were relatively independent hydraulic systems. So, if one of those systems failed or was faulty, the other two would allow you to retain control of the aircraft and not crash. So, I think we need a similar kind of systems analysis and approach to PNT services to ensure that if space is not available to us, then the world doesn't go to heck in a handbasket. As Jade said, that there are other ways of getting it, either fiber or terrestrial broadcasters or some other way.

And that really is the definition of a resilient service. In fact, DHS defines resilience as something that's difficult to disrupt and then when it is disrupted, it comes back online relatively quickly without a whole lot of effort. So, that's the way we think about it at our foundation. Certainly protect the frequencies, toughen the receivers, but also augment, a holistic approach to resilience.

[01:55:26]
Keith Gremban: Stefanie, I see you kind of leaning forward. [Laughs]

[01:55:32]
Stefanie Tompkins: Well, kind of like Jade started — how much time do we have? But I think given how completely and really succinctly everyone else has covered it, the only thing I would add is that you can also think of maybe resilience as expanding the capacity or the capability of navigation to places where GPS doesn't go. And so a lot of the same technologies that both Dana and Jade have been talking about with respect to augmentation are technologies that, in some cases, were sort of born out of trying to figure out how to get GPS capability in areas where the signal simply doesn't effectively penetrate. So, under lots of trees...

[01:56:11]
Keith Gremban: We lost your sound.

[01:56:14]
Stefanie Tompkins: Uh-oh.

[01:56:16]
Jade Morton: I can hear [Inaudible 01:56:16], yeah.

[01:56:18]
Dana Goward: I've got you too.

[01:56:19]
Jade Morton: I've got you, yeah.

[01:56:22]
Stefanie Tompkins: So, inside buildings and underwater. And in my particular case, coming from Colorado School of Mines, we care a lot about underground. And having signals that behave the way GPS would, could take all of the amazing capability that GPS has given us, and sort of take it into whole different dimensions of sort of civilization and society. So, those two kind of hand in hand and it's nice that a solution in one space might actually help the other.

[01:56:55]
Keith Gremban: Tim, did you...? Since you're one of the industries that really depend on PNT.

[01:57:01]
Tim Godfrey: Yeah. I can mention that I also saw a question come up on the alternatives to GPS for resilience. And one of the things that's going on that would not necessarily apply to all of the cases where it has to be wireless, but for fixed applications such as power substations where precision time is needed, the IEEE and IEC are working on what's called the time-sensitive networking to allow fixed terrestrial networks over fiber to improve the precision of precision-timed protocol that's already been used but has been limited by the nature of the backbone networks running on fiber and microwave.

[01:57:47]
Jade Morton: Maybe...

[01:57:49]
Keith Gremban: Go ahead.

[01:57:51]
Jade Morton: I was going to add something maybe because of what Stefanie was saying that at the School of Mines, you care a lot about underground. We're I'm in aerospace engineering, so we care a lot about the space. So, things like navigating on the moon, Mars. And interesting enough, I right now have two student teams doing senior projects. One is doing navigation on the moon, another's [Inaudible 01:58:15] Mars. And interesting enough, both of them are using the architecture of GPS, so they call it GPS-like navigation system to launch, say, a new satellite... Well, not a LEO, as a [Inaudible 01:58:29] maybe around the moon to broadcast signals similar to GPS.

So, I was really kind of taken aback a little back to know that the impact that GPS has, that's the first thing comes to people's mind is it worked so well, let's do it out in space as well. But we know we have issues on Earth but space is a different frontier there. So, quite interesting perspectives of how technology expands in different dimensions.

[01:59:06]
Keith Gremban: Interesting. Let me go over to Tim. Your industry is dependent on PNT and I guess most of us don't realize how much our electricity and lights and so on depend on this. Do you have any examples of evidence being used or misused to create or modify spectrum policy in this area?

[01:59:31]
Tim Godfrey: A great question and a complicated one, I'll approach it from three points. The first is directly to the topic we're talking about is the GPS timing synchronization. And in the bulk electric power system that forms the backbone of the three grids that serve North America, much of this energy is transported on transmission lines that are operating above 300 kilovolts and are carrying hundreds of megawatts of power.

And to protect those lines, if there are faults or instability conditions, action has to be taken in significantly less than one AC cycle, which in North American is 16 milliseconds. And to do that, it has to be significantly faster so these decisions are being made on relative phase angles of the signals at both ends of a length which could be great distances apart and that is where the precision time synchronization comes in. And the go-to, the implementation that's been widely deployed is based on GPS because it is available, but because of availability and even of cyber threats to GPS signals, the industry's now looking very closely at ways to make that more resilient.

In EPRI we have a project called Resilient Time Synchronization. It's bringing together the power and protection disciplines with our telecommunications disciplines that I'm involved in. One of the underlying reasons for the need of why we can't just go back to doing it over the fixed fiber networks is because the industry has gone through a transition from the historical synchronous optical networks, or SONET, to IP and packet-based networks which are at a low level of the physical layer operating asynchronously and no longer provide a master clock that's synchronized to a picosecond or such as that you had in the past. So, that brings us back to that opportunity for working with IEEE 802.1 on TSN to improve the precision of terrestrial fiber networks as a backup for precision time. So, that's point one.

Then the second point related to our topics is the used of shared spectra for grid operations. And as Eric mentioned in the keynote this morning, that the CBRS priority access licenses were just auctioned. Nine electric utilities won those licenses and will be deploying operational grid control networks based on CBRS spectra. So, this is something that's entirely new and we at EPRI will be working with those utilities and trying to gather data and evidence on the effectiveness and operational impact of running a network under the control of a spectrum access system operating in shared spectrum. And tying it back to the PNT, those

CBRS networks operate exclusively in a time division duplexing mode which means they're rapidly alternating between uplink and downlink. That also requires precision time synchronization between the base stations to prevent them from interfering with each other.

Third point, where we have seen the examples of evidence-based policy going both positive and negative is in the area of the 6 GHz [Inaudible 02:03:12] that came out this year, which has been widely publicized as a boon to unlicensed operation for Wi-Fi and other things. But there's also a lot of concern that many critical utility links that are used for the teleprotection as I was mentioning on the first point, as well as other operational networks, are currently conducted on licensed spectrum links operating in that same 6 GHz band.

The FCC will allow the unlicensed devices to operate under specific rules and through this [Inaudible 02:03:48] process there's been significant debate, it's all on the record, of positions and a lot of paper analysis has gone on. But this policy decision was made without any actual field data or testing to support the conclusions. So, from the concern of the utility industry is that these links are operating on a very long tailed reliability curve. Reliability is five or six nines or five sigmas out, so even a small change in the interference profile out at that level of reliability, when we're talking about a number of seconds per year of outage, could have significant impacts.

And the utilities that operate these links and the power distribution are responsible to the regulators to ensure that they have designed and can operate their communications and the grid to the level of reliability that's required by those regulatory agencies. So, this is another area that we'll be working with our utilities to understand the impact and gather data and evidence as these unlicensed devices come into the market and we start to see them in the wild in the field. Thanks.

[02:05:09]
Keith Gremban: Yeah, thank you. Stefanie, you're leaning forward again. [Laughs] Do you have a comment on that?

[02:05:18]
Stefanie Tompkins: Well, I wasn't really leaning forward but I can throw in just maybe a slightly different perspective. I think Dana wrote, either authored or co-authored a really interesting piece about the difference between different communities and how they might understand the same actual evidence and physics.

So, I'm not going to try to jump in his way in talking about that but I will throw out a little example that I always remember. And it had to do with the fact that when we were working years ago on a navigation program dealing with the problem Jade just mentioned, which was multipath, where GPS or other navigation signals are bouncing and essentially it means those signals are going longer distances than you might have been calculating, and thus you get your navigation information incorrect.

We used a commercial software package to model the multipath but it was designed by communications people. And it took us months to figure out that they rounded off the speed of light just enough to completely screw up all of our predictions. But it had never occurred to us that anybody would think to round off the speed of light. But in the world of communications, you don't need to be as precise as you do in the world of navigation.

And so that fundamental kind of cultural difference led to — I cannot tell you how many middle of the night panic attacks we were having. [Distortion 02:06:44]. It's not really misuse of evidence but it's sort of a cultural mismatch that can lead to an accidental series of very profound mistakes. So, that's sort of my two cents on this topic.

[02:06:59]
Keith Gremban: That's really interesting. Dana?

[02:07:01]
Dana Goward: Yeah. So, Stefanie, that is an amazing story. I've mentally jotted that one down, I'll come back to you if I get it precisely right and make sure. But yes, absolutely right. As I mentioned earlier, it can be a matter of individual and social psychology, as you say, your background and your community. So, just some specific examples of the differences between PNT wireless and communications wireless.

So, in two-way radio communications, the receiver looks for an unknown message but it's a strong signal pushing through the noise. It's about 100 times typically stronger than the background noise. In PNT, or I should say in GPS with one-way satellite radio navigation, it's a known message but it's an incredibly weak signal. It's about 1% of the background noise. So, your receiver is looking for a coded signal down in the background noise while the sun and the stars are making 100 times more noise than the signal that you're looking for. So, the receivers work, it's great, it's a miracle of technology. But you can see right there, there's a incredible difference. In a communications radio, if you get a little static, well, it kind of degrades the quality of the communications you're getting. If you start to get a little static in a GPS receiver, it will start to wander off until you're someplace that you're not.

So, a great example of the cultural difference and background is I was on a panel with Doug Smith, the CEO of Ligato, and I made some statement like that Ligato tested a GPS. And by the way, Ligato and the government did similar tests and it came up with similar results but understood them completely differently. So, at the panel, I mentioned that Doug and his folks had tested GPS receivers to failure. And Doug corrected me and said, "No. We didn't test them to failure. We just tested them to the point where they were giving bad information." And I'm saying, "Well, one, for a navigator, that sounds like failure to me, and two, that's worse than the receiver not working at all because it's bad information."

So, Doug's not a bad guy. I'm sure he's good to his wife and kids and he's trying to run a company and there are no villains in this story, but it's just folks from completely different backgrounds with completely different understandings looking at the same physics and the same phenomena and interpreting it in their own lens. And Keith, you can send the link to that article that Stefanie mentioned if you like, everybody in case they want to read my nattering on.

[02:09:53]
Keith Gremban: All right. Jade, you want to follow up on that?

[02:09:57]
Jade Morton: Well, since you guys are into this topic, I would like to also interject something from really also different cultures and the way they understand problems, the way they utilize the information. And since I do a lot of remote sensing applications, one of the things we do is develop receivers that can monitor space [Inaudible 02:10:17]. And there are products out there that you can buy and deploy at various locations to do the monitoring. And interesting enough, the [Inaudible 02:10:28] phenomena in equatorial area and high latitude are due to [Inaudible 02:10:33] of the physics.

In equatorial area, there will be these very thick large plasma bubbles which will actually impact the signal amplitude very much so it create a fading so your signal's weak. In high latitude, there will be bursts of smaller structures that will...you can think of them as these small random plasma clouds drifting across your line of sight of your receiver to a satellite. And so as a result, these plasma clouds will create...basically, the atmosphere delay will change and as they move along it. So, you create the range fluctuations or phase measurement fluctuations.

So, you think about it, if you have a large phase fluctuation you’re tracking, really, you can think of this signal as if it has very high dynamics. It's as if you're grabbing the satellite, moving it back and forth. So, you need a receiver that has a wider bandwidth in order to compensate [Phonetic 02:11:32] . It's as if your platform has high band and it's okay. But in the equatorial area because the signals are fading more, with all these kind of dynamics, so what you really need is a receiver that can process a weak signal. Nobody want to have very narrow bandwidth to allow you to squeeze out more noise.

So, you can see the designs are opposite of each other. Although they're both due to the same physical name, phenomena name, which we call ionospheric [Phonetic 02:11:59] scintillation. But you can't just buy one receiver that's optimized for one and put them both in high latitude or equatorial area. But that's what the people do all the time, so what happens is that the algorithm optimized for one but not both. Because if you do well in one, you're bound to really mess up on the other. But the people continue to take data and they use the data to analyze the science of it and that obviously can be extremely misleading.

And so this is really a lesson where engineering and science really have to come together to achieve the kind of optimization that we need instead of just blindly believing something and apply to all cases.

[02:12:52]
Keith Gremban: Interesting. We've got to move to our Q&A from the audience now. And our first question is from law student Conner May.

[02:13:03]
Conner May: Hi. Well, first of all, thank you all for a great panel, this has been really interesting. And this question may be borne out of ignorance but I was just curious given how clearly critical these systems and services are, whether you all have a perspective on whether the incentives are properly in line to support information sharing? Whether government entities provide forums for that or industry groups to ensure the best practices and whatnot are really being used to increase resilience and safety or whether that's something that you think there could be improvement in.

[02:13:39]
Keith Gremban: Anybody want to volunteer for that one? Dana?

[02:13:47]
Dana Goward: So, that's a really good question and I don't know that I've ever thought about the incentives that way, which may mean just the evidence of my complete ignorance or that it hasn't popped up as a big deal. And my sense is that, as I mentioned, everybody's trying to do the right thing but what we might need is some more professional cross-cultural interchange and understanding. So, in the article, I said, "Well, should it still be the Federal Communications Commission?" Because just the name carries a lot of baggage and presupposition and assumptions with it. Maybe we are a point or well past the point where it should be the Federal Spectrum Commission and it includes all kinds of folks in terms of

the engineers, technologists, and policy makers on it that have backgrounds across the wide use of spectrum, not just communications.

[02:14:57]
Keith Gremban: Okay, Doug. Are you wanting to weigh in on this, Tim?

[02:15:04]
Tim Godfrey: I can mention that in terms of industry groups to deal with, at least on a specific issue of the 6 GHz activity which isn't specifically around PNT but is definitely a spectrum policy issue, the FCC, as far as I know, it's a new precedent that in the [Inaudible 02:15:24] they asked industry to create a multi-stakeholder group to work through issues that emerge. So, they're not taking it on themselves, they're delegating it to the industry to come together and try to bring all the parties who are stakeholders which involve large utilities, commercial cellular, broadcasters, and public safety and many others on the fixed services side to work with the unlicensed users to discuss and hopefully develop resolutions and mitigations to any problems that emerge.

[02:16:03]
Keith Gremban: Anybody else want to attack that question or shall we go on to the next one?

[02:16:10]
Conner May: Thank you.

[02:16:10]
Keith Gremban: Thank you, Conner. Good question. So, we have a question from the audience about could the panel address non-GPS technologies that are used for PNT and the respective pros and cons? Jade, I think I'll toss that one out to you first.

[02:16:27]
Jade Morton: Okay. Thank you. That's a very good question. It's also a very big question because there are many different techniques that we use that are not GPS-based PNT. So, it depends on what they are, the pros and the cons are different. But in general, typically when we wanted to use another technology that'll augment the GPS, that's because they have somewhat different properties or quite often offset.

For example, inertial sense of property is the most common to [Inaudible 02:17:00] technology as alternative PNT and which acts very much the opposite of GPS. GPS is absolute positioning and so when you get position fixed and you may have a large error, depends on the technology itself, of course. But that error is an error that's in a three-dimensional space and you basically have your X, Y, Z or latitude, longitude, altitude.

But inertial is just the opposite of that. It doesn't give you an absolute position solution. It gives you a couple measures. For example, maybe your acceleration which can be double integrated back into displacement. And what is that displacement relative to? That is not known. So, inertial tends to be very high rate, very low noise. Again, depends on the grade of the inertial sensors. Unlike GPS, it can be noisy, especially code-based navigation solutions. And so when the two got together, you have the best of the both worlds. And inertial cannot be jammed because it doesn't rely on any other signals other than gravity. As long as you [Inaudible 02:18:15] from the surface of Earth, you got it. So, that's one of those properties.

But there are other signals that you use to augment GPS like radio signals. Quite often those radio signals are much stronger than GPS. GPS is weak and normally the GPS signal is about 15 dB below noise floor. But your communications cellular network and all those other things, they tend to be stronger and [Inaudible 02:18:37]. They're not universally available and they also typically don't have good geometry. Most cities may have a hill somewhere, all of their TV stations, all of their towers are sitting up there. You've got all the signals coming from the same direction, unlike GPS which is very well-distributed, it has a good geometry.

And there are other technologies like laser, camera, and even magnetic field. Some people even propose using odor and if you have some odor transmitting device by using device that can sense odor. But all of these devices, it tends to be not the readily available everywhere. And they all have their own limitations but in some ways, they augment what the GPS can do. So, if you want a really comprehensive answer for that, you have to look into that particular sensor and the key thing is diversity. You use properties that are orthogonal to each other and that's your best solution.

[02:19:42]
Keith Gremban: Great. Dana, you had something to add to that?

[02:19:45]
Dana Goward: Yeah, so when addressing that question, it's important to remember that the question includes positioning, navigation, and timing. So, a number of things offer positioning and navigation, but they don't offer time. There are a number of ways to get time, like fiber, but don't necessarily offer you navigation.

I agree completely with Jade, and in fact, China probably leads the — no, doesn't "probably." China does lead the world in terms of a comprehensive approach to PNT services for both government, military, and their general population. They have their own PNT satellites at MEO just like GPS is. They're looking at putting satellites at geostationary orbit and establishing satellites at a low Earth orbit. So, they have a triple redundancy just in space. They also have for decades maintained a terrestrial LORAN system which they are in the process of expanding further to the west. So, it will be an entirely complete backup for signals from space.

Now, LORAN is a terrestrial broadcast that we used to have in the United States and in Europe that is in excess of 1 million times stronger than GPS. And not only is it not in space but it has a thousands of kilometer waveform so it penetrates very well. And you don't need a space shuttle to get to it, you can drive to it in a Ford 150 in terms of if you need to make adjustments to the transmitter or change the software.

So, Russia, China as I mentioned, South Korea, Saudi Arabia, all have some version of LORAN systems. And in fact, the British still have a LORAN transmitter providing a timing signal. So, all of this — so, a former federal bureaucrat, I tend to run on, I apologize — but all of this to say yes on what Jade said. You need [Inaudible 02:21:38] system, multiple systems with dissimilar failure modes so that you're not reliant on one if something goes south. Even in a big way, like there's a solar flare and all signals from space are not available, you're still going to have those essential positioning, navigation, and timing services that you need.

And in fact, today or tomorrow, our foundation has a paper coming out on Resilient National Timing Architecture that posits we need a GNSS, we need to reestablish the LORAN system here in the United States, upgrade it to eLORAN, and a improved timing system over fiber so that everybody has three paths just for timing. And by the way, if you build the whole thing out, you'll also have positioning and navigation as well using LORAN.

[02:22:33]

Keith Gremban: Thank you. Okay. And with that, we're at the end of the time for our panel. Thank you very much to the panelists, I learned a lot on this, I really appreciate the time and energy you spent preparing for this. Thank you. So, everyone, for the audience and previous panelists and so on, again, also thank you for participating, attending. Stay tuned to the Event page. We will be preparing a conference report and additionally posting a video record and transcript of the event within a couple of weeks.

Before we head to the breakout rooms, I'd like to make some special acknowledgements. First of all, thank you very much to Amy Stepanovich, the Silicon Flatirons Director for all the support we were given in planning, organizing, and executing this event. And thanks to all the supporters of Silicon Flatirons that were listed in the program. Without their support, we wouldn't be able to hold events like this. And again, thank you to all the speakers, panelists, moderators. I know how much time and energy you all spent in preparing for this and I really appreciate it and we were the benefit of all this energy you did.

Thanks, of course, to the Wolf Law School and Dean Jim Anaya for supporting Silicon Flatirons in this conference. And I want to specifically acknowledge Pierre de Vries and Dale Hatfield who organized this conference and put in a lot of work and energy in organizing and as always, I learned a lot by just being able to work with them. But I want to close with a special shout out to the Silicon Flatirons staff and students because they did all the behind-the-scenes work that made all of this actually work and they did a great job at it. So, can I have a quick round of virtual applause for everybody. [Applause] Thank you.

And so now we're going to go to these virtual breakout rooms, although they're really virtual tables, to enable networking with the speakers. So, this is an important part of every Silicon Flatirons conference. We're doing our best to do it virtually. I believe everybody should have received a link to Airmeet which is the browser-based platform we're using for the breakouts. So, please, when you go to Airmeet, log out of Zoom, connect via the Airmeet link that was sent to you by Heather Martin.

Each breakout table will have the name of a speaker from today and speakers will have to join their own tables. And then attendees are encouraged to wander around, join any table, switch when you want to and ask follow-on questions. To join a table, you simply click on an empty seat. To all of the moderators and panelists and speakers, please remember that you too have to take a seat at your own table, otherwise it doesn't work. So, thank you all. This was a great event. I really appreciate everybody's time and energy and attention on this. And so with that, let's head out to the breakout rooms.

[Silence 02:25:45 to 02:28:59]